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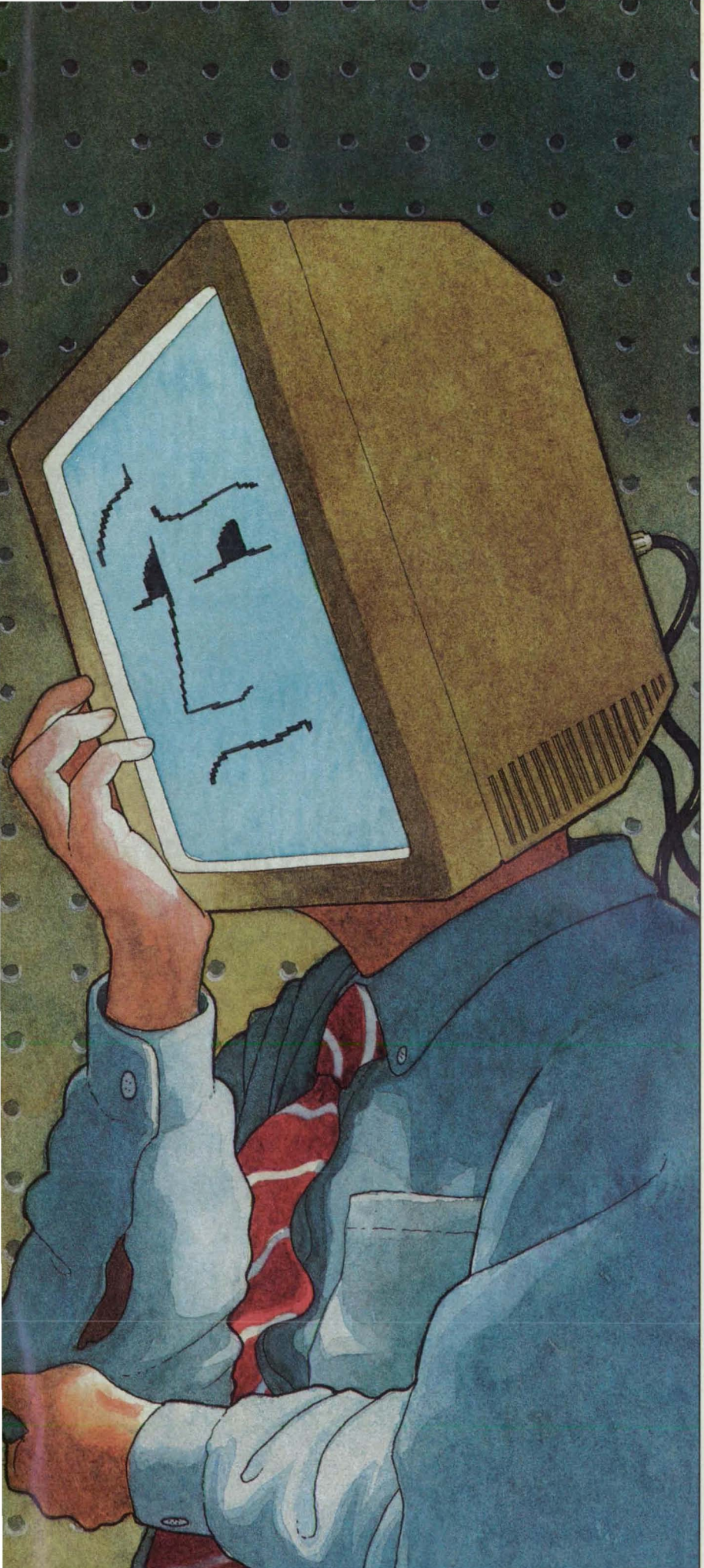

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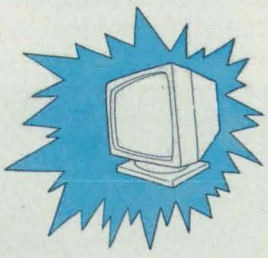

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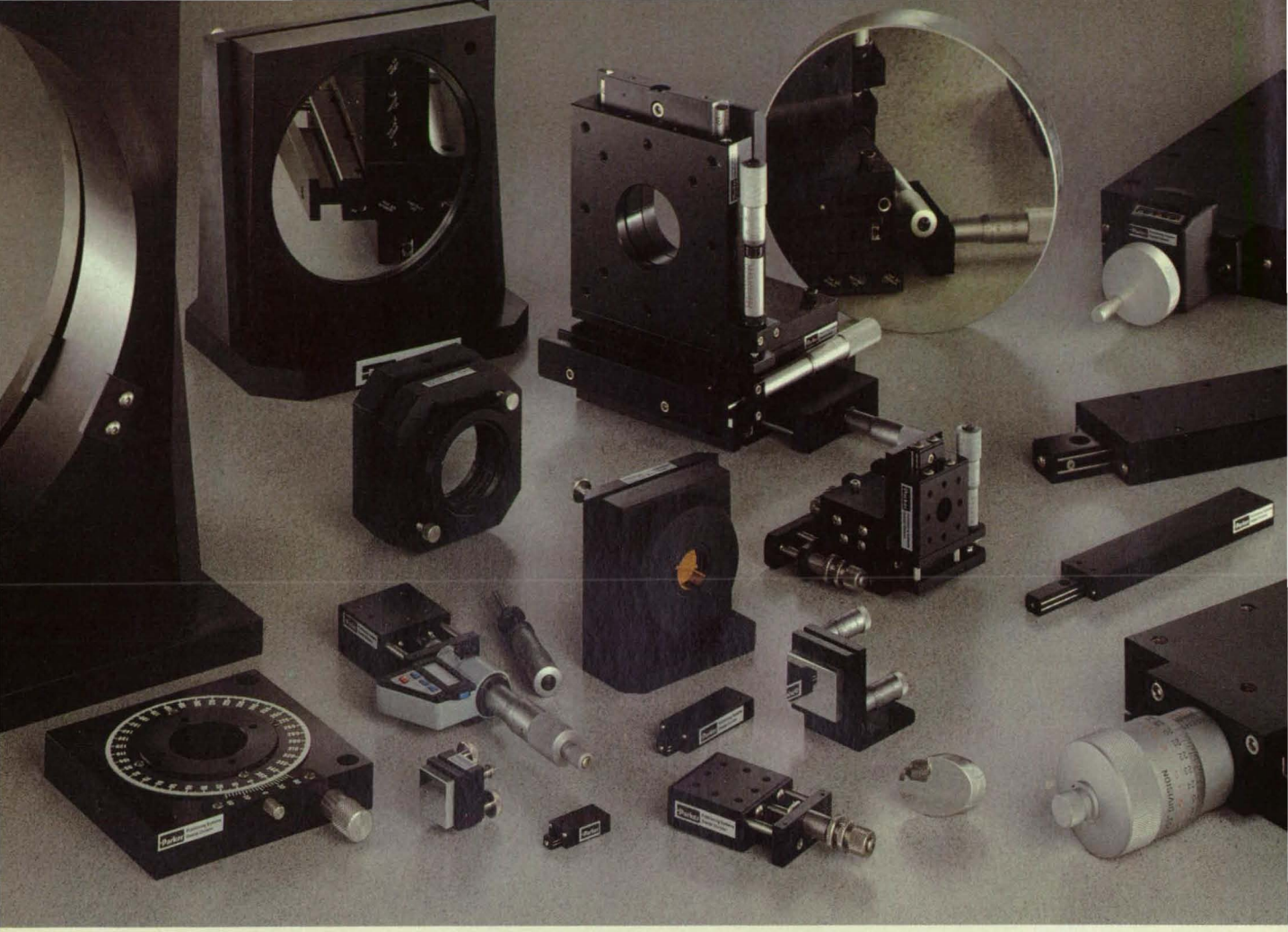

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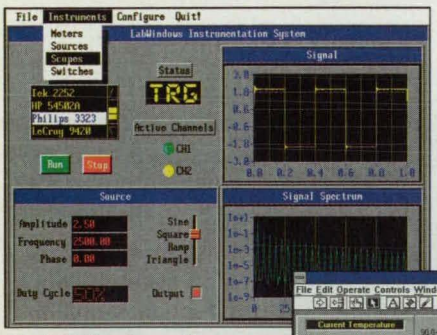

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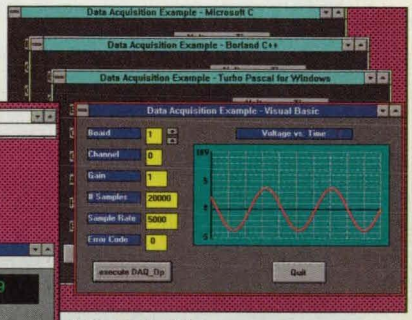

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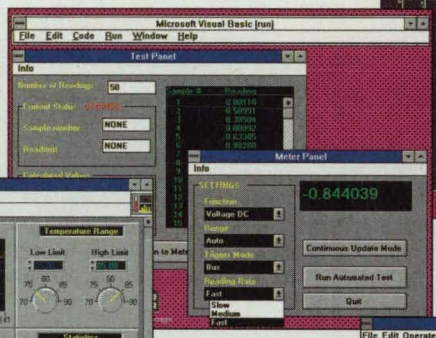

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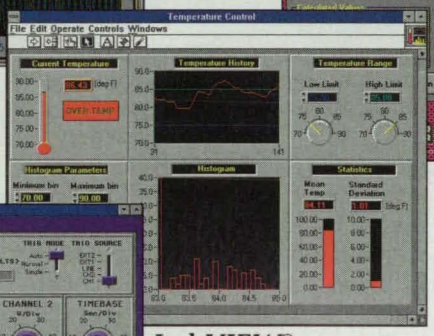

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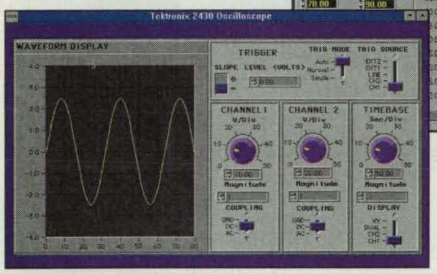

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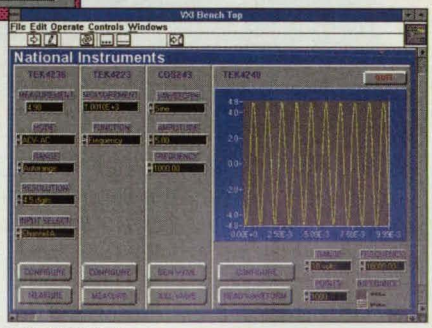

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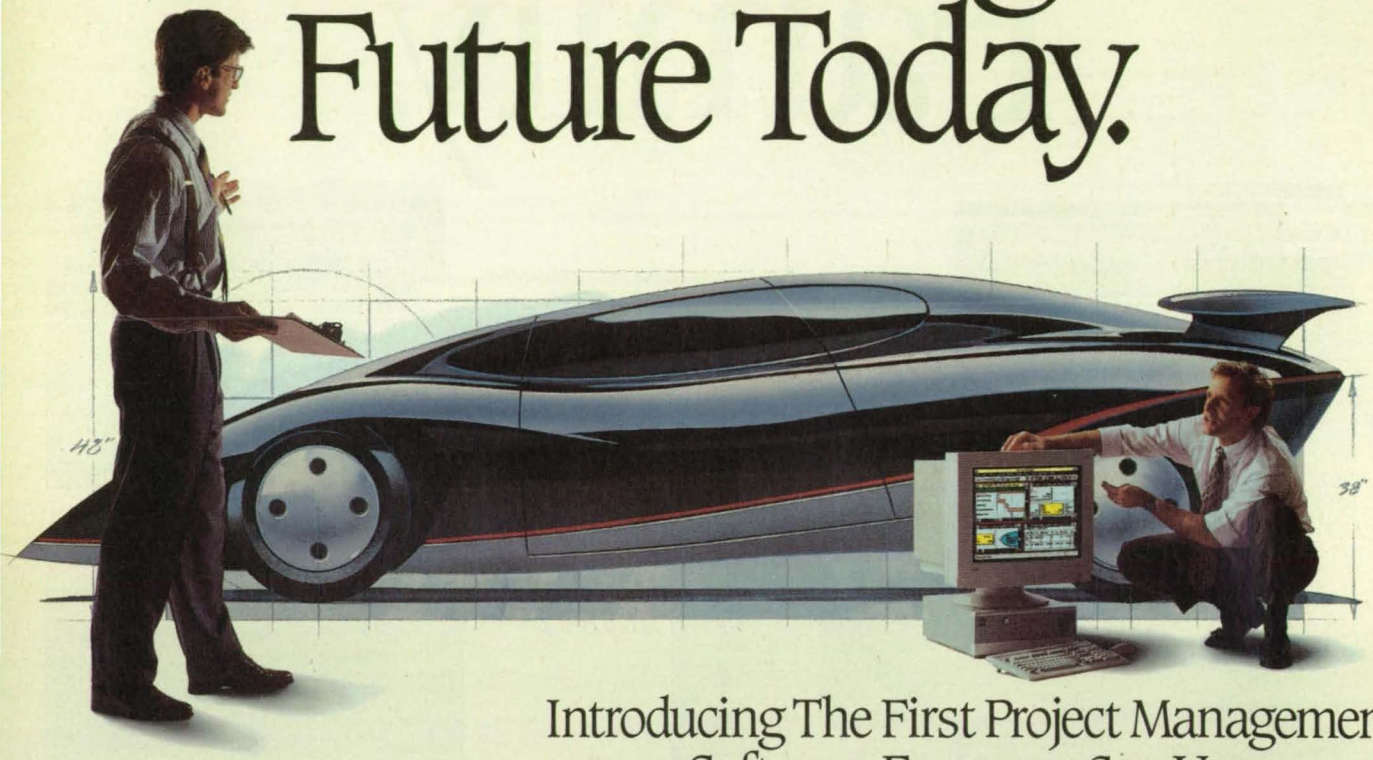

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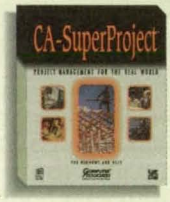

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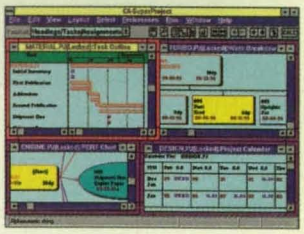

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December 1993
Volume 17 Number 12

Contents

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FEATURES

TECHNICAL SECTION

An end effector developed at Marshall Space Flight Center imitates the dexterous motions of a human hand. The device incorporates innovative pitch/yaw joints in the wrist and knuckles as well as miniature linear actuators to provide a high load capacity. Removable and interchangeable parts, such as the fingers, simplify servicing and maintenance. See the tech brief on page 84.

Photo courtesy Ross-Hime Designs Inc.

(continued on page 8)

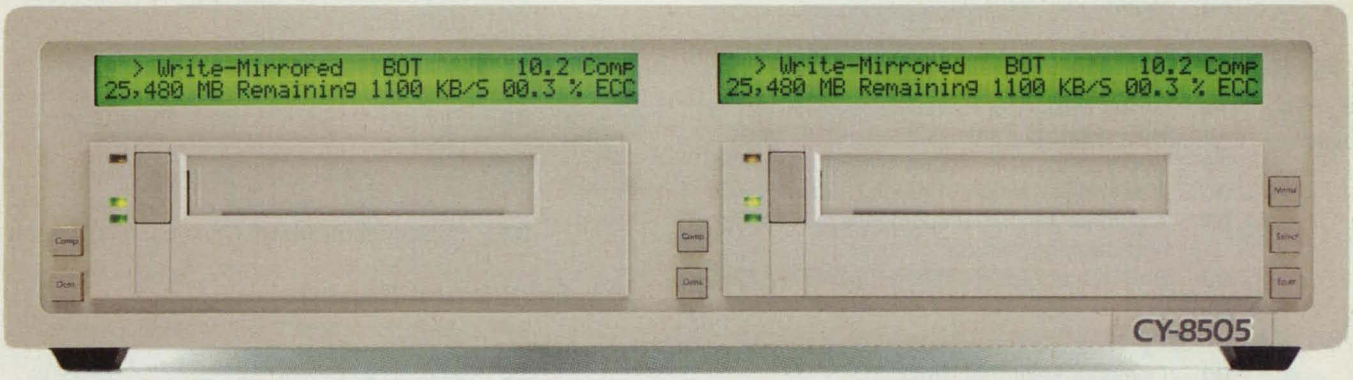
To Backup 50 GB, Two Recording Heads Are Better Than One.

Single:
Drives can operate independently.

Cascade:
Data automatically writes to the second tape when the first tape is full.

Mirroring:
Writes the same data to both tapes simultaneously.

Striping:
Writes data to two tapes at once, in alternate blocks, doubling capacity and speed.



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On the cover:

Descended from software first released by NASA in 1970, state-of-the-art finite element analysis software from MacNeal-Schwendler Corp. now can be used in conjunction with solid modeling for predictive engineering. This model of a mini-van brake assembly incorporates an analysis investigating brake chatter and squeal. Turn to Mission Accomplished, page 14.

Photo courtesy MacNeal-Schwendler Corporation

DEPARTMENTS

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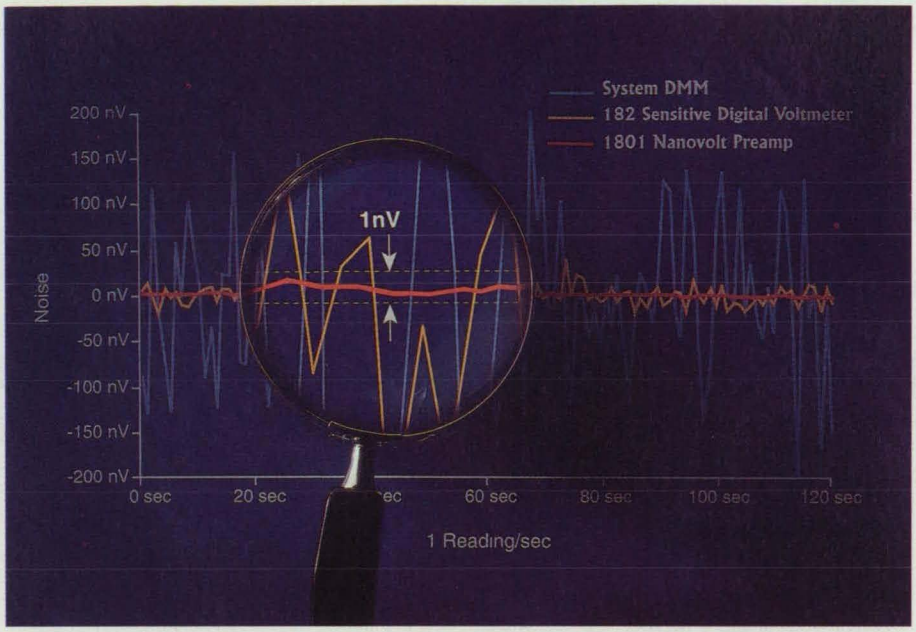

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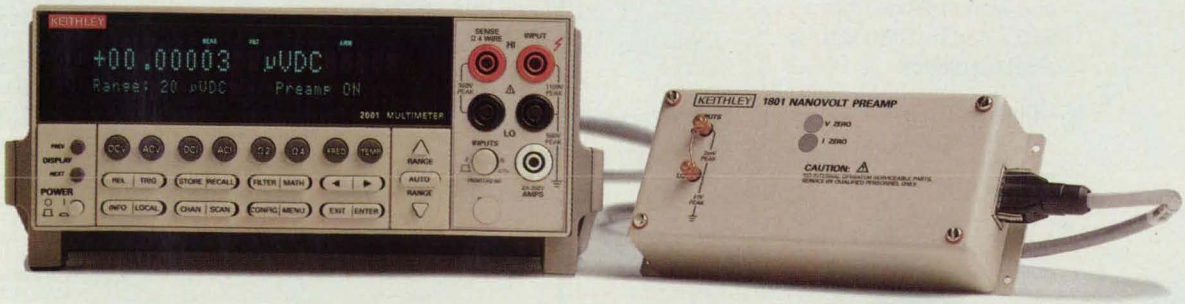

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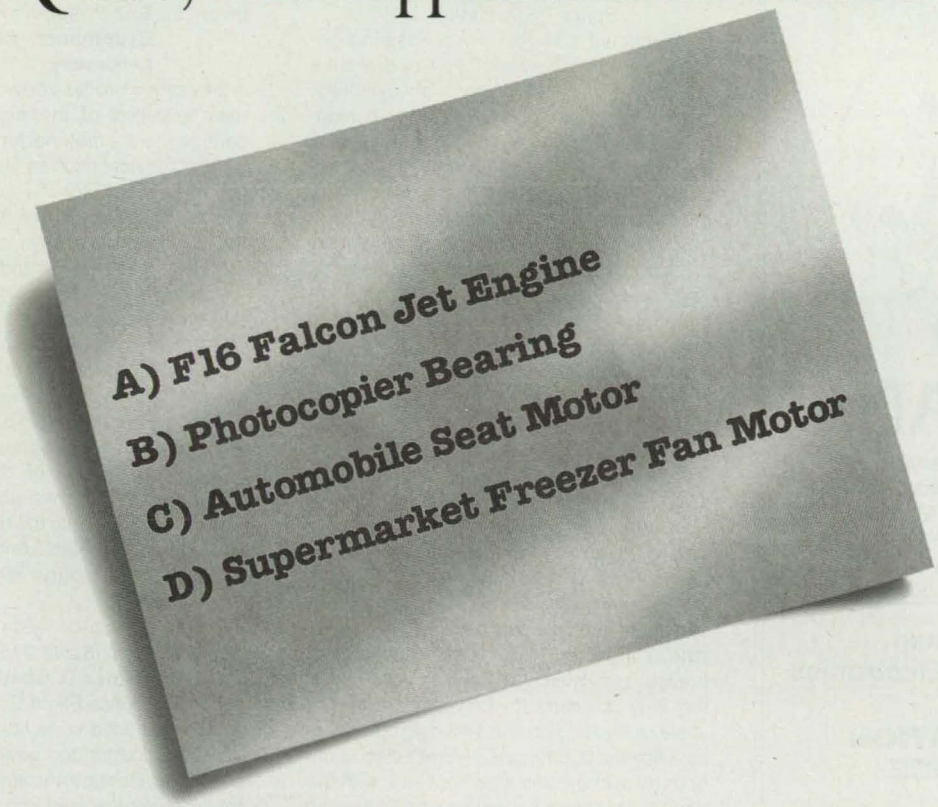

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NASA PATENTS

NASA has a portfolio of 3000 patents and pending applications available now for license by businesses and individuals, including these recently patented inventions:

Method and Apparatus for Deflection Measurements Using Eddy-Current Effects

(US Patent No. 5,214,379)

Inventor: **Engmin J. Chern**, Goddard Space Flight Center

Conventional eddy-current measuring devices are operator-dependent and require direct line-of-measurement accessibility. Hence, they cannot be used within elongated closed structures such as curved metal pipes or tubes. Mr. Chern employs a computer-controlled, mechanical positioner to move an eddy-current sensing assembly to the desired location within a specimen. Angle, displacement, and deflection measurements are made by monitoring changes in the impedance of the eddy-current sensor coils as they move through the specimen.

For More Information Write In No. 730

Valve Malfunction Detection Apparatus

(US Patent No. 5,226,447)

Inventor: **Richard K. Burley**, Marshall Space Flight Center

Mr. Burley's detection system, for either liquids or gases in remote and automated applications, is not limited by size and can detect even very small valve leaks or a valve's failure to open or close. A bypass pipe, connected to a pipe through which pressurized liquid flows, diverts a portion of the flow downstream and away from the valve. A housing, divided into two chambers by a flexible diaphragm, is connected to the primary and bypass pipe sections, with the diaphragm spring-biased toward the second chamber. Check valves and orifices in the two pipes maintain a negative pressure in the first pipe and a positive pressure in the bypass when the valve closes. If the valve leaks or fails to close, the pressure in the first pipe section and chamber rises, triggering an alarm via computer.

For More Information Write In No. 731

Method of Recertifying a Loaded Bearing Member Using a Phase Point

(US Patent No. 5,237,516)

Inventor: **Joseph S. Heyman**, Langley Research Center

A novel ultrasonic technique uses a pulsed phase-locked loop strain monitor to nondestructively measure any change in load on a bearing member such as a bolt or connector. The method also can compensate for temperature variations or equipment changes between original load measurement and recertification. A phase detector compares the phase of an ultrasonic tone-burst applied to the bearing member with the phase of a tone-burst reflected through the member. Locking the phase-locked loop at a phase point on the second signal corresponding to a sample/hold phase point on the first determines the first load measurement. Repeating the step yields a frequency indicative of the second loading condition.

For More Information Write In No. 732

Method for Producing a Hybridization of Detector Array and Integrated Circuit for Readout

(US Patent No. 5,236,871)

Inventors: **Eric Fossum** and **Frank J. Grunthaner**, Jet Propulsion Laboratory

A fabrication process developed at JPL permits selection of the highest performing semiconductor material for each structure in a hybrid device, such as GaAs for the detector array and Si for the integrated readout circuit. Photodiodes are fabricated by epitaxially growing a layer of semiconductor material on a substrate and processing it into an array, each with a separate metallized surface contact and at least one second contact. An integrated readout circuit is fabricated in a separate layer of semiconductor material grown on another substrate. After applying a planarizing film of adhesive over the surface of the integrated circuit, the detector array is lifted off the first substrate and laminated onto the planarized surface. Channels etched into the diodes for reticulation provide electrical connections.

For More Information Write In No. 733

Micro-Pulse Laser Radar

(US Patent No. 5,241,315)

Inventor: **James D. Spinhirne**, Goddard Space Flight Center

A compact solid-state lidar system is well-suited to unattended profiling of cloud and aerosol scattering in the atmosphere, through the troposphere, and into the stratosphere. The system ensures eye safety at all ranges by expanding the beam of a diode-pumped microjoule high-repetition-rate Nd:YLF laser. Photon-counting signal detection is achieved using Geiger-mode avalanche photodiodes. A single-card multichannel scaler handles data acquisition.

For More Information Write In No. 734

Force Reflection with Compliance Control

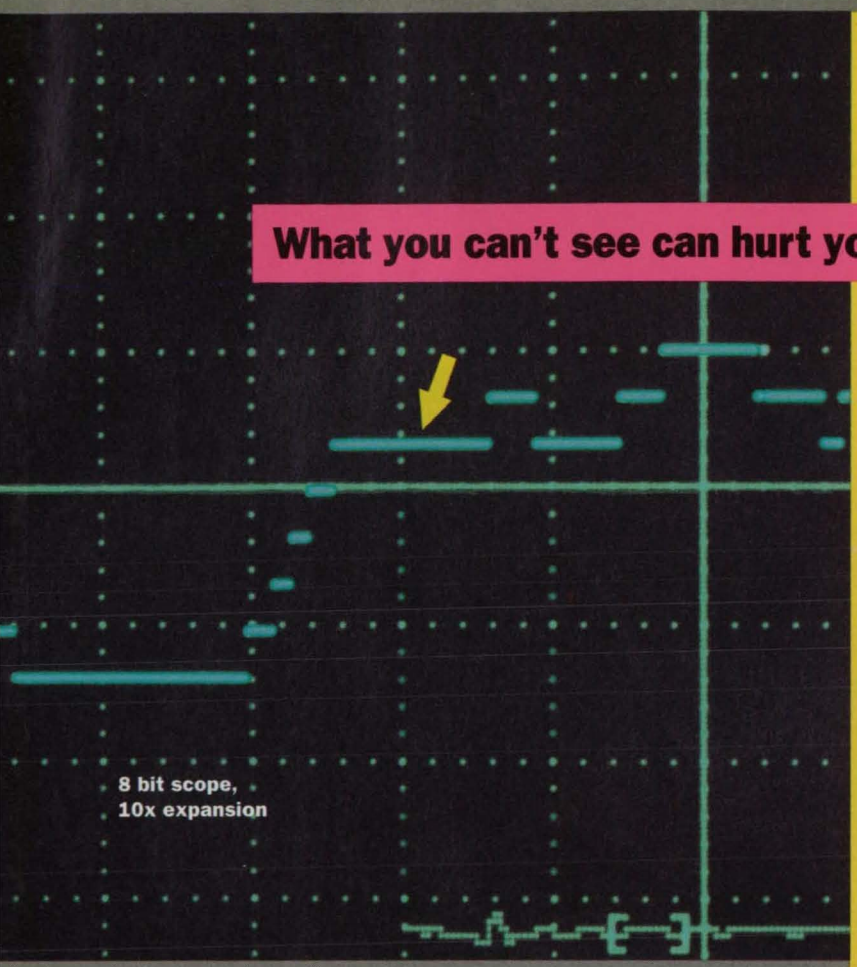
(U.S. Patent 5,239,246)

Inventor: **Won S. Kim**, Jet Propulsion Laboratory

High force-reflection gain can improve operator performance during teleoperation of a robot arm. Kim has developed two new schemes for force-reflecting control—position-error-based and low-pass-filtered force reflection—that achieve up to a tenfold force-reflection gain over conventional high-bandwidth systems and that can be used for dissimilar master/slave arms. In the first, the position error between the commanded and actual position of a compliantly-controlled robot determines force reflection. In the second, the low-pass-filtered output of the compliance control provides the force reflection.

For More Information Write In No. 735

What you can't see can hurt you.



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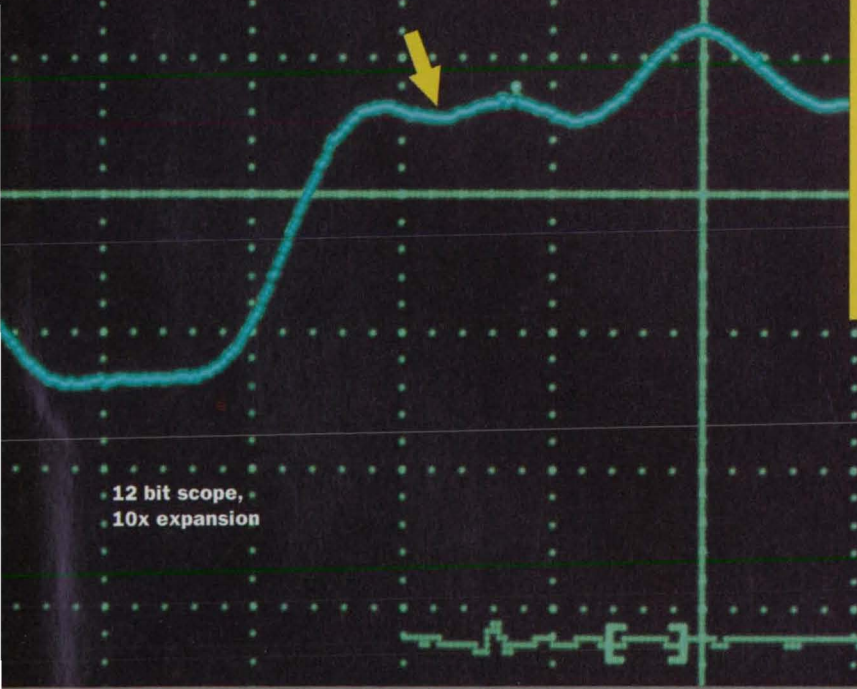

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Mission Accomplished

Through the technology transfer process, many of the systems, methods, and products pioneered by NASA are reapplied in the private sector, obviating duplicate research and making a broad range of new products and services available to the public.

In 1964, a relatively new structural analysis technique called finite element analysis (FEA) was gaining in sophistication just as digital computers such as the IBM 7094 and the Univac 1107 were increasing in power. The time was ripe for development of FEA software to take advantage of burgeoning computer capacities.

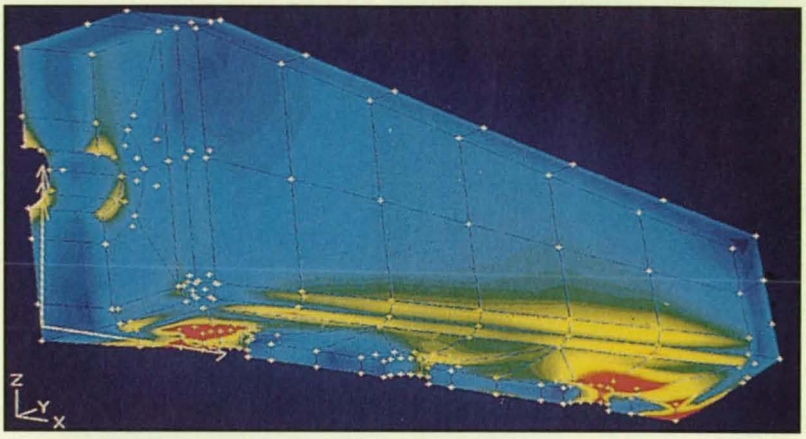
That year, Thomas Butler, manager of structural research at Goddard Space Flight Center, proposed to NASA Headquarters that computerized FEA could be applied to upgrade agency-wide structural analysis, particularly for aircraft construction. After investigating existing FEA programs, NASA elected to develop its own. The contract was awarded in 1966 to a team comprising MacNeal-Schwendler Corp., Computer Sciences Corp., and Martin Marietta Corp.

The initial version of NASTRAN (NASA STructural ANalysis Program) was completed in 1969 and made available to the public through NASA's Computer Software Management and Information Center in 1970. MacNeal-Schwendler Corp. (MSC) of Los Angeles, CA, the contractor responsible for NASTRAN's engineering content, continued developing the code and began leasing its own version in the early 1970s. MSC/NASTRAN, currently the world's leading FEA software, continues to expand both in capabilities and number and types of users.

"The most remarkable thing about NASTRAN is that it has existed for over 20 years," said Dr. Richard MacNeal, MSC's chairman and chief executive officer. "The initial NASTRAN release contained about 150,000 statements, today it's close to 1,400,000. We're continually going through to get rid of old-fashioned and obsolete code. Remember, the very idea of a database didn't exist back then."

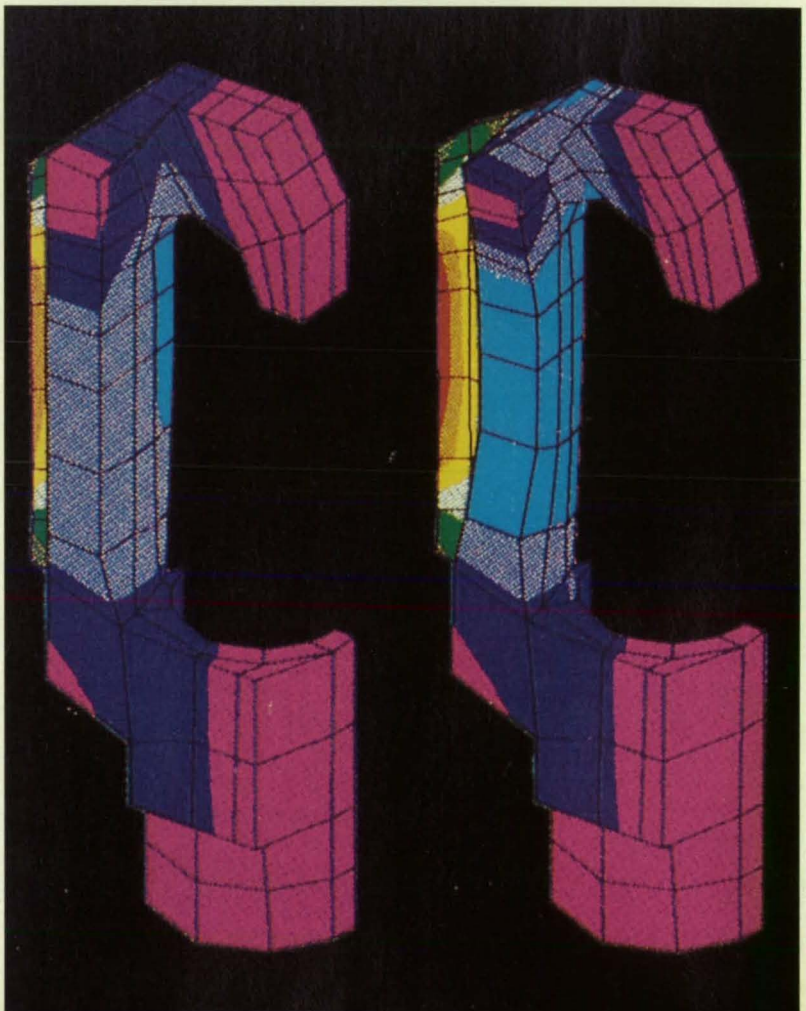
Like all FEA programs, MSC/NASTRAN permits an engineer to divide a complex structure into small substructures, or finite elements, to greatly enhance the accuracy and efficiency of the analysis. Mathematical simulation of these elements can reveal how a design will respond to conditions such as stress, vibration, and heat. FEA can significantly reduce the time and expense of prototyping and physical testing as well as help ensure product performance, safety, and reliability.

Once available exclusively on mainframe computers, analysis packages such as MSC/NASTRAN are becoming increasingly common



(Above) The latest version of MSC/NASTRAN, finite element analysis software from MacNeal-Schwendler Corp., features p-elements that can be integrated with h-elements as illustrated in this contour plot of a static analysis.

(Below) MSC/NASTRAN's shape optimization capability was applied to the original design (left) of a cable clamping device, resulting in a 9% weight reduction in the final design (right).



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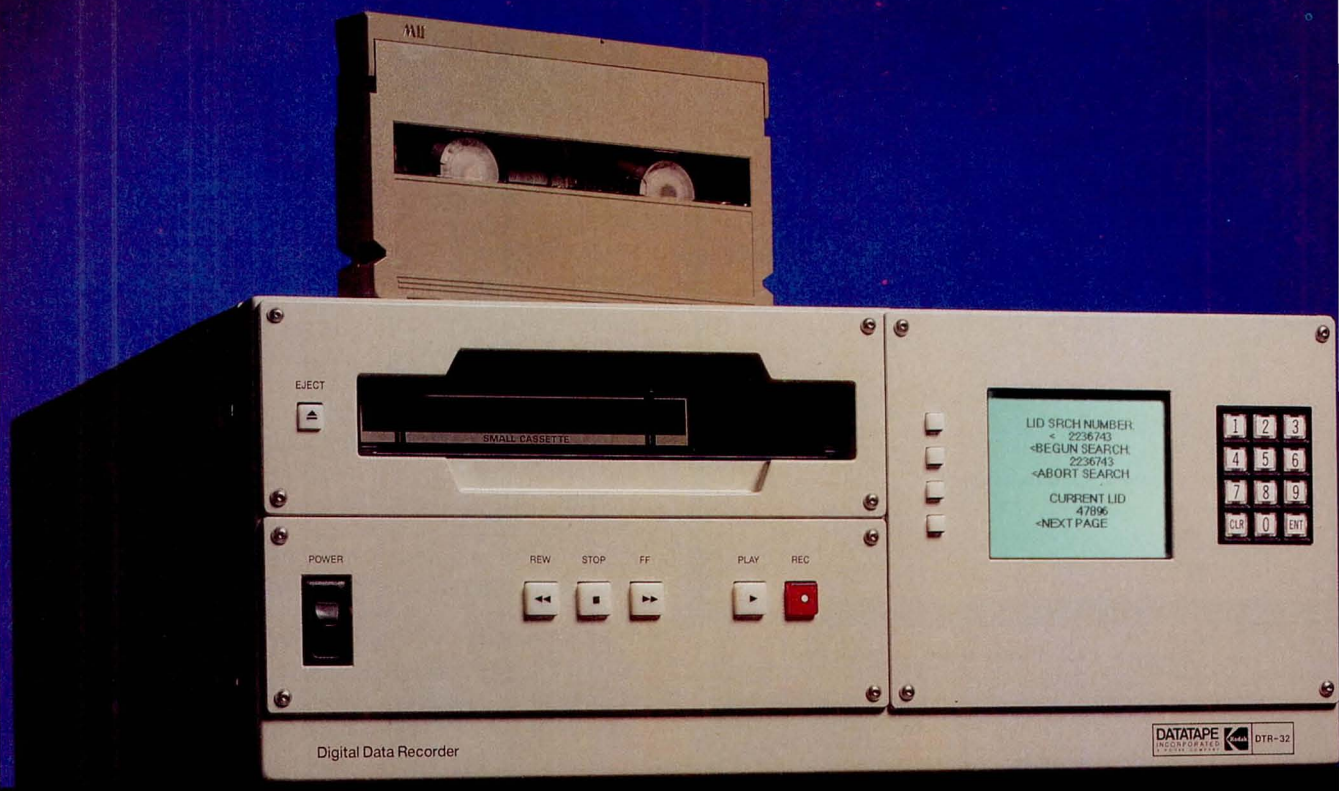

DATATAPE's DTR-32 Bridges the Gap Between Traditional Instrumentation and Tape Storage Systems

The DTR-32 data storage system is a dual-use product equipped with both SCSI-II and NRZ-L interfaces

Designed as a data storage system, the DTR-32 will support sustained transfer rates of 4 MBytes/s with 10 MByte burst transfer rates through the SCSI-II interface

The same transfer rates are supported through a cross compatible NRZ-L interface making the DTR-32 a true gateway between data collection and data storage products

The DTR-32 offers you exceptional benefits such as:

Time Efficiency and Convenience

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- A storage capacity up to 21.6 GBytes (when using M90L cassettes)

Cost Savings

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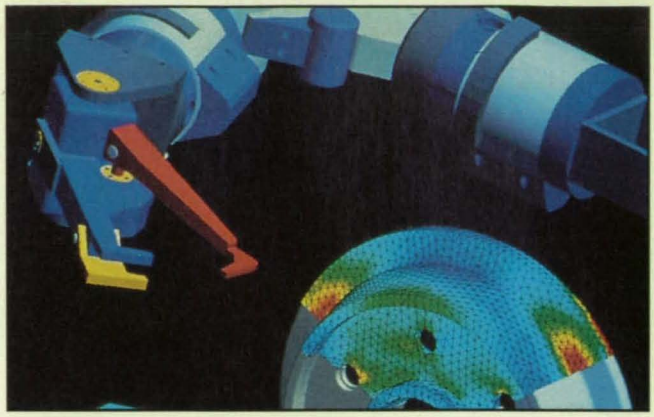

MSC/ARIES, a solid modeler, can be used in tandem with MSC/NASTRAN early in the product development process to reduce time to market. Shown above is a parametric solid model of a robotic arm incorporating a finite element analysis of a wheel.

on desktop workstations. MSC software is available on Intel-based 386/486 PCs, UNIX-based workstations from Hewlett-Packard, Sun, SGI, and DEC, as well as supercomputers.

The latest release of MSC/NASTRAN, version 68, offers new capabilities aimed at both the traditional finite element analyst and the growing population of design engineers using FEA. The fields of predictive or concurrent engineering are requiring modeling and analysis earlier in the product development process, which can result in a significantly reduced time to market. These trends recently led MSC into a strategic partnership agreement with Aries Technology, Lowell, MA.

"The Aries product had what we needed: solid geometry and automatic meshing capability," said MacNeal. Using MSC/ARIES, formerly known as the ConceptStation products, in conjunction with MSC/NASTRAN permits engineers to create a design rapidly and easily, prepare it for analysis by defining loads and constraints, perform the analysis, and visualize the results.

Additionally, version 68 adds dynamic, acoustic, aeroelastic, and superelement design optimization capabilities, as well as general shape optimization for static and design analyses. Shape optimization allows an engineer to automatically modify the physical shape of a part to maximize or minimize a particular value such as weight for a given series of design constraints. Similarly, size or property optimization allows the user to alter the element or material properties of a finite element model to achieve similar results.

According to MacNeal, version 68's most important enhancement is its p-elements, which can represent curvature directly and can be integrated into models based on MSC's h-element technology. He explained: "For the design engineer, the p-elements are extremely useful for two reasons. First, coupling them with an error estimator provides an easy way to adaptively reduce error by simply increasing the polynomial order of the element. Second, they adapt themselves very well to automated optimization."

The company anticipates that MSC/NASTRAN applications will continue to expand beyond the traditional high-end aerospace analyses. The package recently has been used to evaluate a sensor that determines when automotive airbags should inflate and to analyze the stress on a golf club when it strikes a ball. ❑

Editor's note: MacNeal-Schwendler will demonstrate MSC/NASTRAN and MSC/ARIES at Technology 2003. Visit booth 925 for more information.

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INNOVATION AT WORK.

NASA's INNOVATORS

Technology 2003, the fourth national technology transfer conference and exposition (December 7-9, Anaheim convention center) will feature presentations by more than 50 of NASA's leading technologists detailing a broad array of commercially-promising inventions and processes. In the second of two parts, we highlight some of their cutting-edge work.

MAPS Guides Building Planners

In recent years, building planners have become increasingly concerned with how their site and design decisions will affect the environment. A new tool, developed jointly by the Kennedy Space Center's Biomedical Operations and Research Office and Bionetics Corp., Hampton, VA, aids in environmental monitoring, impact assessment, and resource management. The computer-based expert system, dubbed the Mapping Analysis and Planning System (MAPS), combines environmental research data, legal information, analytical capability, and multimedia display techniques in a unique database.

Photo courtesy Kennedy Space Center

MAPS, an expert computer system designed to aid environmental management, offers multimedia display techniques. This aerial photo illustrates the distribution of endangered manatees in waters near Kennedy Space Center.

Using a UNIX workstation, planners can access data and photographs on such subjects as soils, water quality, vegetation, and endangered species habitats. Site- and project-specific information is available on federal and state environmental regulations, hazardous material storage areas, and landfills. MAPS also can create analytical models for stormwater, groundwater, and atmospheric diffusion.

MAPS users can simulate a project's environmental impact as well as determine applicable environmental regulations. Geographic images stored in the database provide a wide view of surrounding areas and allow users to form visual overlays showing different forms of data.

"Recall the pictures of human skeletons in encyclopedias—you turn one overlay to see the circulatory system, then one to see the muscles, and then another to see the organs," explained Burton Summerfield, a Biomedical Operations and Research Officer at Kennedy. "With MAPS, the user can define the layers needed for each application."

MAPS houses data from more than ten years of environmental research in the area surrounding Kennedy Space Center, meticulously compiled by NASA and a host of contractors. Kennedy's south Florida location has the largest number of federally-designated threatened or endangered species of any protected region in the continental US. Continuous monitoring of this biologically unique ecosystem ensures that the database contains current and accurate information. "We also try to anticipate regulatory changes, developing in advance new overlays to reflect them," said Summerfield.

MAPS currently is used by the Environmental Protection Agency, US Fish and Wildlife Service, Department of Energy, Department of Defense, and many city and state governments to assist environmental management decisions. Future efforts will include a collaboration with Stennis Space Center to integrate remote sensing data into the system. NASA's ultimate goal for MAPS is to make it available to managers and planners at all levels in a PC format.

Star Camera Has Bright Future

An advanced infrared camera affords a new window on the stars while promising improved imaging capabilities for a wide range of industrial applications. At its heart is an unusual detector developed earlier this year at Rockwell Science Center: a 128 x 128 pixel blocked impurity band (BIB) array exhibiting high sensitivity at far-infrared wavelengths and an extremely high data rate—approximately 1000 frames per second.

Such large 2D arrays hold particular significance for astronomers because they can cover more sky in less time than single elements or linear arrays.

When Harvey Moseley of Goddard Space Flight Center's Infrared Astrophysics Branch learned of the new array, he was eager to use one to study the large-scale structure of star-forming regions in our galaxy. He turned to Goddard's Solid-State Device Development Branch for help. A team assembled by Jeffrey Travis, head of the Detector Systems Section, and Peter Shu designed a camera around the array and linked it to a small telescope with a wide field of view. The system will enable astronomers to obtain large-scale images, about 10 arc-minutes in extent, of galactic regions with minimal off-axis aberrations.

The camera consists of a focal plane dewar, which houses the array, a compact camera head electronics package, and a digital signal processor-based data system residing in a standard 486 PC platform. The electronics subsystem incorporates the latest in high-speed amplification, analog-to-digital convertor technology, field-programmable gate arrays, and fiber optics to drive the BIB array and deliver 12-bit data to the DSP cards over four fiber-optic channels at a 4 MHz/channel

pixel rate. The DSPs receive the detector data in digital form, store and process it in real time, and output completed observations.

"One of our objectives was to push the state of the art," Travis said. "But the design has wide potential in less rigorous commercial and industrial infrared imaging or spectroscopic applications." These include thermal machine vision in robotic manufacturing, observation of short-duration thermal events such as combustion or chemical reactions, high-speed IR photography, and high-resolution surveillance imaging.

SOBIEC: Small, Powerful Processor Solves Data Bottlenecks

An extremely small and dense computer node designed for use in spaceborne massively parallel computers will aid in the processing of satellite data about the Earth and benefit a wide range of computer systems on the ground.

The Spacecraft Onboard Information Extraction Computer (SOBIEC) project was initiated in 1991 in anticipation of an explosion in the amount of data collected from future spacecraft. A collaboration between two California companies—Irvine Sensors Corp. and nCUBE—and sponsored by the Jet Propulsion Laboratory (JPL) through a Small Business Innovation Research grant, SOBIEC addresses current constraints on data communications by space-to-ground telemetry links and on-board processing and storage capacities. The computer provides a new processing architecture and means to implement efficient data compression and extraction.

"Onboard data compression can dramatically reduce the required storage capacity, communication bandwidth, and telemetry link bandwidth—which in turn can dramatically increase the information return," said project coordinator David Eisenman, deputy manager of Flight Command & Data Management Systems at JPL.

Earth resources data communicated to the ground are used for detailed analyses of the planet's surface. According to Eisenman, direct extraction onboard the spacecraft of biophysical parameters used to study global vegetation changes, mineral types, and ice/snow cover can reduce significantly the cost and complexity of ground data operations. It also can enable fast response to short- and medium-term events such as volcanos and hurricanes, he said.

SOBIEC's high density is made possible by coupling 3D chip stacking technology [see the cover story in the May 1993 issue] with a 64-bit processor to create a general-purpose computer node with up to 16 MB of memory and 14 bi-directional, high-speed serial I/O channels. Roughly equivalent in size, weight, and power dissipation to a single chip processor, the node provides a building block for a massively parallel processor, distributed processing system, or stand-alone embedded processor. Terrestrial applications include portable computing systems, workstation accelerators, avionics systems, and database processors.

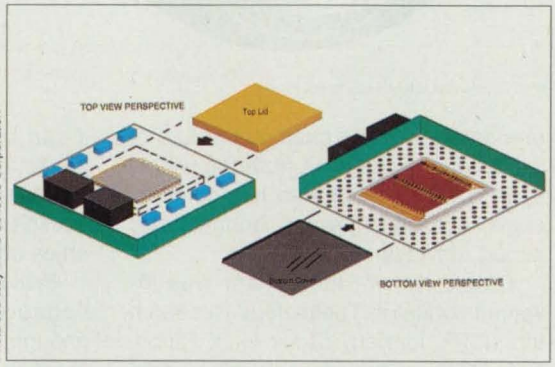

Photo courtesy Irvine Sensors Corporation

SOBIEC, a small and highly dense processing node designed for use in massively parallel spaceborne computers, integrates a 3D chip stack with innovative processing architecture to provide efficient data compression and extraction.

The development team recently began fabrication of the first SOBIEC node and expects completion by spring of 1994. Future plans include developing multiple SOBIEC MCM processor nodes and demonstrating data compression and information extraction processing applications using one or more SOBIEC nodes.

Sensor Warns of Ice Buildup

Ice on aircraft wings has caused at least seven major US airline accidents in the past 10 years. Current preventive measures are costly: last year, US airports sprayed 10 million gallons of toxic ethylene glycol and water deicing solution on aircraft wings. The cost to Northwest Airlines alone was $23 million.

A new sensor developed through a NASA-sponsored Space Act Agreement could help prevent such tragedies and expense by relaying accu-

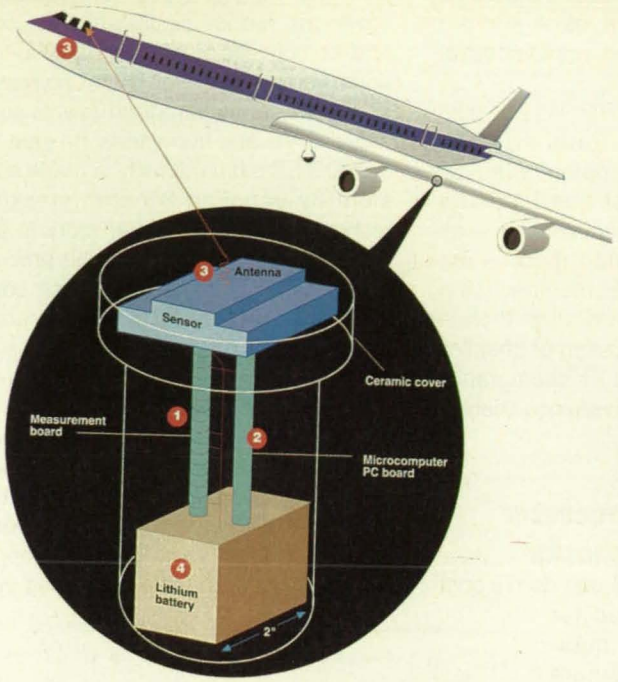

Photo courtesy Raton Technology Research Inc.

A new aircraft wing monitoring system can warn pilots of dangerous ice buildup in real time. The sensors (1), arranged in an array on an aircraft wing, detect and measure ice as it accumulates, sending a signal to an internal microcomputer PC board (2) for analysis. Data on ice thickness and composition is relayed through a small antenna (3) to the cockpit. A lithium battery (4) with a five year life powers the device.

rate data about the changing nature of ice buildup in real time from the wing's surface. The sensor also has potential application on highways, bridges, and airport runways.

Called Kelvin, the sensor was invented by Raton Technology Research Inc. (RTR, formerly Stolar Inc.), Raton, NM. RTR, a mining technology firm that has patented a radio imaging technique to detect underground coal seams, set out to develop an uncut coal thickness sensor to steer cutting machines. "When mining a coal seam, you need to leave 3 to 4 inches of coal on the floor and roof because this outermost layer contains most of the sulfur," explained RTR electrical engineer Larry G. Stolarcyck.

The sensor attracted the interest of Dickey Arndt, chief of electromagnetic systems at Johnson Space Center, as a potential means to detect ice on the space shuttle's liquid oxygen fuel tanks. Through an agreement with Johnson, RTR has been developing the sensor for a variety of ice-detection applications.

Kelvin is based on a resonant circular microstrip antenna sensor that accurately detects and measures ice buildup according to changes in resonance frequency and impedance. It also can define the composition of the ice—whether it is slush, snow, ice, or an ethylene glycol/water solution. In addition to the sensor, the device incorporates a narrow microcomputer board and a lithium battery.

"The sensor is so attractive because it can be made as thin as a sheet of paper and placed on an aircraft wing surface without drilling into it. So it doesn't change the aerodynamic properties of the wing," said Stolarcyck.

Previously developed ice-detection sensors have not proven reliable enough to replace sight and tactile inspection—one of RTR's goals. Problems typically arise after an initial deicing, when planes are taxiing and waiting for takeoff. A pilot who fears the wings have iced again and cannot see them clearly will likely return for another deicing rather than risk an unsafe takeoff.

RTR has assembled various users groups to help evaluate the sensor and is working with the FAA to obtain certification. "We expect to have the equipment on commercial aircraft in time for the 1994 winter season," he said.

While the aircraft market for Kelvin is about $180 million, the highway market is nearly $20 billion, according to Stolarcyck, who expects it to play a key role in tomorrow's "smart" highways. Electronic road signals linked to imbedded sensors could warn drivers of hazards on the roughly 4 million miles of highway and 500,000 bridges in the US that are subject to icing. Said Stolarcyck: "I think these sensors are going to be as common on the highway as those little yellow reflectors are today." ❑

For more information about the technologies described above, contact the NASA field center that sponsored the research (see page 24).

The Delta Clipper Experimental DC-X.

THE NEXT BREAKTHROUGH IS YOURS.

Some people called McDonnell Douglas Aerospace's mission "unthinkable": develop a prototype reusable single-stage rocket vehicle in less than two years. And do it on a budget that was unthinkably tight.

But only eighteen months later and under budget, McDonnell Douglas' Guidance Navigation and Control Group delivered flight control software for the Delta Clipper Experimental rocket. On its first flight on August 18, 1993, the autonomously controlled DC-X performed flawlessly, taking off and landing vertically, right on target.

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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 24). NASA's patent-licensing program to encourage commercial development is described on page 24.

High-Flow, High-Molecular-Weight, Addition-Curing Polyimides

These polyimides are highly processable high-temperature matrix resins that can be used to make composite materials with excellent retention properties during long-term exposure to air at 650 °F (343 °C). Additional applications may be in electronics.
(See page 62.)

Nonvolatile Array of Synapses for Neural Network

A 32×32 very-large-scale integrated circuit array of electronic synapses serves as a building-block chip for an analog neural-network computer. A fully parallel array of 1,024 cells can perform about 5×10^8 operations per second.
(See page 26.)

Three-Dimensional Magnetic-Bubble Memory System

A proposed system would include a stack of two-dimensional memory modules. Data would be read out via the Faraday effect.
(See page 32.)

Rectangular Array of Digital Processors for Planning Paths

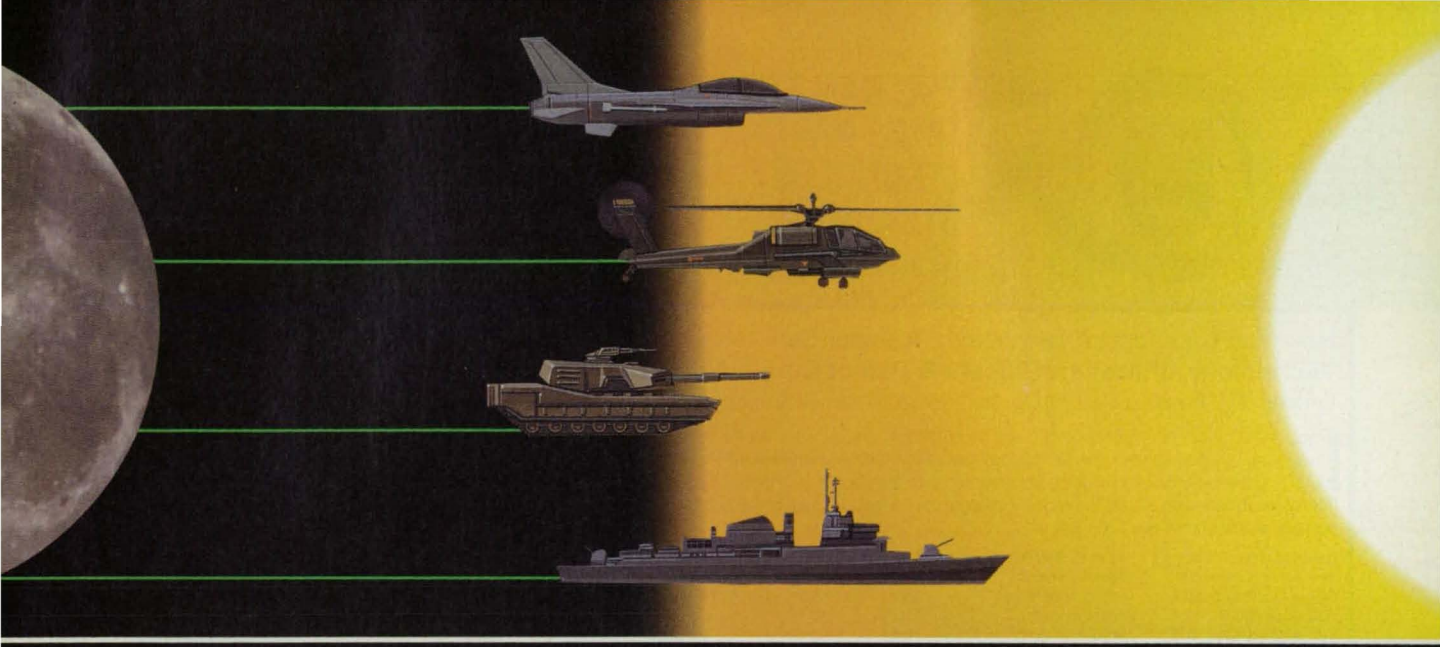
A prototype 24×25 rectangular array of asynchronous parallel digital processors rapidly finds the best path across a patch of terrain to be traversed, for example, by a robot. In preliminary tests, the array found the best path in about one-thousandth the time needed by a more conventional computer.
(See page 34.)

Packet Controller for Wireless Headset

This circuit converts voice signals into digital packets of data and vice versa. It would occupy minimal space in a headset and extend the life of the headset battery.
(See page 44.)

Fluorescent-Antibody Measurement of Cancer-Cell Urokinase

A combination of laboratory techniques for measuring the amounts of urokinase holds promise of revealing the metastatic potentials of tumors. If proved, such measurements can help in the treatment and prognosis of patients after surgical removal of tumors.
(See page 92.)



The LED Electro-Optical Display solution for NVIS-Sunlight requirements.

The VIVISUN 5000 electro-optical display system incorporates LED lighting that is both NVIS compatible and sunlight readable per MIL-L-85762A. This interactive system also provides rugged reliability and meets the environmental extremes that military programs demand.

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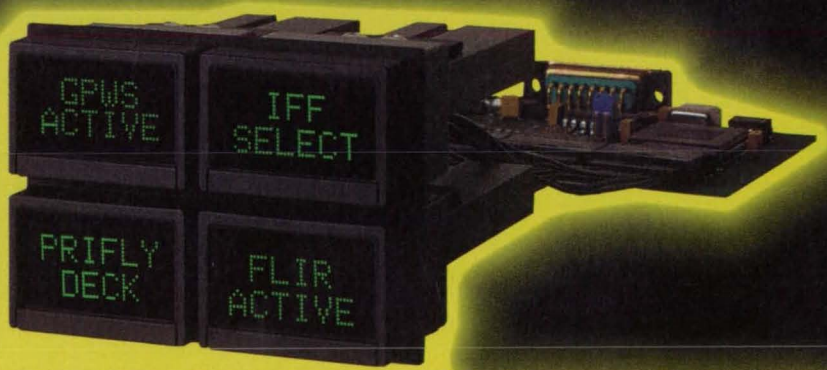
VIVISUN 5000 electro-optical display system. The day-night all weather lighting solution.



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If you're a regular reader of TECH BRIEFS, then you're already making use of one of the low-and no-cost services provided by NASA's Technology Transfer Program. But a TECH BRIEFS subscription represents only a fraction of the technical information and applications/engineering services offered by this Program. In fact, when all of the components of NASA's Technology Transfer Network are considered, TECH BRIEFS represents the proverbial tip of the iceberg.

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

How You Can Access Technology Transfer Services At NASA Field Centers:

Technology Utilization Officers & Patent Counsels—Each NASA Field Center has a Technology Utilization Officer (TUO) and a Patent Counsel to facilitate technology transfer between NASA and the private sector.

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

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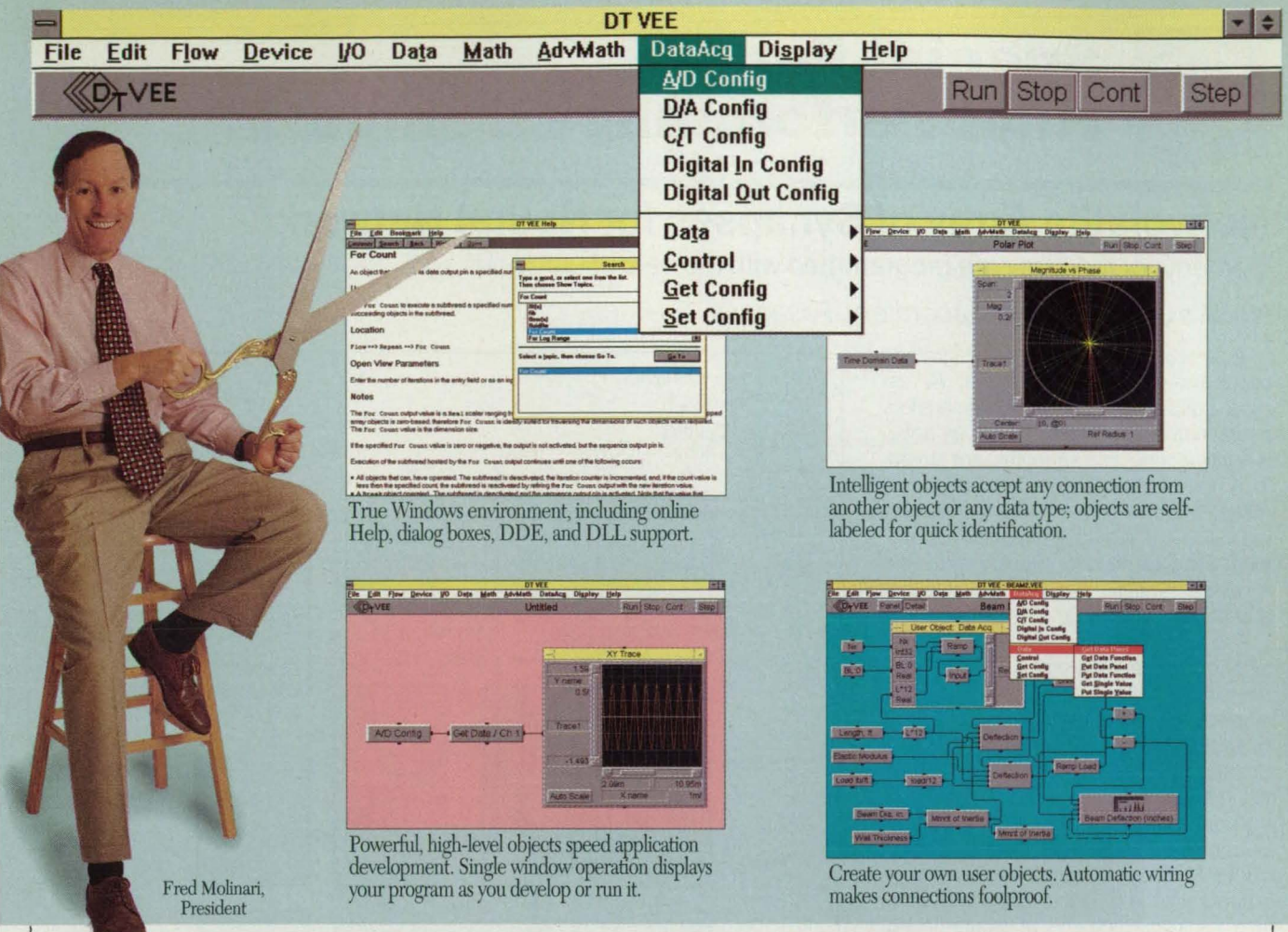

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For More Information Write In No. 558

Nonvolatile Array of Synapses for Neural Network

Elements of the array are programmed with the help of ultraviolet light.

NASA's Jet Propulsion Laboratory, Pasadena, California

A 32 ×32 very-large-scale integrated-circuit array of electronic synapses serves as a building-block chip for an analog neural-network computer. The synaptic weights (connection strengths) are stored in a nonvolatile manner. This approach makes the information content of the array invulnerable to loss of power, and, by eliminating the need for circuitry to refresh a volatile synaptic memory, it makes the architecture simpler and more compact.

The array (see Figure 1) operates in conjunction with analog bias and digital addressing circuits. Each cell of the array is an electronic synapse in the form of a four-quadrant analog multiplier circuit with two differential voltage inputs: (V_{X+}, V_{X-}) and (V_{Y+}, V_{Y-}). V_{X+}, V_{X-}, and V_{Y-} are fed via conductive paths directly to the gates of complementary metal oxide/semiconductor (CMOS) transistors. However, V_{Y+} establishes the synaptic weight and is fed to a transistor gate only at programming time. The rest of the time, the V_{Y+} gate is electrically isolated; that is, it "floats" at the value of V_{Y+} set during the most recent programming session.

Figure 2 illustrates part of the structure of a cell and the physical mechanism of programming. The transistor's floating gate is electrically isolated by a thick layer of silicon dioxide, which separates it from a polycrystalline silicon conductor connected to V_{Y+}. The entire array is covered with a UV metal shield that has an opening over the V_{Y+} conductor and floating gate in each cell.

During programming, the array is illuminated with ultraviolet light at a wavelength of 254 nm; the energy of the photons is 4.8 eV, which is sufficient to excite a significant number of electrons across the silicon dioxide energy barrier. Consequently, the SiO_2 between the V_{Y+} conductor and the otherwise floating gate appears to be weakly "conductive," and the potential of the floating gate can be programmed to V_{Y+}. The illumination is then removed, causing the gate to "float" at V_{Y+}. During programming, the associated addressing circuitry prevents the leakage of charge to or from those floating gates that are not to be programmed.

With a standard 5-Vdc supply, the typical range of V_{Y+} is 2.7 to 3.5 V, and the usable differential input voltages in both the X and Y channels lie in the range ±0.25 V. The settling time of the multiplier circuit in each cell is about 2 μs; this means that a fully parallel array of 1,024 cells can perform about 5×10^8 opera-

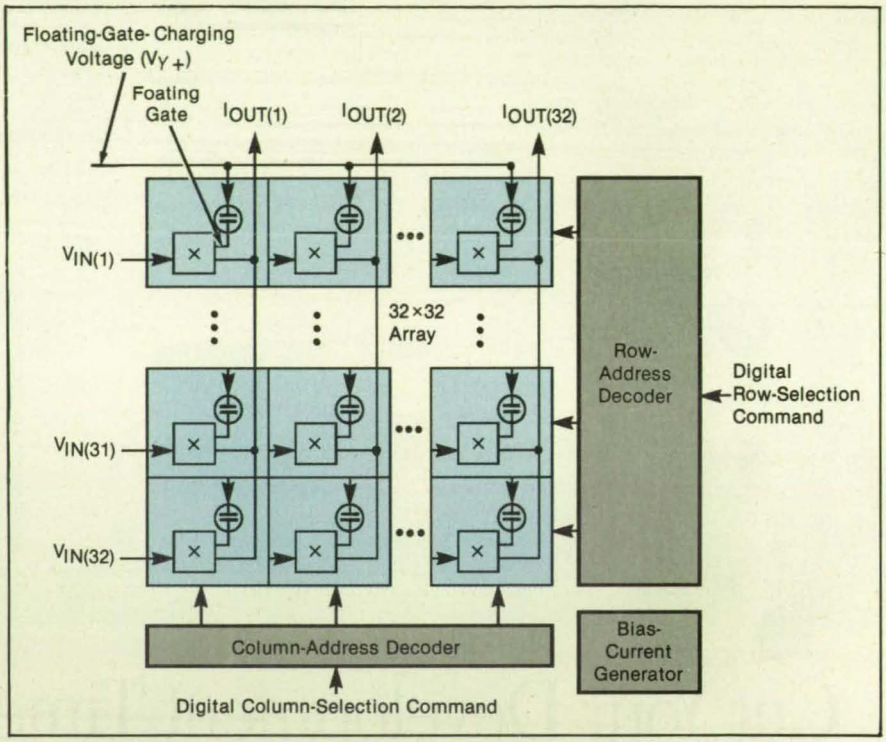

Figure 1. The **Array of Electronic Synapses**, shown here greatly simplified, contains 1,024 four-quadrant analog multipliers with differential inputs. The label "V_{IN}" on each row denotes the V_{X+}, V_{X-}, and V_{Y-} input voltages collectively.

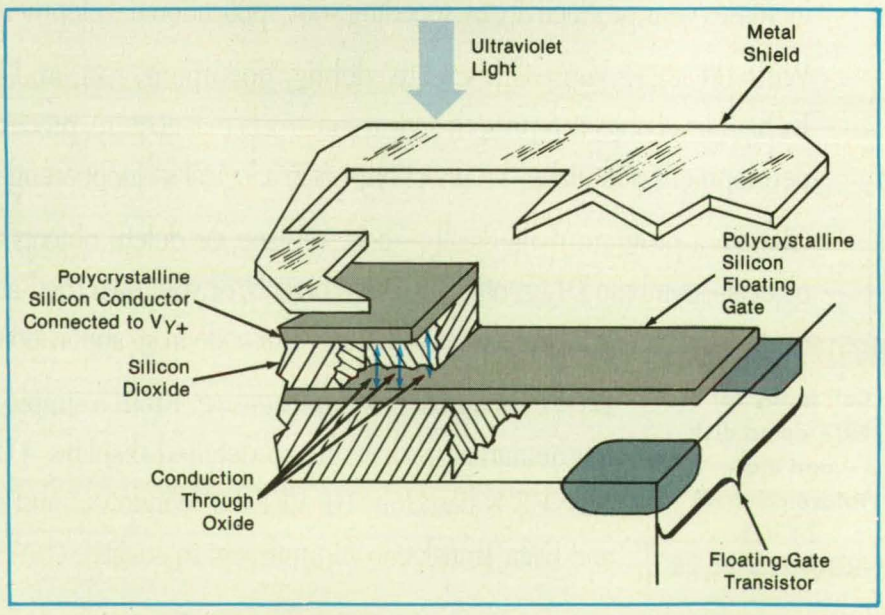

Figure 2. A **Floating Gate Is Charged** to potential V_{Y+} by ultraviolet-induced conduction of electrons through SiO_2 from a nearby conductor at potential V_{Y+}.

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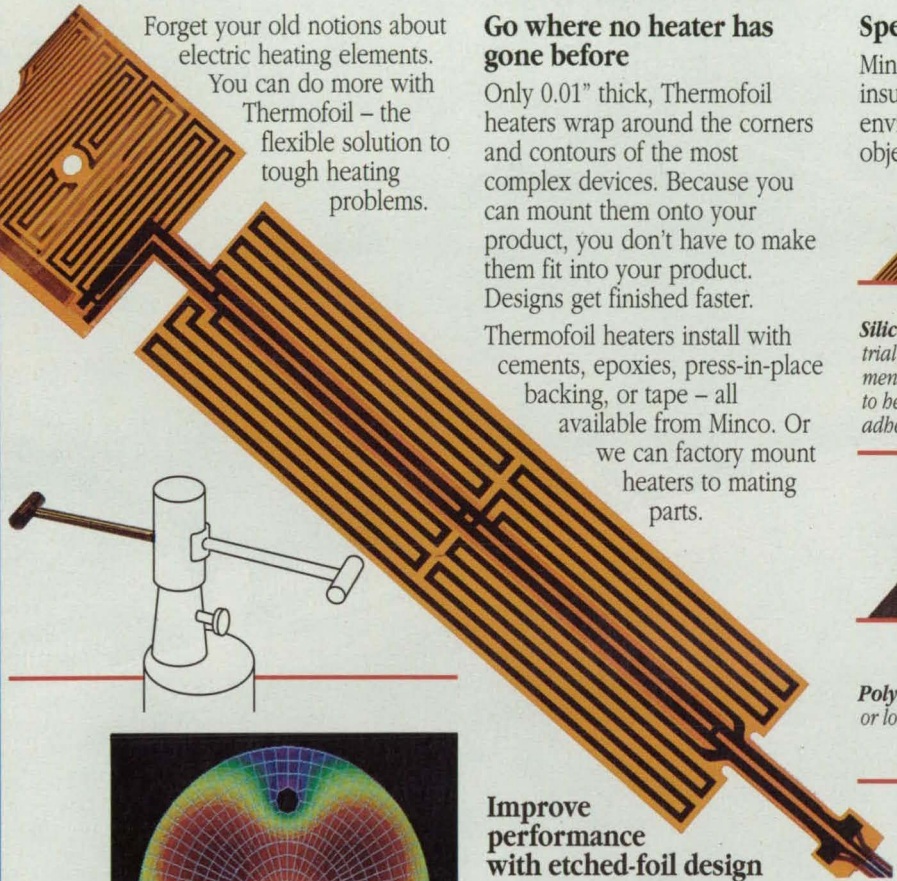

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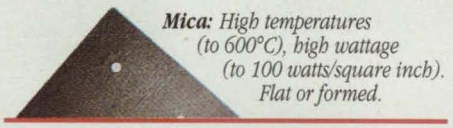
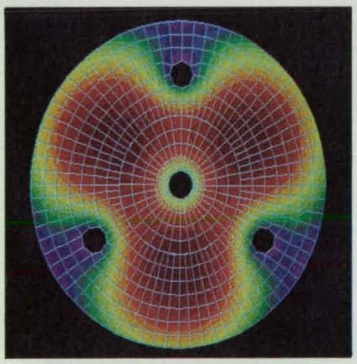


Mica: *High temperatures (to 600°C), high wattage (to 100 watts/square inch). Flat or formed.*

Polyester: *For transparent or low-cost heaters.*



To eliminate uneven temperature gradients add higher wattage around holes and edges.

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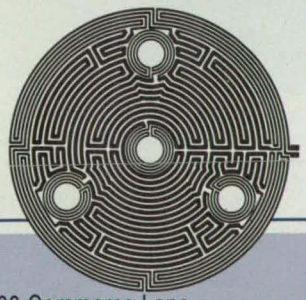

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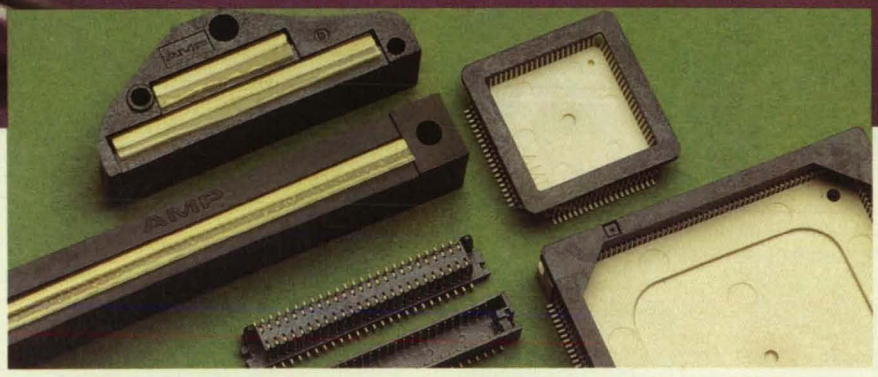
How to beat the squeeze in today's tight design environments.



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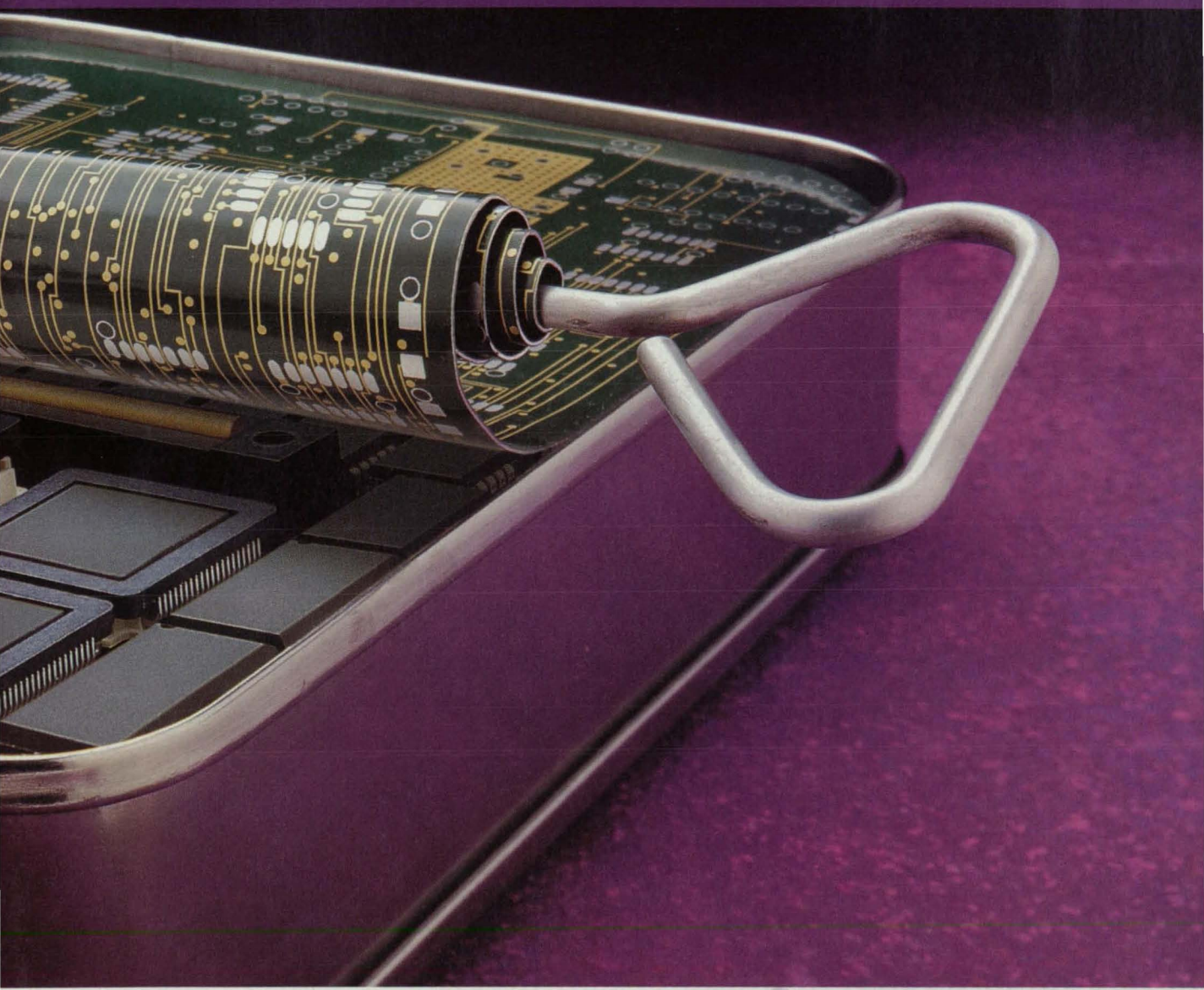

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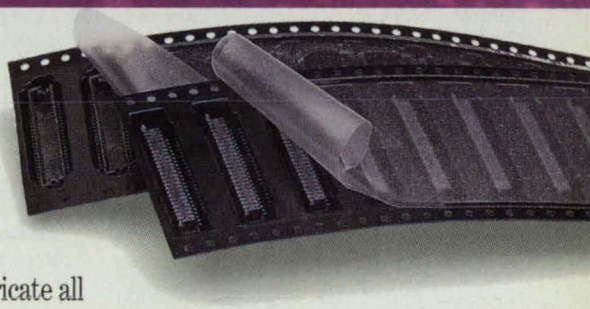

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This work was done by Raoul Tawel of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 7*** *on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 24]. Refer to NPO-18578.

Parallel Computation of Forward Dynamics of Manipulators

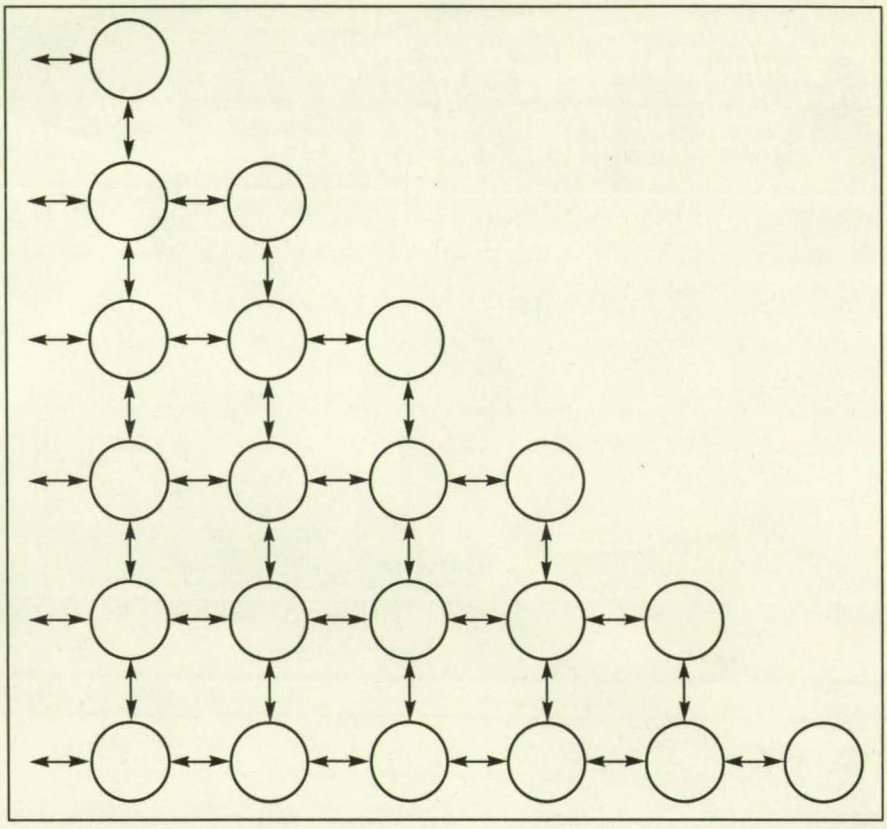
Significant speedup of computation is anticipated.

NASA's Jet Propulsion Laboratory, Pasadena, California

A report presents parallel algorithms and a special parallel architecture for computation of the forward dynamics of robotics manipulators. The manipulator forward-dynamics (or, dynamic-simulation) problem concerns the determination of the motion of the mechanical system resulting from the application of a set of control forces/torques. Fast algorithms for the problem are needed for applications that involve extensive off-line simulation, as well as for applications that require real-time simulation capability. For many anticipated space teleoperation applications, a faster-than-real-time simulation capability will be essential. In fact, in the presence of unavoidable communication delay, such a capability would allow a human operator to preview a number of scenarios before run time.

At present, even the fastest serial algorithms are far from providing real-time or faster-than-real-time simulation capability. The proposed parallel algorithms and architecture are products of an effort to find the best method of parallel computation to achieve the required computational efficiency. To this end, an extensive comparative analysis of the efficiency of various methods for parallel computation is performed. This analysis reveals that the $O(n^3)$ methods (n denotes the number of degrees of freedom of the system) are more efficient for parallel computation than the $O(n)$ and $O(n^2)$ methods.

On the basis of this finding, a set of fast parallel algorithms for computation of the $O(n^3)$ method is developed. The $O(n^3)$ method solves the problem by explicit computation and inversion of the inertia (mass) matrix, as well as explicit computation of the bias vector (which represents the contribution due to the nonlinear terms). The approach taken in the development of parallel algorithms for computation and inversion of the inertia matrix and for computation of the bias vector was to strive to optimize them, not only with respect to computational complexity but also with respect to the requirement to simplify the architecture (particularly, to keep the required communication and synchronization mechanism as simple as possible).



This **Two-Dimensional Array of Processors** is proposed for parallel computation of forward dynamics of a manipulator with $n = 6$.

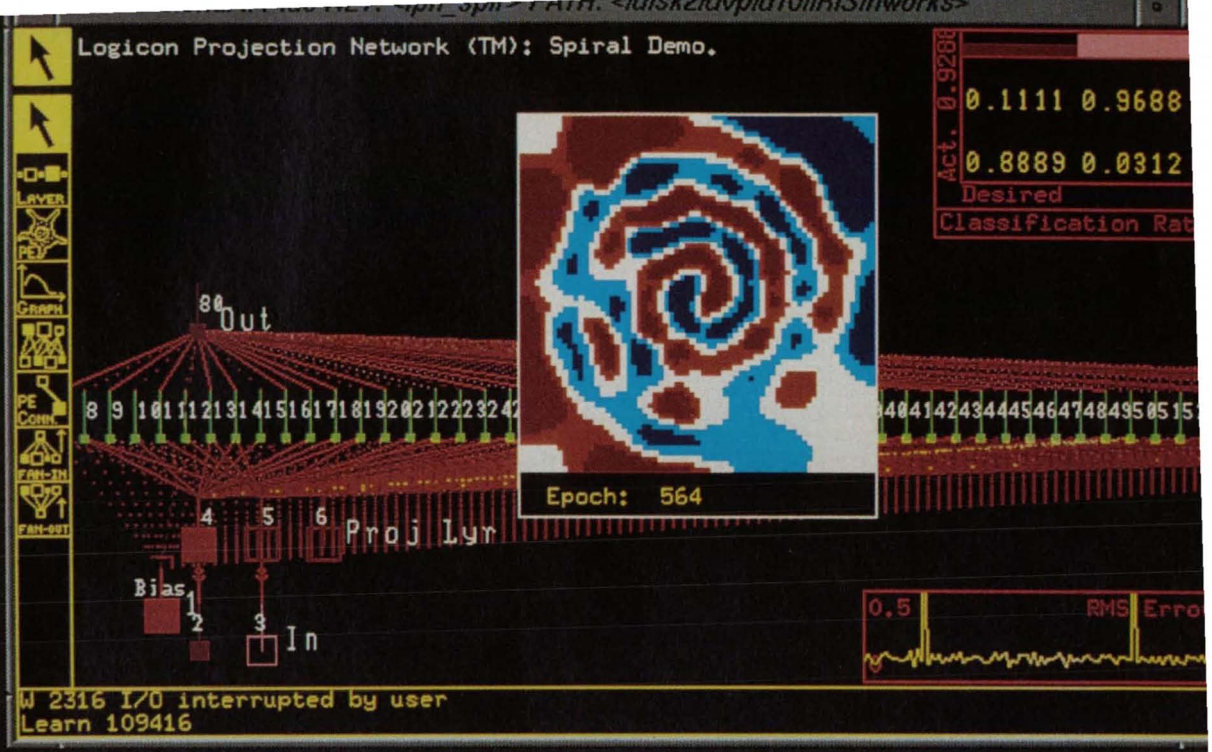
Algorithm		Relative Cost of Computation		Number of Processors
		In General	$n = 6$	
Serial	Older $O(n)$ Algorithm	$682n - 371$	4,092	1
	One Older $O(n^3)$ Algorithm	$(1/3)n^3 + (43/2)n^2 + (1,549/6)n - 113$	2,882	1
Parallel	Two Other Older $O(n^3)$ Algorithms	$5\lceil(n^2 - 1)/6\rceil + 15\lceil(n+1)/2\rceil + 5n + 74\lceil\log_2 n\rceil + 355$	721	n
		$14\lceil(n+1)/2\rceil + 15n + 74\lceil\log_2 n\rceil + 355$	722	$n(n+1)/2 + n$
	Proposed $O(n^3)$ Algorithm	$6n + 69\lceil\log_2 n\rceil + 340$	583	$n(n+1)/2$

The **Cost of Computation Would Be Reduced** significantly by using the proposed algorithms and architecture.

The proposed algorithms could be efficiently executed on a triangular array of $n(n+1)/2$ processors with simple nearest-neighbor interconnection (the figure shows the array for $n = 6$). This architecture is particularly suitable for VLSI implementation. The table shows a comparison of the computational cost of the proposed algorithms and of the previously proposed serial and parallel algorithms for the problem. As can be seen, the efficiency of the proposed parallel algorithms increases for larger n.

This work was done by Amir Fijany and Antal K. Bejczy of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 82*** *on the TSP Request Card.*

NPO-18706



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NEURALWARE

Three-Dimensional Magnetic-Bubble Memory System

Data would be read out via the Faraday effect.

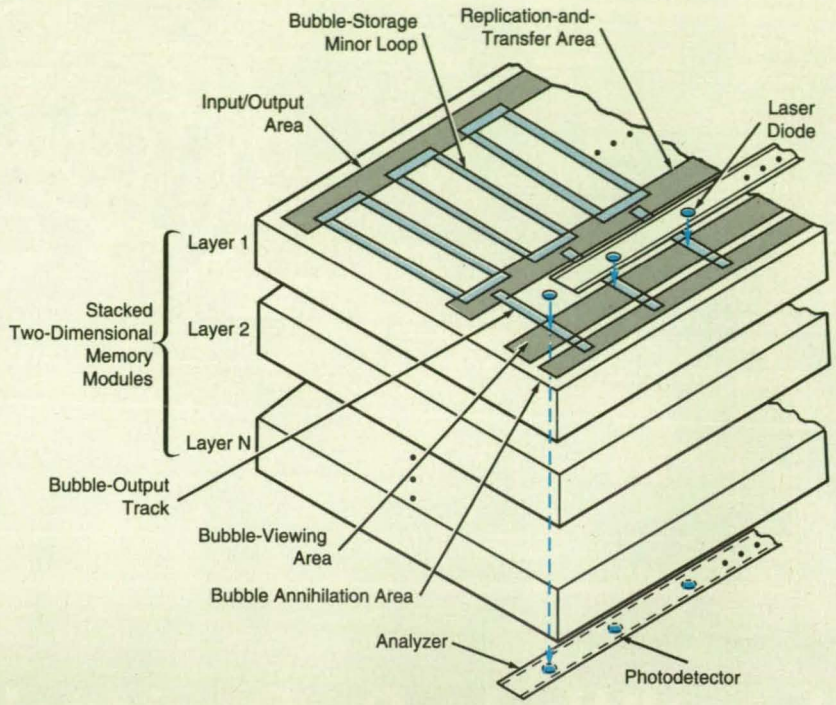
NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed magnetic-bubble memory system would include a stack of two-dimensional memory modules. The three-dimensional design would enable the overall storage density of the system to be greater than that of prior magnetic-bubble memories. The system would provide nonvolatile storage, with readout access times in the millisecond range. It would have a partly parallel input/output configuration that could support high-performance computing. It would also be relatively invulnerable to damage by ionizing radiation.

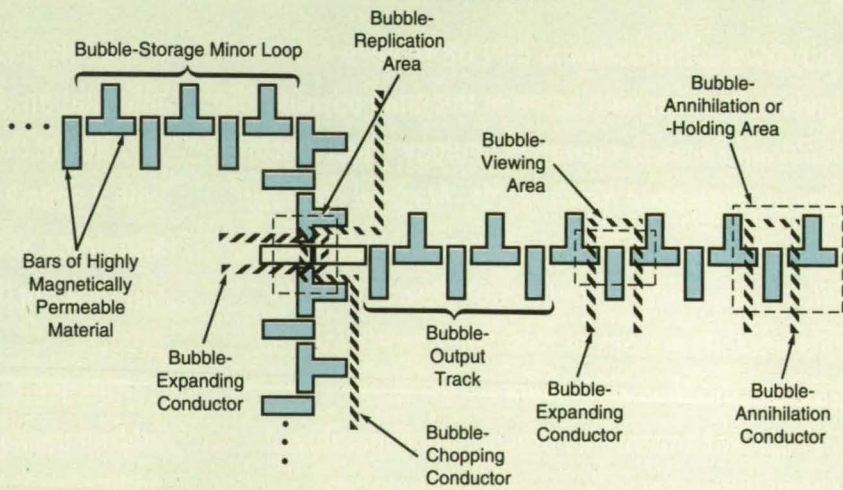
Binary data, as represented by the direction of magnetization of the magnetic bubbles, would be read out via the Faraday effect, which is the rotation of the polarization of light as the light passes through the bubble-memory material along a magnetic field. Whether the polarization rotates right or left depends on whether the magnetic field is parallel or antiparallel to the direction of propagation. A linear array of laser diodes and a strip of polarizing material would generate beams of polarized light, which would propagate downward through the stack of two-dimensional memory modules, through bubble-viewing areas at the right ends of rows in each module (see figure). The rotation of polarization from each stack of rows would be detected by an analyzer and photodetector in a linear array of photodetectors placed under the stock, facing up at the linear array of laser diodes at the top.

Magnetic bubbles would be read out nondestructively. By use of established magnetic-field memory-access techniques, magnetic bubbles would be made to propagate around bubble-storage minor loops, which would constitute the rows in the two-dimensional modules. Each bubble would be brought in sequence to a bubble-replication area. If a bubble in a given row of a given module were designated to be read out, then by means of magnetic fields generated by bubble-expanding and bubble-chopping electrical conductors in the bubble-replication area, a copy of the bubble would be made.

The copy would then be transferred along a bubble-output track to the bubble-viewing area, where it would be probed by the readout light beam. After readout, the bubble would be transferred to an annihilation or holding area, where it would be annihilated by a magnetic field generated by an electrical current or else simply held to prevent it from interfering with the operation of the system.



THREE-DIMENSIONAL MAGNETIC-BUBBLE MEMORY SYSTEM



DETAIL OF BUBBLE-REPLICATING AND -TRANSFERRING COMPONENTS OF ONE ROW OF ONE MODULE

The **Three-Dimensional Magnetic-Bubble Memory** would consist mostly of a stack of two-dimensional memory modules. Magnetic bubbles would be brought to bubble-viewing areas at the right ends of the memory rows. The datum in the designated row of a designated module would be read out via the Faraday effect in the corresponding bubble-viewing area.

This work was done by Romney R. Katti, Jiin-Chuan Wu, and Henry L. Stadler of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 61*** *on the TSP Request Card.*

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

William T. Callaghan, Manager
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Refer to NPO-18533, volume and number of this NASA Tech Briefs *issue, and the page number.*

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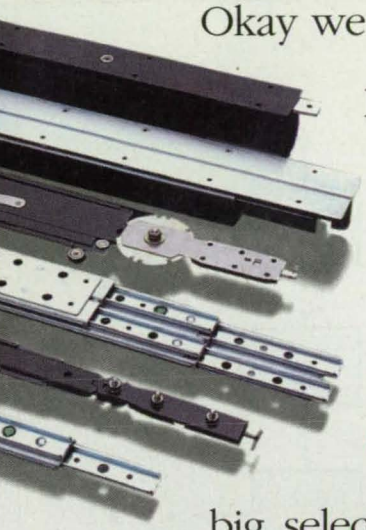

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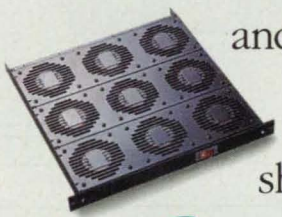

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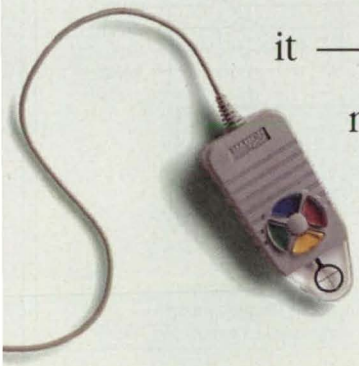

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Rectangular Array of Digital Processors for Planning Paths

Parallel processing greatly reduces the time needed to find the best path.

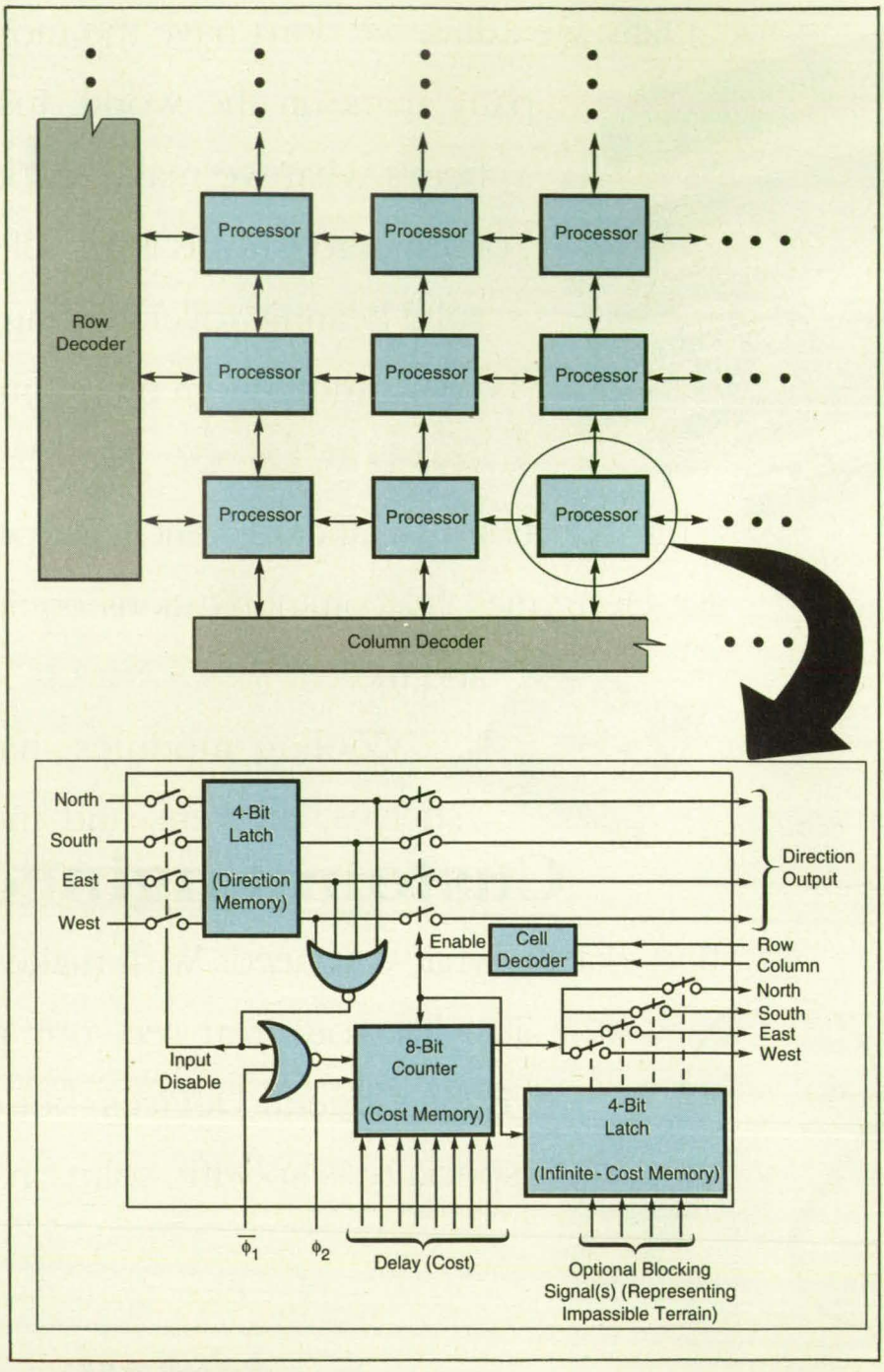
NASA's Jet Propulsion Laboratory, Pasadena, California

A prototype 24×25 rectangular array of asynchronous parallel digital processors rapidly finds the best path across a two-dimensional field, which could be, for example, a patch of terrain to be traversed by a robotic or military vehicle. The best path is defined as the one for which the total time or other measure of the cost and/or difficulty of travel from a given starting point to a given stopping point is minimized. Each processor represents a picture element of the map of the field.

The prototype array of processors is implemented as a single-chip very-large-scale integrated circuit. Excepting the processors on the edges, each processor communicates with its four nearest neighbors along paths that represent travel to the north, south, east, and west. Each processor contains a delay generator in the form of an 8-bit ripple counter, which is preset to 1 of its 256 possible values; the preset value represents the time or other cost of travel across the corresponding picture element.

Operation begins with the choice of a processor that represents the starting point. This processor transmits signals to its nearest neighbor processors, which then retransmit to other neighboring processors, and the process repeats until signals have propagated across the entire field according to the following scheme: Once each processor receives a signal, the direction from which that signal came is stored, and further inputs to that processor are disabled; that is to say, only the first signal (representing the fastest or cheapest path) to reach each processor is used. The receipt of the signal causes the delay-generating counter to count from its preset value down to zero; when it reaches zero, the processor retransmits the delayed signal to its nearest neighbors. In addition to delaying the signal, each cell can also be made to block the propagation of the signal along a given direction to model the effect of impassible terrain.

Once the signal has propagated across the entire array, one can specify any destination, then query the processor that represents the destination to find the shortest path to it from the starting processor. This path is then found by retracing the signal-propagation path along the directions of receipt of signals stored in the processors along the way. Preliminary tests have shown that the prototype array finds the best path in less than 300 μs; this is about one-thousandth the time needed to find the best path across a comparable 600-picture-element field by use of software on a more-conventional general-purpose computer.



This **Rectangular Array of Processors** finds the shortest, least difficult, or cheapest path from a given starting point to a given destination by finding the path of fastest propagation of a signal.

This work was done by Sabrina E. Kemeny, Eric R. Fossum, and Robert H. Nixon of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 5*** *on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office–JPL [see page 24]. Refer to NPO-18727.

Program Helps Simulate Neural Networks

NNETS supports back-propagation and related algorithms.

The primary purpose of the Neural Network Environment on a Transputer System (NNETS) computer program is to provide users a high degree of flexibility in creating and manipulating a wide variety of neural-network topologies at processing speeds not found in conventional computing environments. To serve this purpose, NNETS supports back-propagation and back-propagation-related algorithms. The back-propagation algorithm used is an implementation of Rumelhart's generalized delta rule. NNETS was developed on the INMOS Transputer®.

NNETS predefines a back-propagation network, a Jordan network, and a reinforcement network to assist users in learning and defining their own networks. The program also enables users to configure other neural-network paradigms from the NNETS basic architecture.

The Jordan network is basically a feed-forward network in which the outputs are connected to a pseudoinput layer. The state of the network depends on the inputs from the environment plus the state of the network.

The reinforcement network learns via a scalar feedback signal called "reinforcement." The network propagates forward randomly. The environment looks at the outputs of the network to produce a reinforcement signal that is fed back to the network.

NNETS was written for the INMOS C compiler D711B version 1.3 or later (MS-DOS version). A small portion of the software written in the OCCAM language routes communications between processors. NNETS is configured to operate on a 4 × 10 array of Transputers® in sequence with a Transputer®-based graphics processor controlled by a master IBM PC 286 (or better) Transputer®. A red/green/blue (RGB) monitor capable of 512 × 512 resolution is required. It must be able to receive RGB signals via BNC connectors. NNETS is meant for experienced Transputer® users only. The program is distributed on 5.25-in. (13.34-cm), 1.2Mb MS-DOS format diskettes. NNETS was developed in 1991.

Transputer and OCCAM are registered trademarks of Inmos Corp. MS-DOS is a registered trademark of Microsoft Corp. IBM PC is a registered trademark of International Business Machines Corp.

This program was written by James Villarreal of **Johnson Space Center** *and Gary McIntire of Ford Aerospace. For further information,* ***write in 78*** *on the TSP Request Card.*
MSC-21485

Network Queuing System, Version 2.0

NQS facilitates the allocation of tasks and transfers of files in a computer network.

The Network Queuing System (NQS) computer program is a versatile batch- and device-queuing facility for a single UNIX computer or a group of computers in a network. With the UNIX operating system as a common interface, the user can invoke the NQS collection of user-space programs to move batch and device jobs freely among the different computers in the network. NQS provides facilities for remote queuing, request routing, remote status, queue-status controls, batch-request resource quota limits, and remote output return.

This program was developed as part of an effort aimed at tying together diverse UNIX-based computers into NASA's Numerical Aerodynamic Simulator Processing System Network. This revision of NQS provides for the creation, deletion, addition, and setting of complexes that aid in limiting the number of requests to be handled at one time. It also has improved device-oriented queues along with some revision of the displays.

NQS was designed to meet the following nine goals:

1. Provide for the full support of both batch and device requests.
2. Support all of the resource quotas enforceable by the underlying UNIX kernel implementation that are relevant to any particular batch request and its corresponding batch queue.
3. Support remote queuing and routing of batch and device requests throughout the NQS network.
4. Support queue-access restrictions through user and group access lists for all queues.
5. Enable networked output return of both output and error files to possibly remote computers.
6. Enable the mapping of accounts across the boundaries between computers.
7. Provide friendly configuration and modification mechanisms for each installation.
8. Support status operations across the network, without requiring a user to log in on remote target computers.
9. Provide for file staging or copying of files for movement to the computer on which a program is to be executed.

To support batch and device requests, NQS v.2 implements three queue types: batch, device, and pipe. Batch queues hold and prioritize batch requests; device queues hold and prioritize device requests; pipe queues transport both batch and device requests to other batch, device, or pipe queues at local or remote computers. Unique to batch queues are resource quota limits that restrict the amount of different resources that a batch request can consume during execution. Unique to each device queue is a set of one or more devices, such as a line printer, to which requests can be sent for execution. Pipe queues have associated destinations to which they route and deliver requests. If the proper destination computer is not functioning or unreachable, pipe queues are able to requeue the request and deliver it later when the computer is available. All NQS network conversations are performed by use of the Berkeley socket software mechanism as ported into the respective vendor software kernels.

NQS is written in the C language and has been successfully implemented on a variety of UNIX computers, including Sun3- and Sun4-series computers, SGI IRIS computers running IRIX 3.3, DEC computers running ULTRIX 4.1, AMDAHL computers running UTS 1.3 and 2.1, and computers running BSD 4.3 UNIX. This version of NQS also communicates with the Cray Research, Inc., and Convex, Inc., versions of NQS. The program is available in UNIX tar format on a 60-Mb, QIC-24, 0.25-in. (6.35-mm) Sun cartridge (standard distribution medium). Upon request, this program can be provided in UNIX tar format on alternate media. Please contact COSMIC to discuss the availability and cost of media to meet your specific needs. An electronic copy of the NQS documentation is included on the program medium.

IRIX is a trademark of Silicon Graphics Inc. IRIS is a registered trademark of Silicon Graphics Inc. UNIX is a registered trademark of AT&T Bell Laboratories. Sun3 and Sun4 are trademarks of Sun Microsystems Inc. ULTRIX is a trademark of Digital Equipment Corp.

This program was written by Howard Walter and Mike Bridges of **Ames Research Center**, *Terrie Carver of Computer Sciences Corp., and Brent Kingsbury of Sterling Software, Inc. For further information,* ***write in 107*** *on the TSP Request Card.*
ARC-13179

Synchronizing a Television Camera With an External Reference

A controlled delay is introduced into the path of the external composite sync.

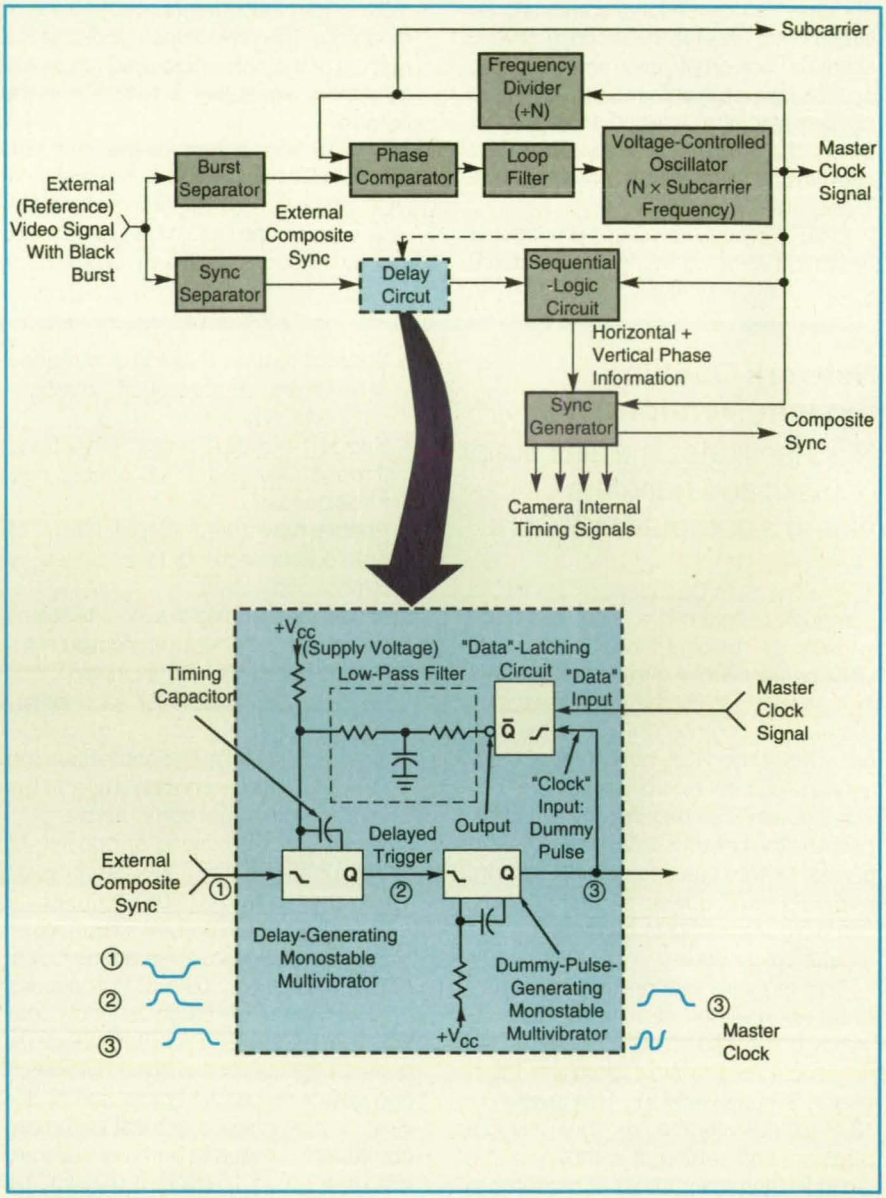
Lyndon B. Johnson Space Center, Houston, Texas

The figure shows the functional blocks of an improved version of genlock circuitry, which synchronizes a television camera with an external (reference) video source. Genlocking is needed in a television broadcasting system because it facilitates the composition of video displays in such multiple-source formats as split screen and windowing in real time. The improvement in this genlock subsystem consists in the incorporation of a controllable delay circuit into the path of the composite synchronization signal that is obtained from the external video source. The delay circuit helps to eliminate potential jitter in the video display, as explained below.

The genlock subsystem is synchronized internally by a master clock, which is an oscillator that is locked in phase to the color-burst subcarrier on the external signal. Typically, the oscillator operates at 4 or 8 times the subcarrier frequency. The master clock controls a digital sequential-logic circuit, which extracts the vertical-sweep and horizontal-sweep phase information for the camera from the composite-sync component of the external signal.

There is potential for a skew between the master-clock signal and the video-phase signal derived from the external composite sync. Depending on the details of the system, the leading (active) edge of a master-clock pulse could coincide with, or lag slightly behind, the leading edge of the corresponding external composite synchronizing pulse: this condition could violate the setup requirements for the digital timing circuits in the camera, thereby giving rise to apparent instability or jitter in a display of the image of this camera. The controllable delay circuit eliminates the instability or jitter by aligning the leading edge of the external sync with the trailing (inactive) edge of the master-clock pulse.

The controlled delay is implemented by use of the trailing edge of the output of a first monostable multivibrator, which is triggered on the leading edge of the reference sync. The duration of the delay is selected to exceed the minimum allowable pulse period by at least one period of the master clock. The delayed output of the first monostable multivibrator triggers a second monostable multivibrator to generate a dummy pulse that satisfies the pulse-width requirements of the subsequent logic stages. The leading edge of the dummy pulse contains the sync timing plus the compensating delay.



The **Delay Circuit** helps to ensure that the setup requirements for the digital timing circuits of the video camera are satisfied.

A data latch serves as a phase detector. The master-clock signal is fed to the latch as the data input while the dummy pulse is used as the clock input to the latch. The latched state then determines whether the synchronization datum contained in the leading edge of the pulse is arriving in the high or the low half cycle of the master clock signal. The

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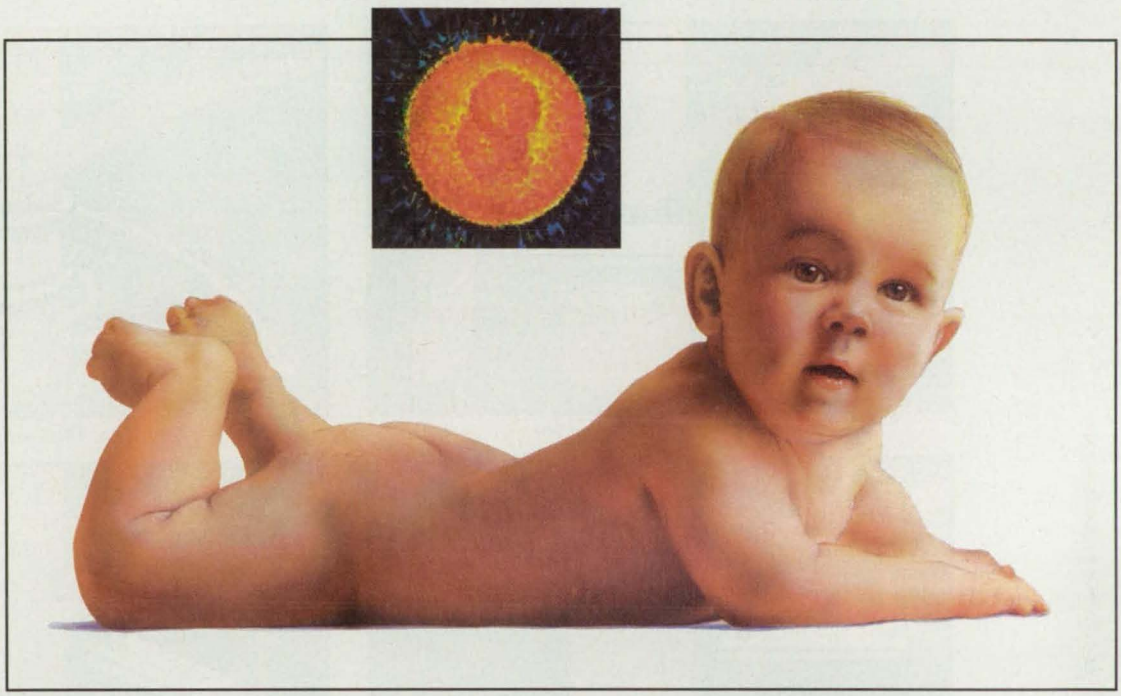

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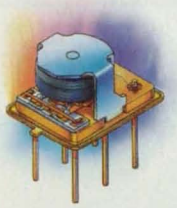

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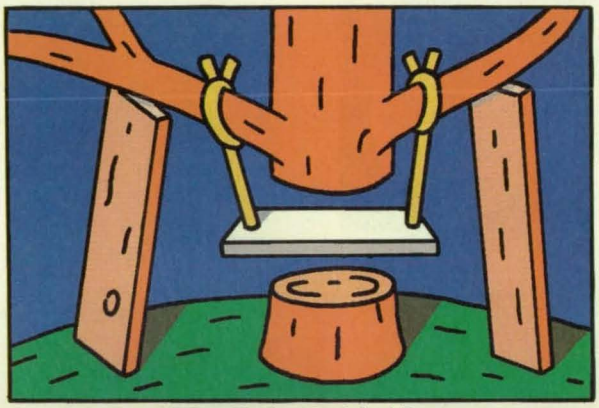
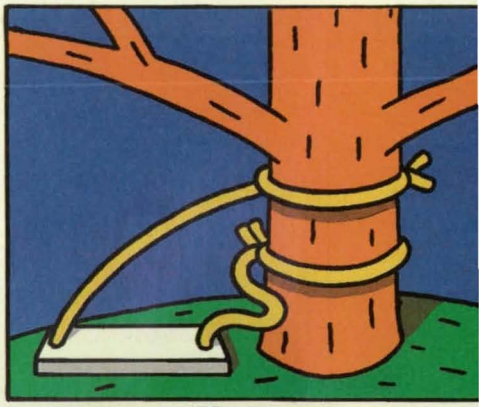
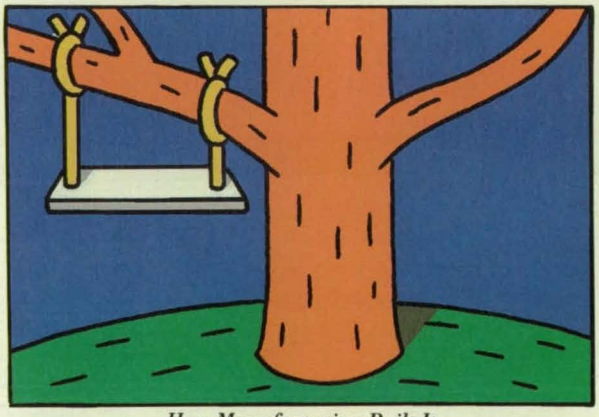


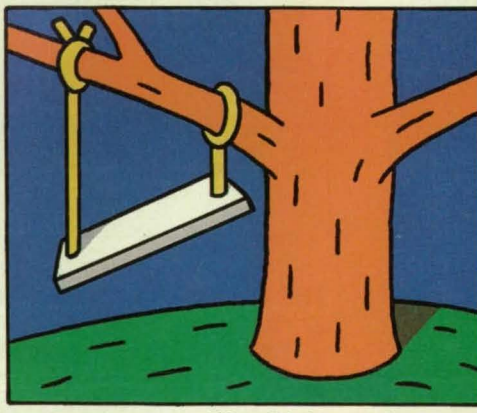
What Marketing Asked For



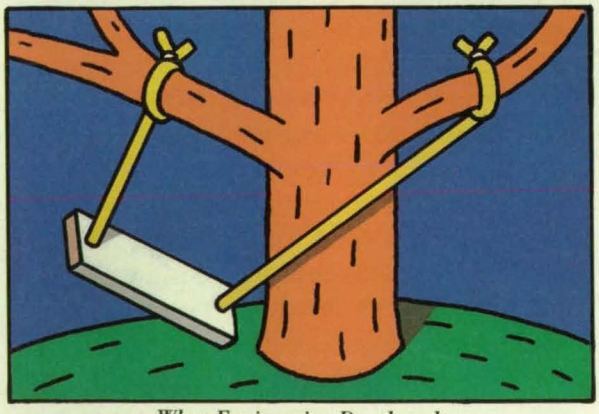
What Design Specified



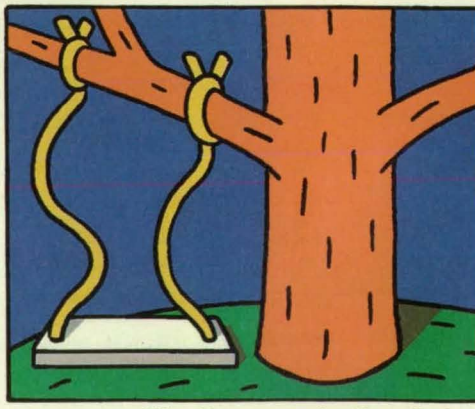
How Manufacturing Built It



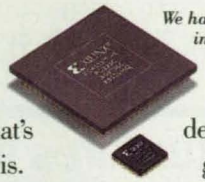
What QA Approved



What Engineering Developed



What Documentation Described



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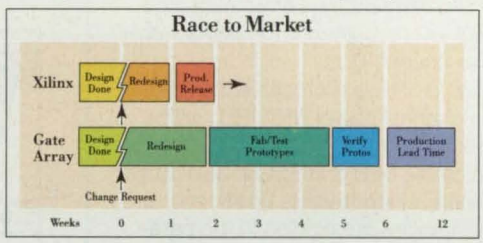

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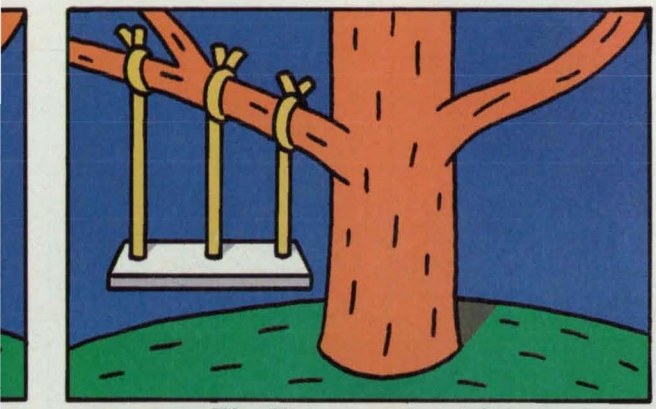
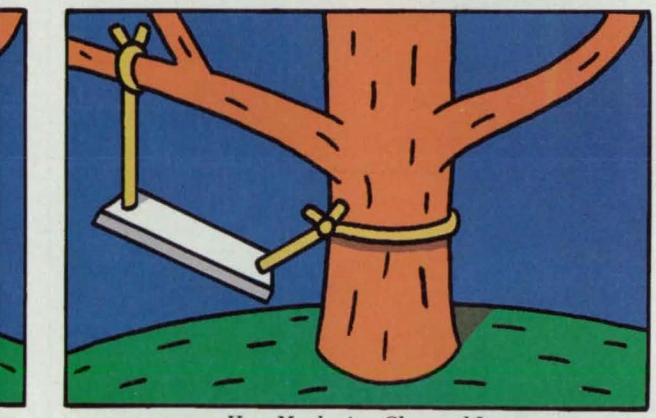
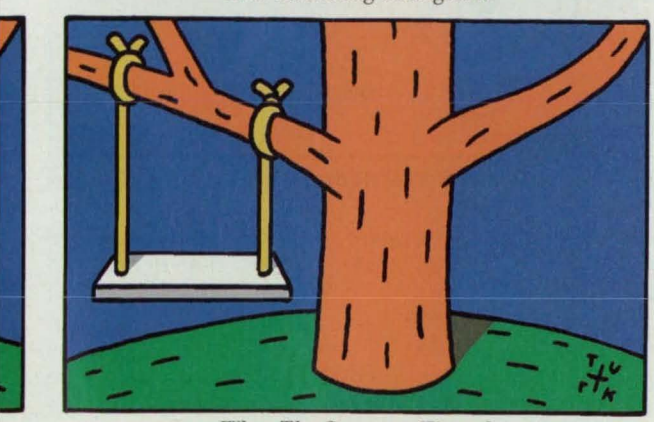


What Management Agreed On



How Marketing Changed It



What The Customer Wanted

For More Information Write In No. 593

inverted latch output is low-pass filtered and the resulting average voltage is applied to the timing network of the delay-generating monostable multivibrator.

The filtered phase information in this voltage either lengthens (or shortens, respectively) the delay by causing current to be siphoned from (or fed into) the timing capacitor. The delay is shortened (or lengthened, respectively) if the average phase is such that the master-clock signal is low (or high) when the sync arrives. These effects force the arriving sync information to assume an average phase relationship with the master clock, such that the sync coincides with the trailing edge of the clock signal.

This work was done by Edward M. Rentsch of General Electric Co. for **Johnson Space Center**. *For further information,* ***write in 10*** *on the TSP Request Card.*
MSC-22085

Analyzing Single-Event Gate Ruptures in Power MOSFET's

Redundant MOSFET's should be maintained at zero bias until needed.

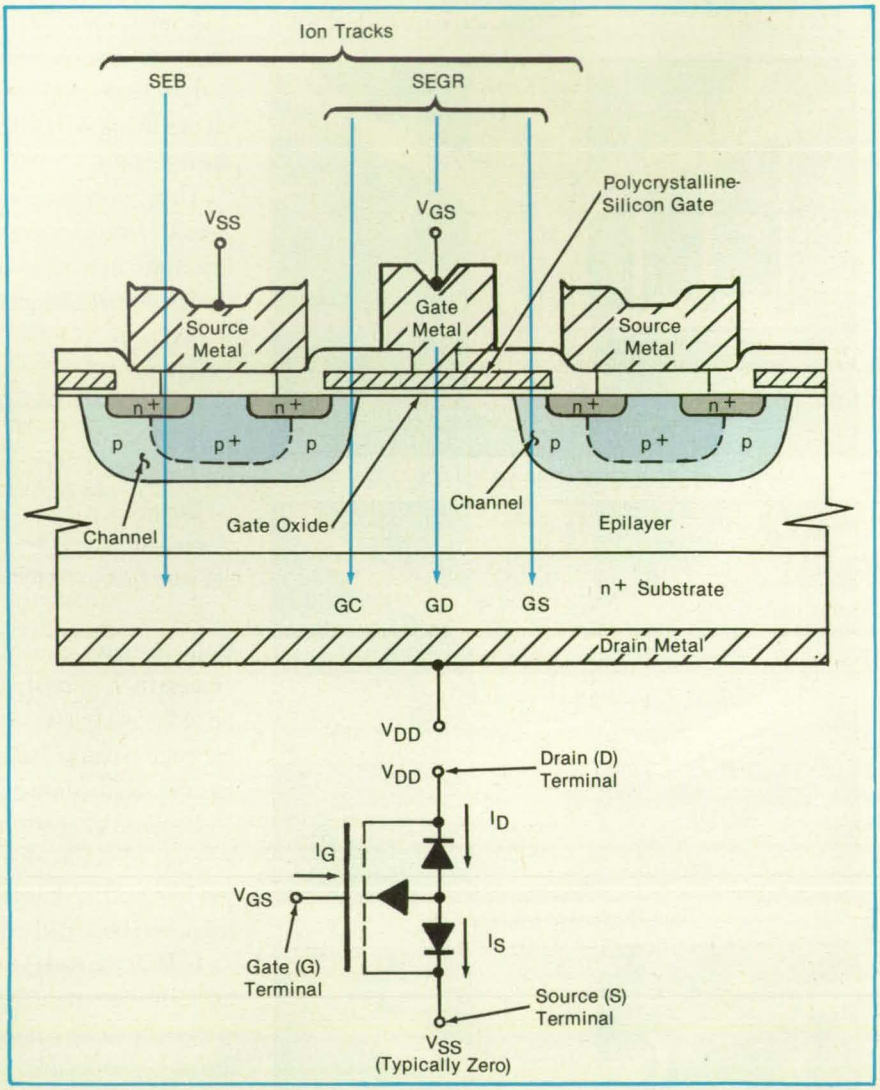
NASA's Jet Propulsion Laboratory, Pasadena, California

The susceptibilities of power metal-oxide/semiconductor field-effect transistors (MOSFET's) to single-event gate ruptures can be analyzed by exposing these devices to beams of energetic bromine ions while applying appropriate bias voltages to the source, gate, and drain terminals and measuring the current flowing into or out of each terminal. Single-event gate rupture (SEGR) and a related phenomenon, single-event burnout (SEB), are electrical-breakdown effects caused by impacts of energetic ions (usually heavy ones) like cosmic rays.

The figure shows a cross section of a typical n-channel power MOSFET, with a few superimposed ion tracks of the types that can cause SEB and SEGR. SEB can occur when an ion track is positioned to cause avalanche breakdown in the parasitic npn bipolar transistor of the vertical MOSFET structure. If the avalanche-breakdown current is not limited, then second breakdown can occur, leaving a permanent short circuit between the drain and source. If the current is limited by use of a resistor in series with the drain-to-source path, one can test the MOSFET for susceptibility to SEB, observing SEB-like transients, without causing permanent damage.

SEGR can occur when an ion track intersects both the polycrystalline-silicon gate and one of three regions under the gate oxide: the gate channel (GC), the epilayer drain region (GD), or the gate/source-overlap region (GS). As in the case of SEB, one can test for susceptibility to SEGR, without causing runaway SEGR, by limiting the breakdown current: in this case, one limits the gate breakdown current to roughly 1 mA by use of a series resistor connected to the gate terminal.

Bias conditions can be chosen for two types of SEGR tests. If the gate and source terminals are connected together (V_{GS} = 0) and a positive drain-supply voltage or bias, V_{DD}, is applied to the drain (with respect to the source), then the configuration of the electric field within the MOSFET is such that only an ion traveling along track GD can cause SEGR. If the drain and source terminals are connected together (V_{DD} = 0) and a positive bias, V_{GS}, is applied to the gate (with respect to the source), then the electric field inside the MOSFET is configured such that ions that travel along tracks GC and GS can cause SEGR.



This Typical Power MOSFET is susceptible to SEB or SEGR, depending on the track followed by an incident energetic ion.

Tests like these were performed on n-channel hexagonal power MOSFET's that had gate oxides 1,000 Å thick and that were rated at a drain-to-source breakdown supply voltage of 300 V. The results of the tests showed that the vertical structure of these MOSFET's makes them intrinsically unsuitable for use in the presence of energetic heavy ions. It appears that the only way to guard against SEGR in designing power supplies that depend on MOSFET's is to (1) include redundant MOSFET's, (2) isolate the redundant MOSFET's and maintain them at zero bias to prevent SEB and SEGR until they are needed, and (3) incorporate circuits to detect SEGR.

This work was done by John A. Zoutendyk of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 23*** *on the TSP Request Card.* *NPO-18663*

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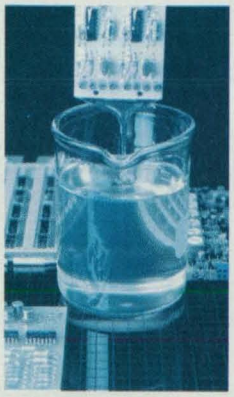

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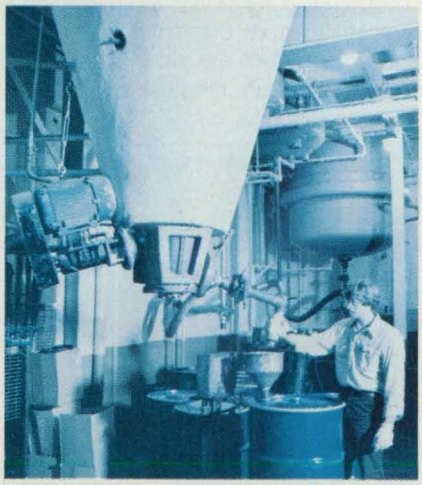

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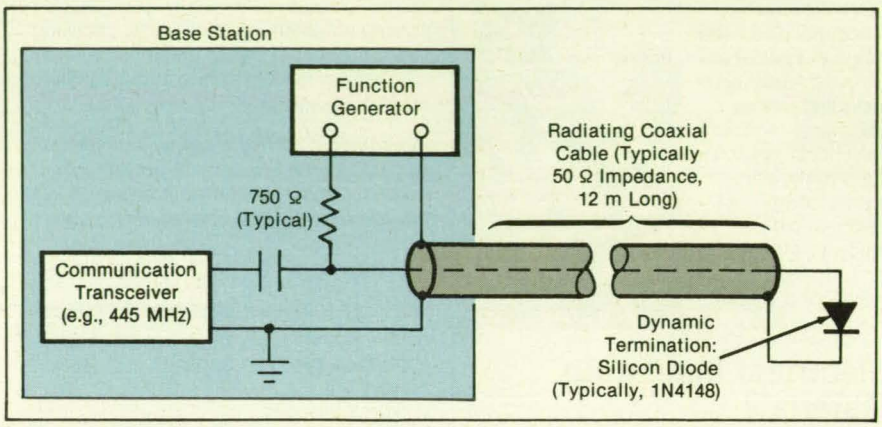
The radiation pattern is dithered to reduce the adverse effect of nulls.

Marshall Space Flight Center, Alabama

In an improved system for radio communication between a base station and portable units within a building, tunnel, ship, or other large structure, a radiating or "leaky" coaxial cable (e.g., a spiral-wound or slotted coaxial cable) serves as the base-station antenna, and the radiation pattern of this cable is dithered by dithering the impedance of a termination at the end of the cable remote from the base station. Radiating coaxial cables and other antennas have been used previously in communication systems of this type. The multiple reflecting surfaces inside structures have been found to give rise to multipath distortion of the signals radiated and received by these antennas. Such distortion includes deep nulls caused by destructive interference.

Heretofore, additional power, typically of the order of 20 dB over the level that might otherwise suffice, has been used to ensure adequate strength of signals in the deepest nulls. This practice wastes energy and entails the greater cost of more-powerful transmitters. When the radiation pattern is dithered instead, the peaks and nulls move around in the enclosed space served by the radiating cable. Thus, no point in that space remains in a deep null during more than a small fraction of the time. The effective signal level is thus smoothed out; at each point, the time-averaged signal has a usable intermediate strength between the peak and null levels.



Alternating Bias is fed, by use of conventional radio-frequency/audio-frequency coupling/decoupling circuitry, to the diode at the far end of the radiating coaxial cable. The radio-frequency impedance of the diode is thereby made to alternate between high and low values, causing the radiation pattern of the cable to dither.

As shown in the figure, the variable-impedance termination can be a silicon diode. The radio-frequency impedance of a silicon diode depends on the bias current or voltage applied to it. For example, it can be strongly forward-biased to obtain a low radio-frequency impedance or strongly reverse-biased to obtain a high radio-frequency impedance. The application of a bias voltage that alternates between these two extremes causes the positions of the peaks and nulls in the radiation to shift by about half the wavelength of the radio-frequency carrier signal. In the case of a typical 445-MHz carrier used by a maintenance or security crew, this amounts to a shift of about 13 in. (about 0.33 m).

The alternating bias signal can be generated by a function or waveform generator; the bias signal can be a sinusoidal, square, rectangular, ramp, triangular, or other suitable waveform. To prevent flutter in the communication channel, the frequency of alternation of the bias signal should be set higher than the highest modulation frequency of the communication signal. For example, in a typical base-station/portable voice communication system, the maximum frequency of audio modulation is a few kHz. A bias square wave with a frequency of 20 to 25 kHz would be suitable for this system.

This work was done by Robert Lombardi, Jon Stern, and George Rassweiler of Harris Corp. for **Marshall Space Flight Center**. *For further information,* ***write in 59*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 24]. Refer to MFS-28679.

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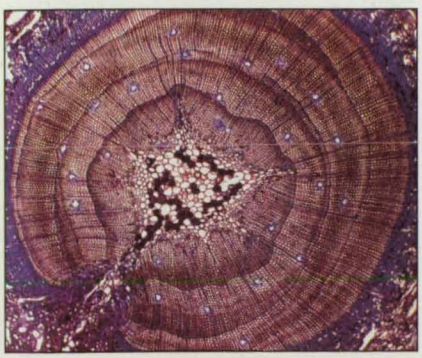

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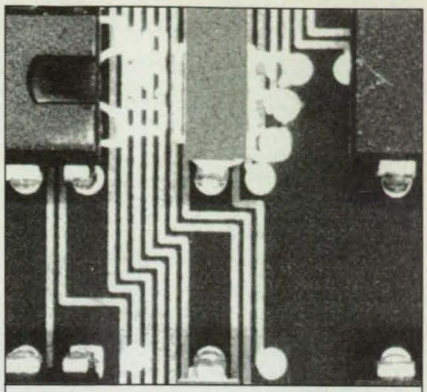

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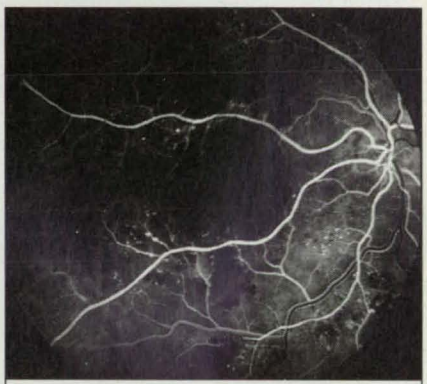

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Packet Controller for Wireless Headset

This circuit converts continuous voice signals into digital packets of data and vice versa.

John F. Kennedy Space Center, Florida

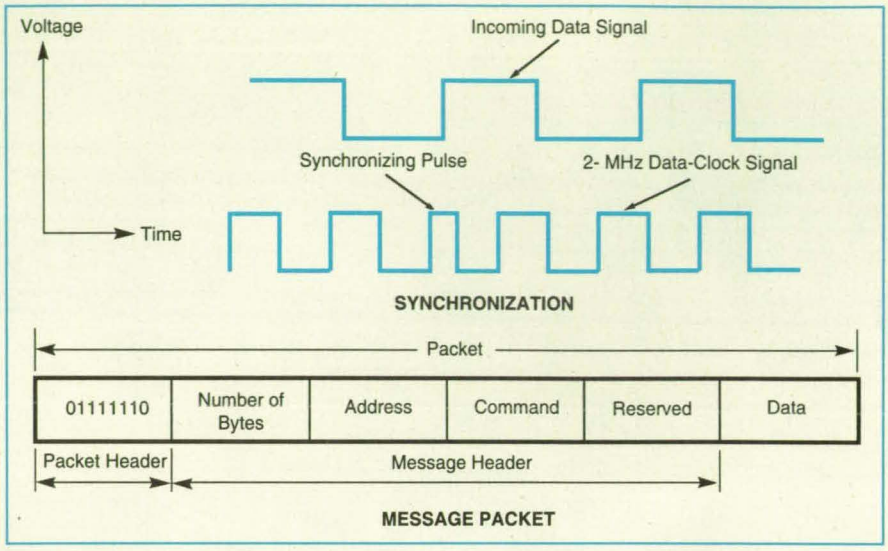
A packet-message controller implements the communications protocol of a network of wireless headsets. Although designed for the headset application, the controller can readily be adapted to other uses; for example, a slight modification would enable the controller to implement the Integrated Services Digital Network (ISDN) X.25 protocol, giving it far-reaching applications in telecommunications.

It controls the formation, transmission, and reception of packets of digital voice data in a wireless headset. It accepts data from a coder/decoder at a constant rate of 16 or 32 kHz, assembles the data into packets, and sends the packets to a transceiver at a rate of 2 MHz. It also receives 2-MHz data packets from the transceiver, buffers them, and delivers the data to the coder/decoder at a continuous rate of 16 or 32 kHz. The controller sends and receives (audio data) simultaneously.

The controller can operate in a master or a slave mode. In the slave mode, the controller waits to receive a packet that contains a predetermined valid address, ignoring all other packets. When it receives a packet that contains a valid address, the controller accepts and buffers it, then sends a return packet that contains data stored since it last sent a packet.

In the master mode, the controller waits until a strobe signal arrives, then sends a packet and attempts to receive an incoming packet. If the controller receives a packet that contains a valid address, it stores the packet; if not, it times out and waits for the next strobe.

The controller contains one sending and one receiving first-in, first-out buffer, which store the incoming and outgoing digital voice data, respectively, providing full-duplex operation. Each buffer can store 2,048 bits.



A **Synchronizing Pulse** aligns the internal clock with a low-to-high transition of the incoming data (as shown at the top). A packet header (shown at the bottom), which includes a string of six 1's preceded and followed by a 0, signals the beginning of a packet. The packet header is followed by a message header that provides the number of bytes, a headset address, and a command. A byte in the header is reserved for possible future use.

A clock-signal generator that contains a crystal oscillator and divider produces clock signals at frequencies of 8 MHz, 2 MHz, 15,625 Hz, and 31,250 Hz for various circuits in the controller. It also synchronizes the 2-MHz data clock with the clock in the base station of the network to ensure correct timing of data.

The controller forms a packet by attaching a message header to a sequence of voice data, about 1,500 bits long, representing about 0.05 s of speech at the sampling rate of 32 kHz or about 0.1 s at the sampling rate of 16 kHz. The header identifies the start of a packet and contains headset address and other information (see figure).

The controller can be reduced to a single complementary metal oxide/semiconductor integrated-circuit chip. It would occupy minimal space in a headset and would consume little power, thereby extending the life of the headset battery.

This work was done by Kurt K. Christensen and Richard J. Swanson of Apeiron for **Kennedy Space Center**. *For further information,* ***write in 83*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, John F. Kennedy Space Center [see page 24]. Refer to KSC-11476.

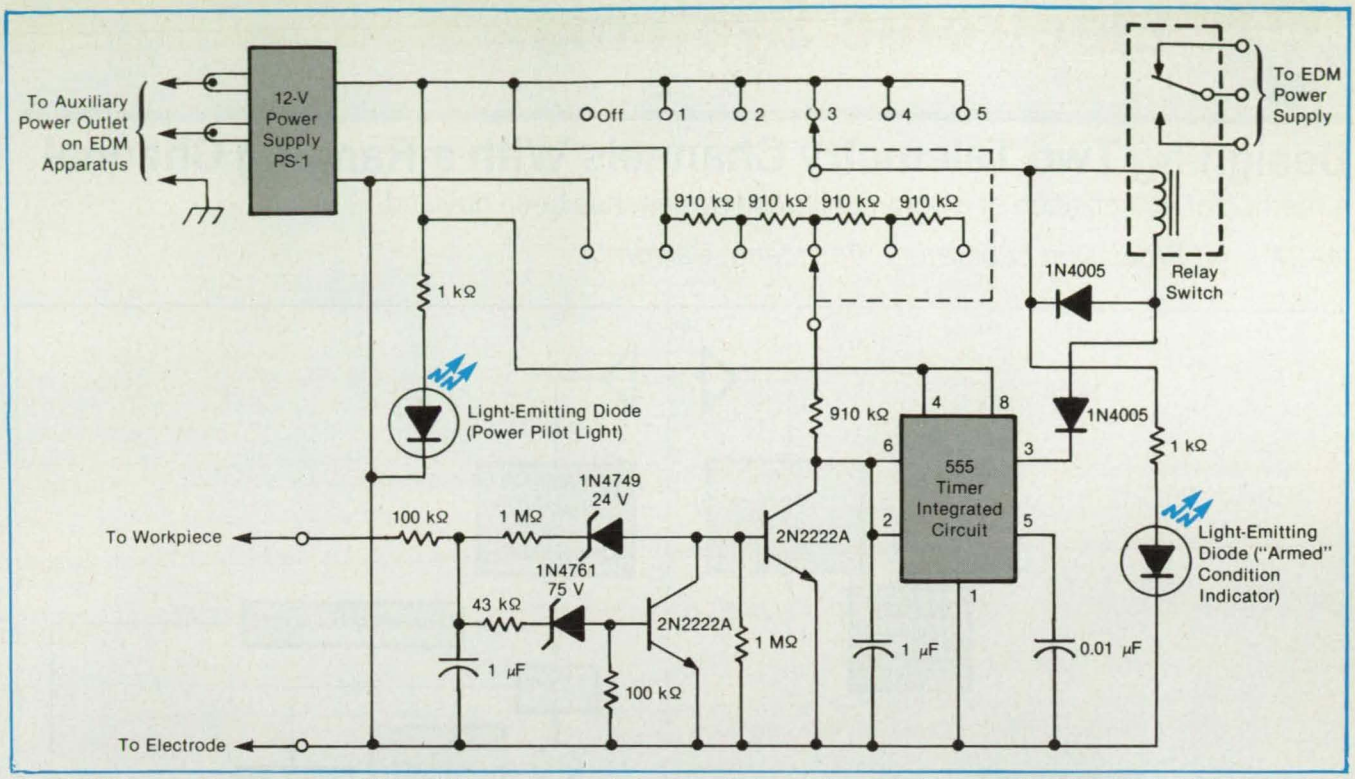
Monitor for Electrical-Discharge Machining

When it detects abnormal arcing, this circuit turns off EDM power.

Marshall Space Flight Center, Alabama

The circuit shown in the figure monitors an electrical-discharge-machining (EDM) process to detect and prevent abnormal arcing, which can produce unacceptable "burn" marks on the workpiece. The circuit is needed because often an operator cannot detect abnormal arcing and/or cannot respond quickly enough by turning off the EDM power in time to prevent the burn marks. For example, the operator may have several machines running simultaneously, or the working end of the EDM electrode could be hidden from view in a deep hole, making it impossible to detect abnormal arcing visually.

The monitor circuit includes one input terminal that is connected to the workpiece and another that is connected to the EDM electrode. The circuit also includes a relay switch that controls the EDM power. In normal operation, the monitor is said to be "armed," and the relay switch is actuated, in the power-on position. When voltage between the EDM electrode and the workpiece behaves in a manner indicative of abnormal arcing, the relay is made to switch off the EDM power, which then remains off until the operator attends to the EDM setup and resets (rearms) the monitor.



The EDM-Process Monitor turns off the EDM power when the voltage between the workpiece and the EDM electrode behaves in a manner indicative of abnormal arcing.

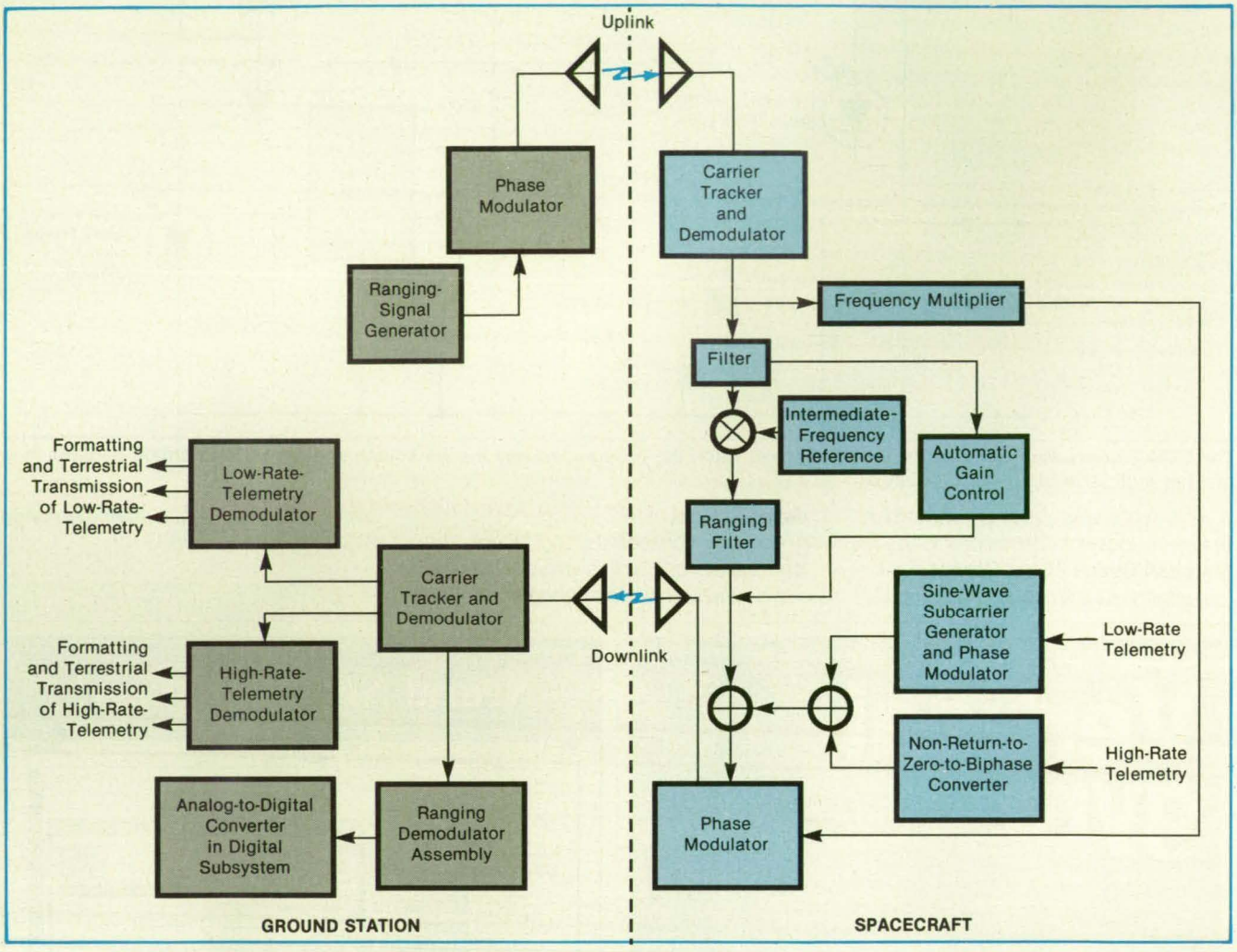
This work was done by Richard K. Burley of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information,* ***write in 64*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 24]. Refer to MFS-29853.

Designing Two Telemetry Channels With a Ranging Channel

A method of optimization of a communication system has been devised.

NASA's Jet Propulsion Laboratory, Pasadena, California



This **Communication System** is characterized by a number of design parameters that can be selected by use of an 18-step algorithm that optimizes performance under the various design constraints.

A method of optimization has been devised for use in selecting the frequencies, powers, modulation indices, and other parameters of two digital-data telemetry channels and a coherent turnaround ranging channel of the Earth-station/satellite communication system illustrated in the figure. The method is also applicable to the design of terrestrial communication systems that are based on similar modulation schemes and that present similar design problems; e.g., to avoid interferences among the channels and to obtain the desired levels of performance in the channels while allocating limited total power among the channels and using the available frequency band(s) efficiently.

In this communication system, the ranging signal is phase-modulated onto the uplink carrier signal. In the satellite, the uplink signal is tracked by a phase-locked loop, and the uplink frequency is down-converted to an intermediate frequency for demodulation of the ranging signal. The turnaround downlink ranging signal thus consists of the uplink ranging signal plus feed-through noise. It is transmitted as phase modulation on the downlink carrier. The power of this turnaround ranging signal is controlled by the automatic gain-control (AGC) loop.

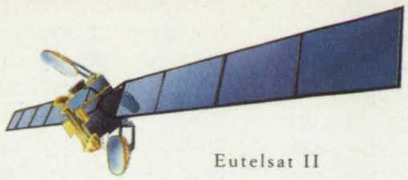
One of the two telemetry signals, which are transmitted on the downlink, is a low-data-rate signal. This signal is phase-modulated, in non-return-to-zero format, onto a sine-wave subcarrier that is, in turn, phase-modulated onto the downlink carrier. The other downlink telemetry signal is a high-rate data signal that is biphase (Manchester) modulated onto the downlink carrier.

The method of optimization is implemented in an 18-step algorithm that is derived from a simplified mathematical model of the system by imposing a number of quantitative criteria regarding the minimization of interference, allocation of power, and maximization of performance under given constraints. It provides a compromise between (1) suppression of the ranging signal to reduce interferences among the signals in the data and ranging channels to keep the bit-error rates in the data channels acceptably low and (2) elevation of the ranging signal to obtain acceptably high rang-

Ariane 5

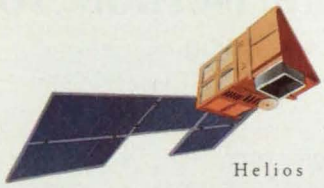
Ariane 4

ISO



Eutelsat II

Huygens



Helios

Meteosat

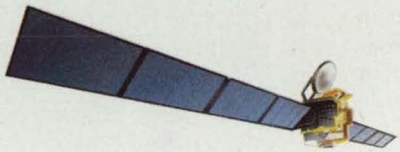
Hermes

Arabsat

space station

MSBS
strategic missile

Hypersonics



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ing accuracy. It also involves a search for the subcarrier frequency that minimizes interferences among the channels.

When the parameters of the system are fully optimized, they provide maximum available power in both data channels and in the ranging channel at allowable levels of degradation of signals in the data channels and at the required data rates, and they maintain bit-error rates below maximum allowable levels and maintain the required ranging accuracy over a maximum distance under a given set of conditions. The optimized parameters provide adequate power for tracking the carrier without degradation of the thresholds in the data channels. Furthermore, as the total power of the signal received at the ground station decreases, the signals in both data channels and the ranging channel fall below their thresholds simultaneously.

This work was done by Tien M. Nguyen, Sami M. Hinedi, and John M. Gevargiz of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 85*** *on the TSP Request Card.*
NPO-18618

Cascaded VLSI Chips Help Neural Network To Learn

Cascading provides the 12-bit resolution needed for learning.

NASA's Jet Propulsion Laboratory, Pasadena, California

An electronic neural network comprises a set of neurons connected to each other with synapses (of adjustable weights). The connection density may vary from fully connected (every neuron connected to every other neuron in the network) to sparsely connected, thus offering disparate architectures. One such architecture is the feed forward, where an input layer of neurons is connected either directly to an output layer (called Perceptron) or via one or more hidden layers of neurons (called MultiLayer Perceptron). Here each neuron in the input and hidden layers is connected to each of the neurons in the layer immediately following. Such a feedforward architecture is especially suited to capture ill-defined transformations from a multidimensional input vector space to an output vector space. Furthermore, the network can only be "trained" by presenting it with input-output pair exemplars, when the synaptic weights are progressively modified during this training process. Studies have shown that reprogrammable synaptic weights with a resolution of ≥ 12 bits are necessary for learning (in hardware) by an MLP architecture.

Using the conventional silicon chip fabrication technology of VLSI, a fully connected architecture consisting of 32 wide-range, variable gain, sigmoidal neurons along one diagonal and 7-bit resolution, electrically programmable, synaptic 32 × 31 weight matrix is implemented on a neuron-synapse chip. Figure 1 shows the photograph of such a chip. To increase the weight nominally from 7 to 13 bits, the synapses on the chip are individually cascaded with respective synapses on another 32 × 32 matrix chip with 7-bit resolution synapses only (without neurons).

For supervised learning, the network has been connected to a personal computer, and configured to operate in a feedforward mode by nulling the feedback and unused synapse transconductances. The network has been taught to implement an exclusive-OR (XOR) function by presenting it with four training examples (input 0,0 and 1,1 => output 0; and input 0,1 and 1,0 => output 1) and iteratively adjusting the synaptic weights according to a learning algorithm called "cascade back propagation."

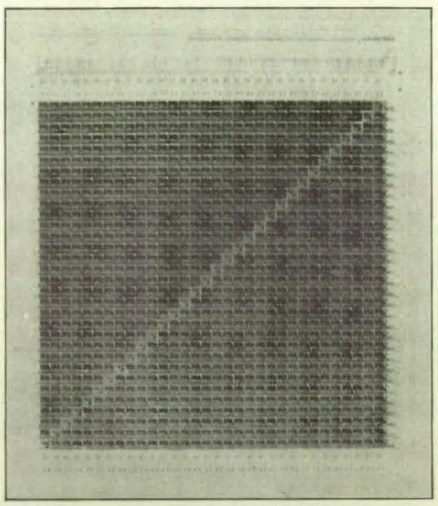


Figure 1. This **VLSI Neuron/Synapse Chip** contains 32 × 31 synapses and 32 neurons along one diagonal.

The cascade back-propagation algorithm is a combination of the back-propagation algorithm and the cascade correlation algorithm. The back-propagation algorithm, which has been described in several previous articles in *NASA Tech Briefs*, involves layer-by-layer adjustments of synaptic weights to reduce output errors, in a backward sequence from the output layer toward the input layer. The cascade correlation algorithm varies the number of layers that are effectively connected into the network; it adds hidden layers one at a time during the learning (synaptic-weight-adjustment) process in such a way as to optimize the overall number of neurons and the complexity and configuration of the network.

Each synapse contains a two-quadrant multiplying digital-to-analog converter, the multiplication factor (in effect, the synaptic weight) of which is contained in multibit static latches that are addressed by the personal computer during training.

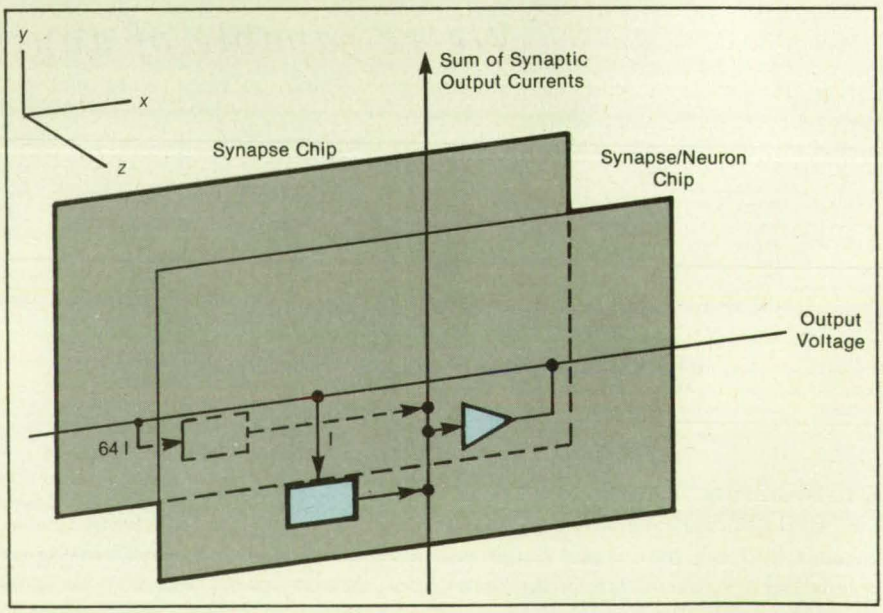


Figure 2. **Two Chips With Respective Synapes** cascaded increase the weight resolution nominally from 7 to 13 bits. Input voltages of individual chips are controlled to obtain input currents in the ratio of 1:64 for the synapses of the respective chips. The output then provides the currents that range from $-4095I$ to $+4095I$ in increments of I, thereby giving a nominal 13-bit resolution for the cascaded chips.

Figure 2 is a simplified illustration of the cascade scheme. The input voltage on the synapse/neuron chip is fixed for a given synapse-input current (I_{in}), so that by setting the digits in the given synapse of this chip, one can make the affected component of the synapse-output current take any value from $-63\,I_{in}$ to $+63\,I_{in}$. At the same time, the input voltage on the synapse chip is fixed to obtain an input current of $64\,I_{in}$ to a synapse in that chip. Then the output of this chip ranges from $-64\times63\,I_{in}$ to $+64\times63\,I_{in}$. Because the synapses of the two chips feed their output currents to a common line, the total output current can range from $-65\times63\,I_{in}$ to $+65\times63\,I_{in}$ in increments of I_{in}; that is, the magnitude of the output current can range over 12 bits, and the sign can be positive or negative.

This work was done by Tuan A. Duong, Taher Daud, and Anilkumar P. Thakoor of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 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 Resident Office–JPL [see page 24]. Refer to NPO-18645.

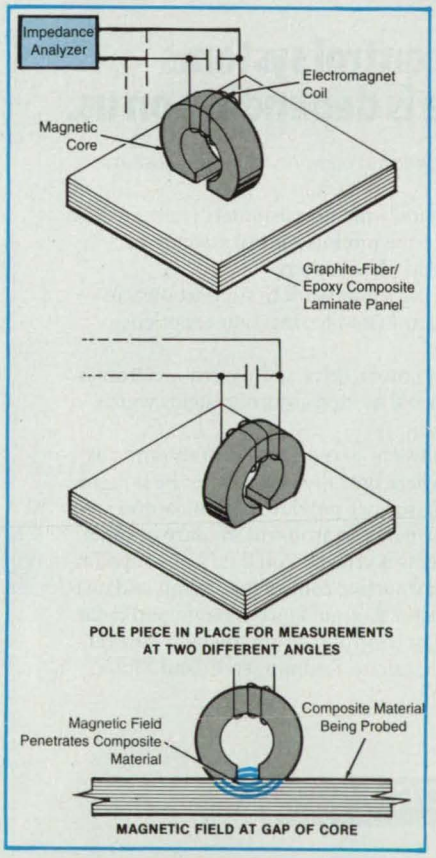
Eddy-Current Monitoring of Composite Layups

Orientations of fibers can be determined nondestructively.

Langley Research Center, Hampton, Virginia

The figure shows the major components of an eddy-current-probe apparatus that can be used to determine the predominant orientations of fibers in fiber/matrix composite materials. The apparatus is a nondestructive, noninvasive means for monitoring composite prepregs and layups during fabrication to ensure predictable and repeatable mechanical properties of the finished composite panels.

The eddy-current probe consists essentially of an electromagnet coil wrapped around a horseshoe-shaped powdered-iron or ferrite core. Optionally, a capacitor can be included in series or parallel with the coil to form a resonant circuit. An impedance monitor excites a radio-frequency current in the coil and measures the impedance of the probe circuit. This impedance is affected by whatever material is placed near the ends of the core, where the material intercepts the alternating magnetic field excited in the core by the current in the coil.



The **Impedance of the Eddy-Current Probe** varies with the orientation of the core with respect to the predominant direction of graphite fibers in the composite panel.

The alternating magnetic field excites eddy currents in the material if the material is electrically conductive. In the case of a graphite fiber/epoxy composite material, the graphite is conductive, and the conductivity averaged over a region containing many fibers is anisotropic because of the orientation of the fibers. This anisotropy of conductivity gives rise to anisotropy of eddy currents and, consequently, anisotropy of the measured impedance. That is, the measured impedance depends on the orientation of the magnetic field with respect to the fibers. The orientation of the magnetic field is known from the orientation of the core. Thus, the orientation of the fibers at a given spot can be determined by placing the core in contact with the material at that spot and measuring the impedance with the pole piece rotated to various angles in the surface plane. The electrical parameters of the circuit can be tuned to maximize the change in impedance with rotation of the core over a given composite material.

This work was done by Robert L. Fox and John D. Buckley of **Langley Research Center**. *No further documentation is available.*

LAR-14947

Switching an Image Processor Between Two Computers

A parallel switch is controlled remotely by the computers.

Lewis Research Center, Cleveland, Ohio

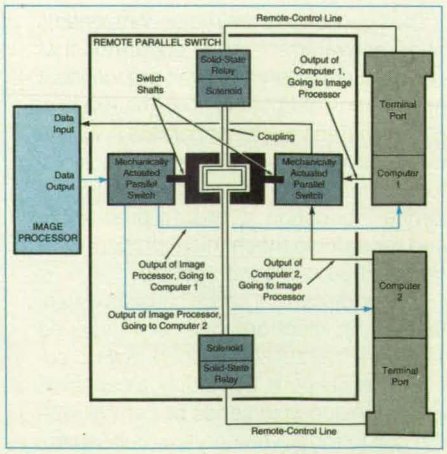
A remote-control parallel switching circuit connects either of two computers (but not both simultaneously) to an image processor. Typically, an image processor is an expensive, specialized computer that is designed to operate in conjunction with a general-purpose computer, with which it must be physically connected via a parallel interface. If processed image data are required on a computer other than one physically connected to an image processor, then the data must first be moved to the connected one and processed there before reaching the requesting computer. This procedure consumes much time and necessitates additional data-storage capacity. The remote-control parallel switching circuit was devised as a relatively inexpensive, less-wasteful alternative.

The switching circuit (see figure) includes two parallel switches that are actuated mechanically by solenoids. Each solenoid is controlled by a solid-state relay connected to the remote-control line from the associated computer. One or the other solenoid is energized to connect the image processor to the computer that requests access according to a protocol that is implemented in software.

The software resides in both computers, and the protocol is as follows: A user at either computer requests access to the image processor by issuing a simple one-word command. If the image processor is operating in connection with the other computer at the time of the request, the user is so notified and access is denied. If the image processor is available at the time of the request, then a message is sent out from the requesting computer through its terminal port onto its remote-control line; this message commands the associated solid-state relay and solenoid to connect the image processor to the requesting computer.

This work was done by Jim Bodis and Edward R. Generazio of **Lewis Research Center** *and David B. Stang of Sverdrup Technology, Inc. For further information,* ***write in 1*** *on the TSP Request Card.*

LEW-15451



Multiple-Pole, Double-Throw Switches are actuated under remote control to connect either of two computers directly to an image processor.

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$$\nabla\times H=J+\epsilon\frac{\partial E}{\partial t}\qquad \nabla\times E=-\mu\frac{\partial H}{\partial t}\qquad \nabla\cdot E=\frac{\rho}{\epsilon}\qquad \nabla\cdot H=0$$

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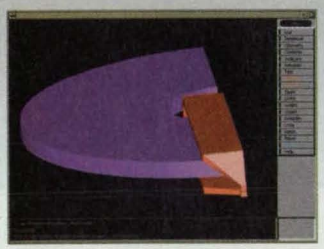

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Dr. Kent Davey
Georgia Institute of Technology

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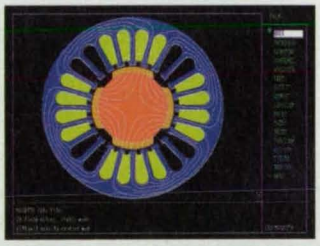

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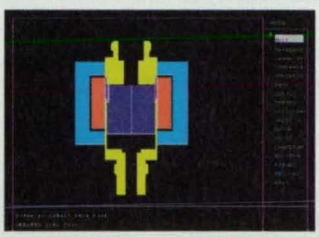

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Groundwater-Seepage Meter

This instrument can be left unattended to measure low-rate, low-pressure flow.

Langley Research Center, Hampton, Virginia

An instrument measures seepage of groundwater into an inland or coastal body of water. The instrument can be positioned at a depth as great as 40 meters, and can measure flow at a low rate and low pressure differential, if necessary. An auxiliary pressure meter provides data for correlation of the flow of groundwater with tides and sea states. This seepage meter can operate independently for several weeks. Its sampling rate can be adjusted to suit hydrologic conditions; for example, to measure more frequently when conditions are changing rapidly. It can be used in water-quality management and for biological and geological research. Potential industrial uses include measurement of seepage of caustic and corrosive liquids.

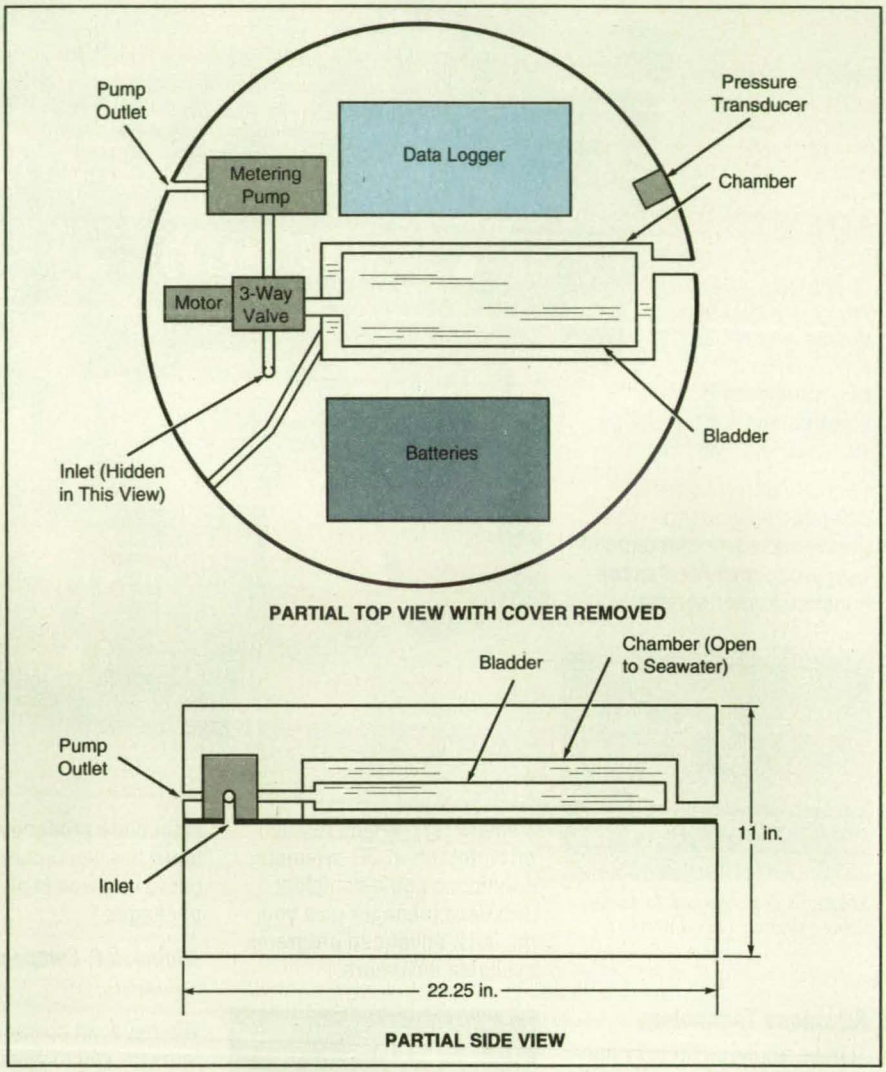
A typical manual meter used heretofore consisted of a cylinder covered by a vented lid to which a water-collection bladder was attached. A diver placed the meter in sediment and returned periodically to collect and replace the bladder. The use of such a meter was labor-intensive, was limited to safe diving depths, yielded only limited time-series data, and did not reveal such short-term effects as diurnal changes.

The present seepage meter, in contrast, can be left unattended while it logs data, and eventually retrieved. It has been used to collect groundwater-discharge data in Chesapeake Bay and Florida Bay. In Chesapeake Bay, it produced 246 data points instead of the 4 to 10 that would have been collected manually. In Florida Bay, it produced 1,166 data points in 22 hours.

The seepage meter includes a battery, electromechanical controls, a data logger, a metering pump, a three-way valve, and a sampling bladder within a water chamber, all housed in the waterproof upper compartment of a stainless-steel cylinder (see figure). The lower compartment is open to the sediment in which the meter is embedded, and water enters the valve and bladder via an inlet at the top of the open lower compartment.

A ceramic magnet on the sampling bladder moves closer to a reed switch as the bladder fills with water. The proximity of the magnet eventually results in closure of the switch, which activates a motor that rotates the valve to disconnect the bladder from the sample-collecting inlet and connect the bladder to the inlet of the metering pump. The pump then empties the bladder, metering the contents as it does so. The pump operates until the bladder has been discharged enough to pull the ceramic magnet away from the reed switch. The reed switch opens, deactivating the pump and causing the valve to be returned to the sampling position. The data logger records the amount and time of the pump discharge. Then the entire electrical and electronic system shuts down to conserve energy.

The entire pump-out and data-logging operation takes only 15 seconds. The rate of collection can be varied over a wide range by changing the size of the bladder, adjusting the magnetic proximity switch, and adjusting the pump timer.



The **Seepage Meter Draws Groundwater** through an inlet into a sampling bladder. Water from the surrounding estuary or lake fills the chamber enclosing the bladder, applying the pressure that groundwater seepage would normally encounter.

This work was done by Harry G. Walthall of **Langley Research Center** *and William G. Reay of Virginia Polytechnic Institute. For further information,* ***write in 103*** *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 24]. Refer to LAR-14835.

Vapor-Generator Wand Helps To Reveal Airflow Patterns

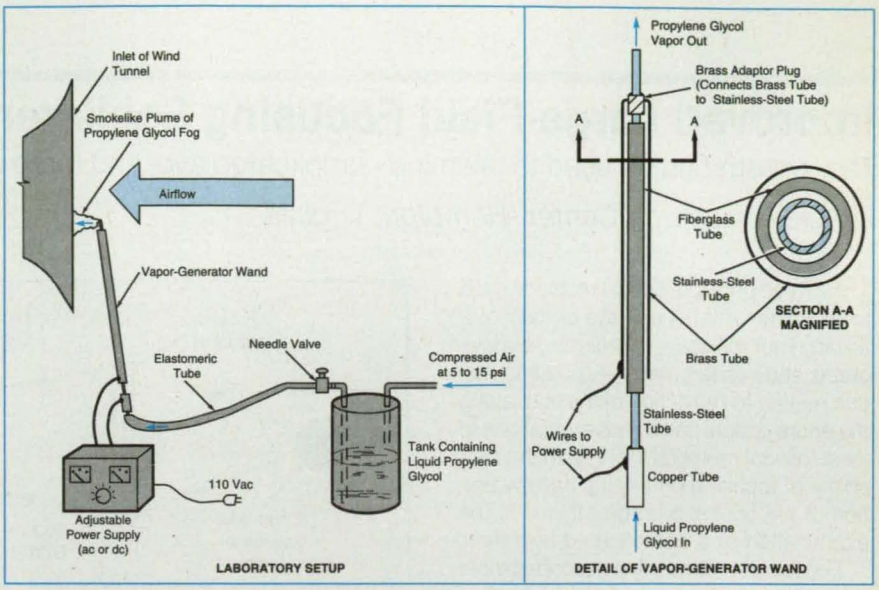
A dense, steady stream of smokelike fog is produced.

Langley Research Center, Hampton, Virginia

A vapor-generator wand produces a plume of smoke to make airflow patterns visible. To be more precise, the plume of smoke is a dense stream of propylene glycol fog, which is relatively nontoxic and nonflammable. The vapor-generator wand can be built in a variety of sizes, suitable for uses ranging from tabletop demonstrations to research in wind tunnels. Liquid propylene glycol flows through a stainless-steel tube in the center of the wand.

The wand (see figure) includes a central stainless-steel tube, into which liquid propylene glycol flows through a metering valve from a pressurized container. The wall of the tube is made thin for high electrical resistance. By applying a suitable voltage to the ends of the tube, the liquid is heated to its boiling temperature of 375 °F (about 191 °C). A stream of propylene glycol vapor emerges from the tip of the wand, forming a smooth, dense stream of bright white fog that readily follows air currents.

Either an ac or a dc power supply can be used to heat the tube; the specific power requirements will depend on the size of the wand constructed. Both the electrical current and the flow of liquid are adjusted to optimize the appearance of the plume.



In the **Vapor-Generator Wand**, liquid propylene glycol flows into an electrically heated stainless-steel tube. The liquid boils in the heated tube, and the emerging vapor forms a dense, smoke-like fog that can be used to make airflow patterns visible.

For best viewing, the plume should be illuminated by a bright, focused incandescent spotlight at a right angle to the viewing direction. Viewing is further enhanced by coating the walls of the test chamber with a flat, dark color to minimize reflections and increase contrast.

This work was done by David B. Robelen of **Langley Research Center**. *For further information,* ***write in 35*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Langley Research Center [see page 24]. Refer to LAR-15058.

Improved Large-Field Focusing Schlieren System

The system can be used to examine complicated two- and three-dimensional flows.

Langley Research Center, Hampton, Virginia

The three principal optical methods used to examine variations in the density of a flowing liquid or gas — schlieren, shadowgraph, and interferometer — give information related to refraction of the light along the entire optical path. Those variations of these optical methods that impart the capability of focusing on a fairly narrow portion of the optical path greatly aid in the examination of a complicated flow field.

Focusing schlieren, first described more than 40 years ago, is capable of producing three-dimensional images, which can be examined in focused planes perpendicular to the optical axis. However, previous focusing optical systems were all limited in some way, such as low brightness, small field of view, large depth of focus, or difficulty of use.

An improved large-field focusing schlieren system has been developed to overcome these limitations. Figure 1 shows an improvement over an earlier system known as the Burton focusing schlieren. This system is the same as Burton's, except for the substitution of a Fresnel lens for a glass diffuser that was used in the Burton system. An extended source of light is required, and the Fresnel lens has to focus the source of light at the location of the camera lens. The result is an image over 100 times as bright as in the diffuser (older Burton) version.

In a system with a large field of view, the image may also be very large. The relay optical system shown in Figure 2 reduces the image to a more convenient size while retaining all of the light. Fresnel relay lenses like the one used here would normally degrade the qualities of the images in most optical systems, but in this system, diffraction of the image from the cutoff grid has already limited the attainable resolution of the image.

To retain the remaining useful resolution, one must place the Fresnel lens close to the image plane. However, some offset is necessary to keep the circular lines from the Fresnel lens sufficiently out of focus to make them invisible in the image. The aperture of the lens on the recording camera has to be at least as large as the image of the aperture of the main imaging lens, due to the Fresnel lens, so as not to stop down the resulting system.

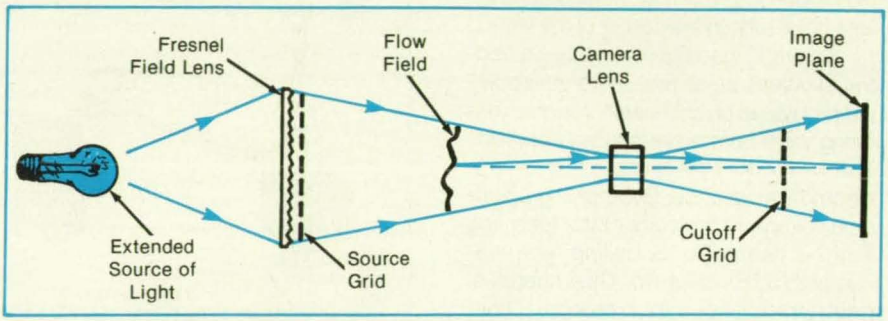


Figure 1. This **High-Brightness Large-Field Focusing Schlieren** system incorporates a Fresnel lens instead of a glass diffuser.

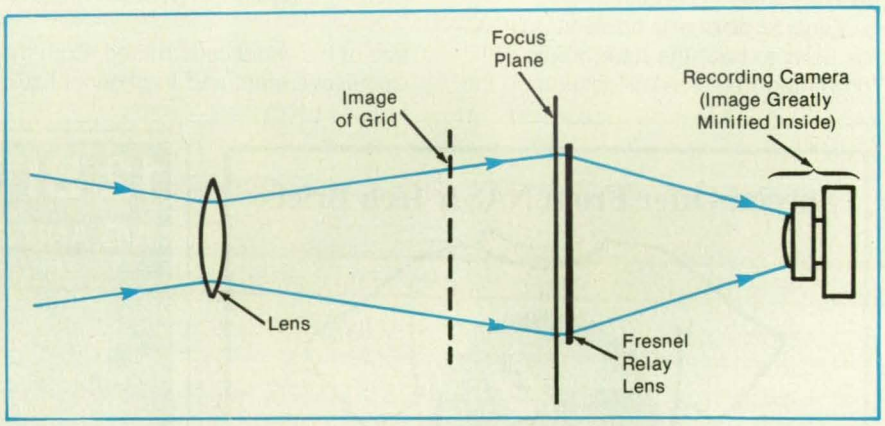


Figure 2. This **Relay Optical Subsystem** minifies a large image while retaining all of the light.

To measure a dynamic flow, one must take a series of snapshots of the flow, with small increments of time between shots. High-speed movies can be used in some cases, but in another approach, which involves at least three time steps, one uses flashes of three different colors (red, green, and blue) with a common diffuser. If a sequence of flashes is recorded on one sheet of color film, rates of exposure would be limited only by durations of, and intervals between, flashes. Rates of 1,000,000 frames a second should be easily attainable. Color filters could be used to examine each time step separately, or color could provide time coding in each single print that contains a sequence of snapshots.

Inasmuch as focusing schlieren can be implemented at relatively low cost, without the need for mirrors or for windows of high optical quality, investigators who decided that schlieren was unsuitable for their facilities might benefit from reconsideration. Facilities that are candidates for use of focusing schlieren include low-speed wind and water tunnels. Heated or cooled flow tracers or injected low- or high-density tracers could be used to make the flows visible for photographic recording.

This work was done by Leonard M. Weinstein of **Langley Research Center**. *Further information may be found in AIAA paper A91-21536, "An Improved Large-Field Focusing Schlieren System."*

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

LAR-14601

Treating Surfaces To Obtain Narrowband Thermal Emission

Specular metal surfaces would be coated with rare-earth oxides.

NASA's Jet Propulsion Laboratory, Pasadena, California

Surfaces that emit electromagnetic radiation predominantly in desired narrow spectral bands when heated ("narrowband thermal emitters," for short) would be made more durable and fabricated less expensively, according to a proposal. Narrowband thermal emitters are needed for efficient operation of thermophotovoltaic energy-conversion systems, for the following reasons: Broad-band emitters (black and gray bodies) emit much of their radiation at wavelengths that cannot be used by thermophotovoltaic cells. To prevent waste of the part of the thermal energy radiated at the unusable wavelengths, it is necessary to reflect 95 to 98 percent of this part from thermophotovoltaic cells back to thermal emitters; this imposes severe constraints upon the design and fabrication of thermophotovoltaic cells. Narrowband thermal emitters would eliminate these severe constraints because they would emit predominantly at the usable wavelengths, making reflection unnecessary. The overall costs of thermophotovoltaic energy-conversion systems would thus be reduced.

Rare-earth oxides are narrowband thermal emitters. They are also very expensive [about $10/g (1992 prices)] and, in bulk, they are brittle ceramics. In previous investigations, rare-earth oxides were incorporated into and onto thermal emitters in various forms that entailed various disadvantages:

- Cast shapes of rare-earth oxides tend to be expensive and sensitive to both thermal and mechanical shock.
- Plasma-sprayed coats of rare-earth oxides on silicon carbide or tungsten substrates have to be made thicker than 1 mm to mask the black-body radiation from the substrates. Although these coats are thinner than cast shapes are, they are still too thick to be economical and to resist thermal and mechanical shock.
- Woven mantles impregnated with rare-earth oxides are not well suited to the designs of many thermophotovoltaic systems and are still expensive.
- Thin films of rare-earth oxides on sapphire substrates are suitable only for special applications that involve heating by helium or another nonradiating heat-transfer medium. Sapphire is also expensive and sensitive to mechanical shock.

The proposed narrowband thermal emitters would be made by polishing metal substrates to specularity, then coating the specular surfaces with films of rare-earth oxides $\leq 1\,\mu m$ thick. It would not be necessary to make the rare-earth films thicker to suppress broad-band thermal radiation from the substrates because the emissivities of typical specular metal surfaces are very low (typically, 0.05 to 0.15). The metal substrates would be inherently resistant to mechanical shock. Resistance to thermal shock would be achieved by choosing metals and rare-earth oxides that have equal or nearly equal coefficients of thermal expansion.

It will be necessary to investigate processes for depositing rare-earth oxides on specular metal surfaces without modifying surface textures in ways that destroy specularity. Candidates include the sol-gel process and physical and chemical vapor deposition processes.

This work was done by Dale R. Burger and Tiong P. Ong of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 98*** *on the TSP Request Card.*

NPO-18876

Dosimeter Badge Detects Hydrazines

Doses are estimated from colors.

John F. Kennedy Space Center, Florida

A disposable dosimeter badge indicates the approximate cumulative exposure (integral of concentration over time) to hydrazine or monomethyl hydrazine in the air. The indication is a change in the colors of both paper tapes — one coated with para-N,N-dimethylaminobenzaldehyde (PDAB), the other coated with vanillin (see Figure 1). The colors of the exposed tapes are compared with colors on two preprinted color wheels to obtain an estimate of exposure (see Figure 2).

These lightweight, easy-to-use, sensitive, and reliable disposable badges can help minimize the risks associated with the exposure of personnel to hydrazine or monomethyl hydrazine, suspected carcinogens for which threshold limit values (TLV's) of 100 and 200 parts per billion (ppb), respectively, have been established by the American Conference of Governmental Industrial Hygienists. The badges can also be used as stationary monitors by taping them on walls or equipment at strategic locations. If hydrazine-detecting instruments are not available, the badges can be used as leak detectors because at concentrations greater than TLV's, colors are developed almost instantaneously. The badges are safe to use, and special handling is not necessary because both PDAB and vanillin are nontoxic.

The paper tapes are sandwiched in a thin cardboard housing 7.3 cm by 4.4 cm in size. Cut out of the face of the housing are two circular windows 1.5 cm in diameter. Each window is surrounded by a transparent circular plastic ring for color contrast. A tabbed section at the bottom of the housing provides a means of removing a protective cover over the color-indicating spots immediately prior to use. A color strip representative of the lowest intensity from each chemistry system is printed adjacent to each detection window to facilitate identification of that color.

The color wheels are mounted in a simple dose-estimator device. Each wheel contains five different shades identified by the numbers 1 (lightest) through 5 (darkest). Holes in the wheels

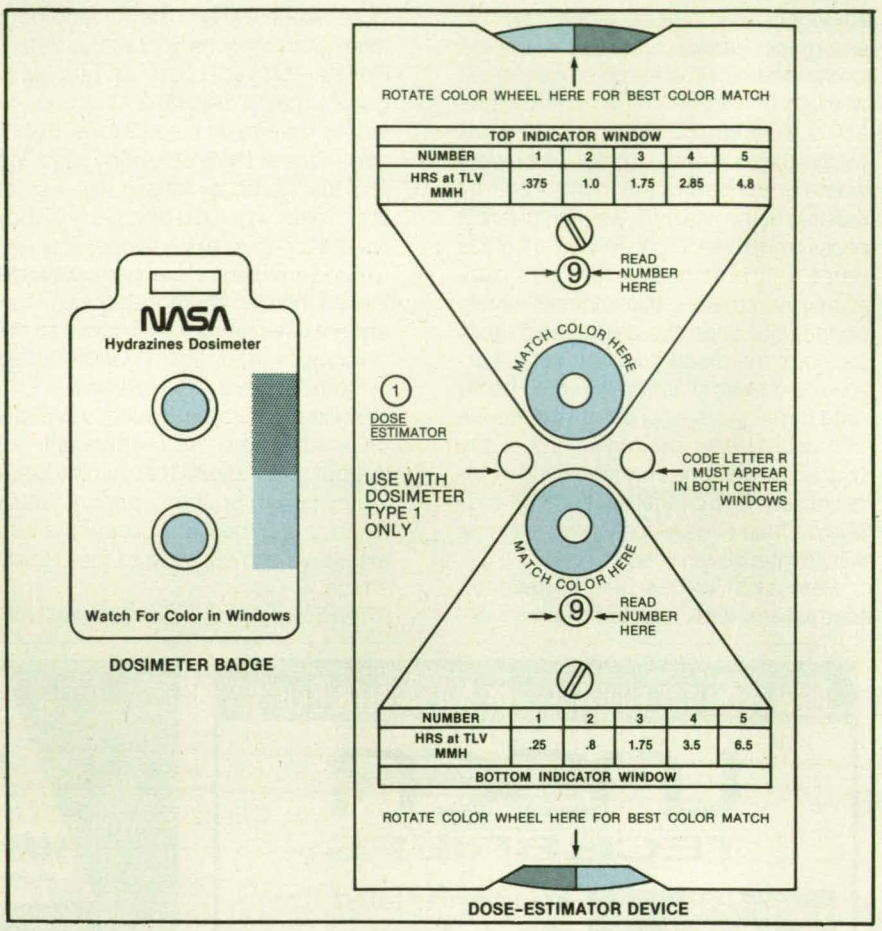


Figure 1. The **Condensation Reactions** of para-N,N-dimethylaminobenzaldehyde (PDAB) (top) or vanillin (bottom) with hydrazine produce colors, the intensities of which can be used to estimate the dosage of hydrazine or monomethyl hydrazine.

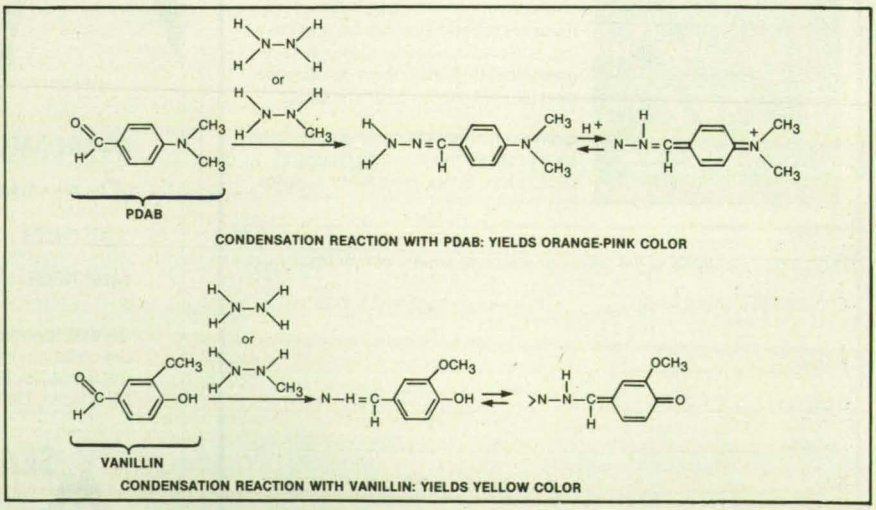


Figure 2. The **Dosimeter Badge and Dose-Estimator Device** indicate the dosage of hydrazine or monomethyl hydrazine.

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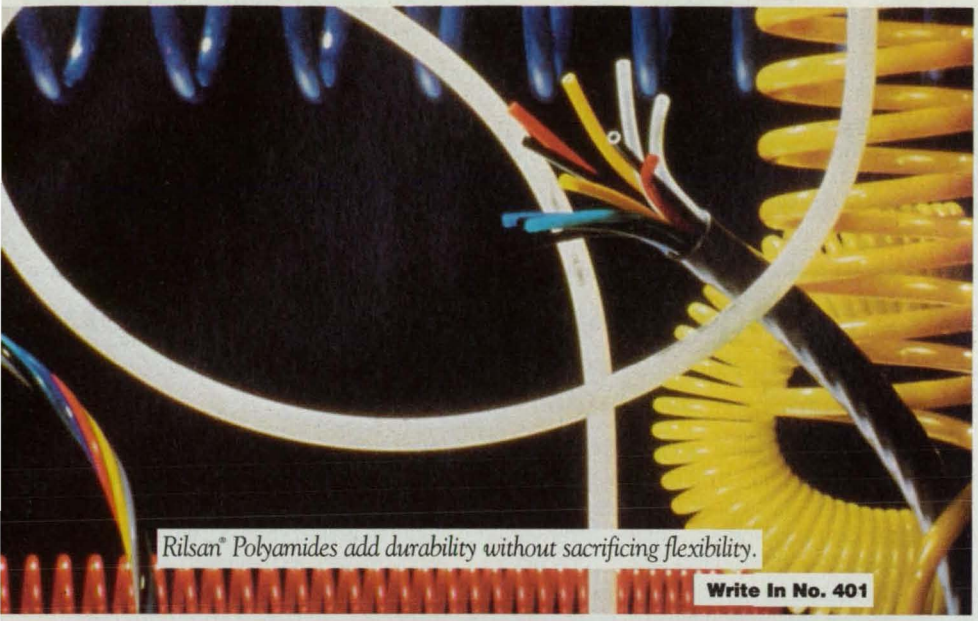

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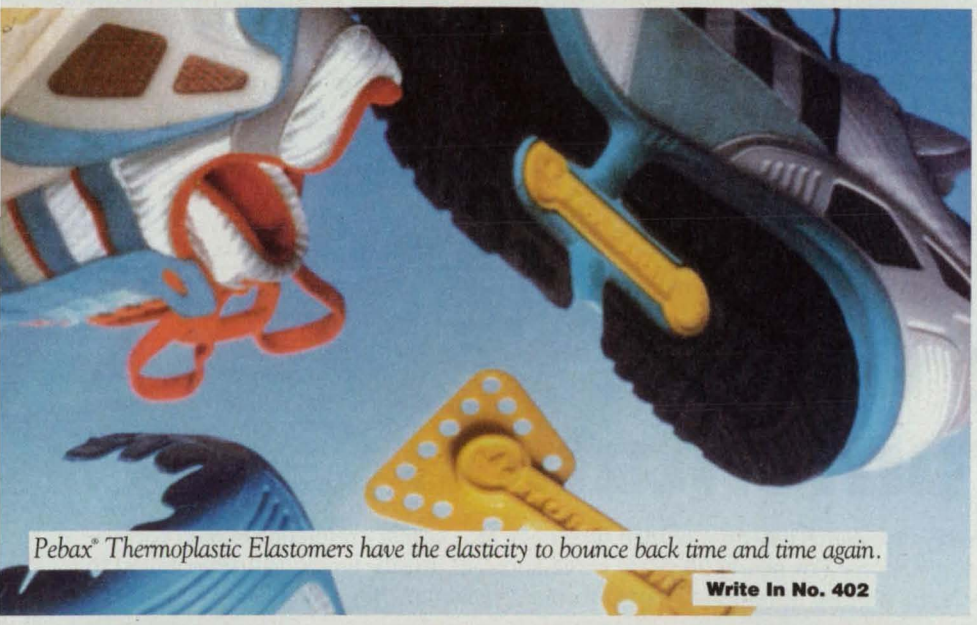

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are provided to enable viewing of the exposed paper. The exposed dosimeter badge is placed behind the dose estimator, the dosimeter windows are aligned with the holes on the wheels, then the wheels are turned until the colors are matched. The operator can then estimate exposure or dose by reading the numbers from the color wheels and referring to respective calibration scales for both chemistries, which are printed on the dose-estimator device.

The incorporation of two chemistries — PDAB and vanillin — allows for positive identification of the vapors. Hydrazine is present if and only if both of the correct colors of orange-pink (with PDAB) and yellow (with vanillin) are developed. Any other combinations of colors indicate the presence of a different vapor. For example, cigarette smoke yields a pink-purple color on the vanillin window and no color change on the PDAB window.

This work was done by Rebecca C. Young and Joshua C. Travis of **Kennedy Space Center**, *Gerald Moore of GMD Systems, Inc., Susan Rose-Pehrsson of Naval Research Laboratory, and Patricia Carver and Karen Brenner of GEO-Centers, Inc. For further information,* ***write in 57*** *on the TSP Request Card.*
KSC-11556

Oxidation-Resistant Coating for Bipolar Lead/Acid Battery

The cathode side of a bipolar substrate is coated with a nonoxidizable conductive layer.

NASA's Jet Propulsion Laboratory, Pasadena, California

An oxidation-resistant coating can help protect the cathode side of the substrate of a bipolar lead/acid battery. The coating is prepared as a water slurry of an aqueous dispersion of a polyethylene copolymer plus such conductive fillers as tin oxide, titanium, tantalum, or tungsten oxide. The slurry can be applied easily to a substrate of polyethylene carbon plastic. As the slurry dries, a conductive, oxidation-resistant coating forms on the positive side of the substrate.

The water-dispersable polyethylene copolymer adheres well to polyethylene. Alternatively, different ethylene copolymers like ethylene/vinyl acetate or ethylene/acrylic acid could be used — either as a water emulsion or as a solution in an appropriate organic solvent like tetrahydrofuran. Any conductive filler can be used, provided that it is chemically and electrochemically stable in the sulfuric acid electrolyte at the battery cathode overpotential of a lead/acid cell, and provided that it can be loaded into the coating in sufficient quantity to yield adequate conductivity; the resistivity of the oxidation-resistant layer should be less than 10 Ω•cm. Examples of such alternative fillers include powdered vitreous carbon, gold, platinum, and tungsten carbide.

The coating slurry can be applied to the substrate by use of any suitable existing technique like brushing, emulsion dispersion, dipping, and extrusion. More than one coat of slurry can be applied, if needed, to ensure complete and uniform coverage.

This work was done by James J. Bolstad of Johnson Controls, Inc., for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 22*** *on the TSP Request Card.*
NPO-18979

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Preparation of Sources for Plasma Vapor Deposition

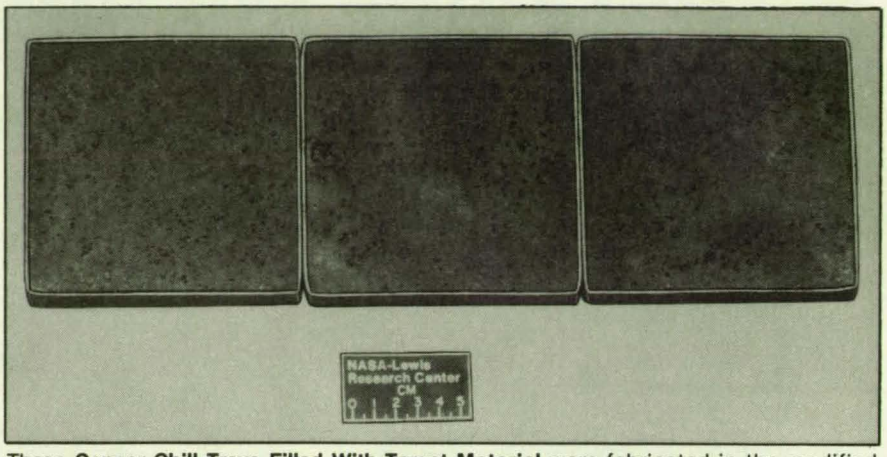
Sintered targets are made in a modified process.

Lewis Research Center, Cleveland, Ohio

Multicomponent metal targets that serve as sources of vapor for plasma vapor deposition can be made in a modified pressureless-sintering process. By use of targets made in the modified process, one can coat components with materials that could previously be plasma-sprayed or sintered but not plasma-vapor-deposited.

The target-fabrication process is critical because densified, homogeneous targets are necessary to the success of plasma vapor deposition. Although most homogeneous, consolidated metals are readily usable in plasma vapor deposition, the nonhomogeneous, multicomponent powdered metals that must sometimes be used to obtain the desired compositions are not suitable for use as targets without further processing. Heretofore, this further processing has included cold pressing into shape, sintering at high temperature, and furnace brazing to copper chill plates. Such processing is time-consuming and expensive.

The modified process is simpler. First, copper chill plates shaped as shallow trays are fabricated. The trays are then filled with a loose powder that consists of the desired mixture of powdered metals plus a low-melting-temperature element that is to be melted and thereby made to fuse the powder mass together into a solid piece. In the case of two targets, silver was both the low-temperature melting element and a component of the material chemistry being plasma-vapor-deposited. The powder-filled trays are placed in a vacuum brazing furnace, where they are heated to a temperature of 1,800 °F (about 980 °C), held at that temperature for 30 min, then cooled.



These **Copper Chill Trays Filled With Target Material** were fabricated in the modified pressureless-sintering process.

The resultant products are copper chill trays filled with densified, nonfriable sintered powder target material (see figure). The sintered target material is homogeneous, dense, and ready to use.

This work was done by William J. Waters of Waters & Associates and Hal Sliney and D. Kowalski of **Lewis Research Center**. *No further documentation is available. LEW-15343*

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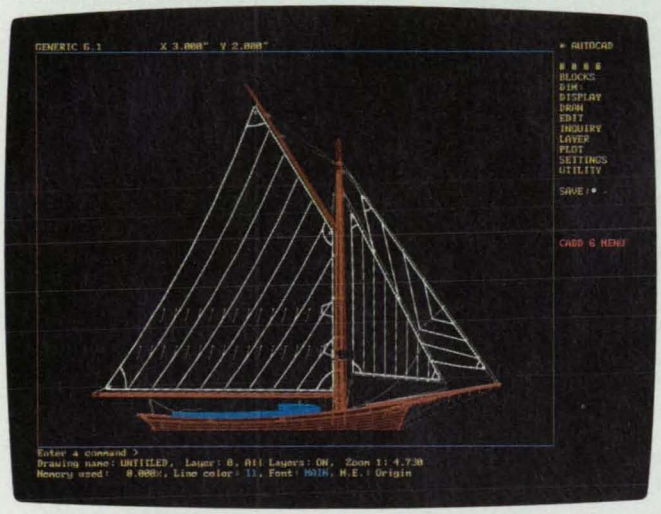

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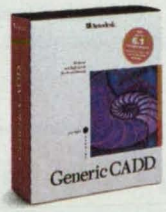

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Lightweight Phase-Change Material for Solar Power

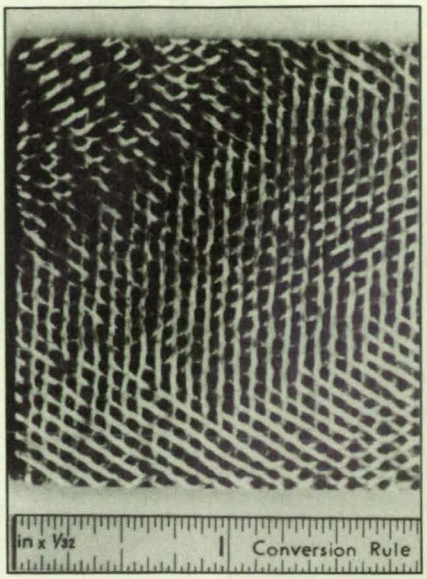
Porous carbon structures are imbued with germanium.

Lewis Research Center, Cleveland, Ohio

Lightweight panels containing phase-change materials are being developed for use as heat-storage elements of a compact, lightweight, advanced solar dynamic power system. During high insolation, heat would be stored in the panels via the latent heat of fusion of the phase-change material; during low insolation, heat would be withdrawn from the panels.

NASA is developing the advanced solar dynamic power system for use aboard a space station in orbit around the Earth, where it would be necessary to level the heat load between alternating periods of sunlight and full or partial solar eclipse. Presumably, the concept of the system and of the lightweight heat-storage material could also be adapted to the development of lightweight, compact, portable solar-power systems for use on Earth. As it has been envisioned thus far, the combined solar receiver/heat-storage subsystem would be the heaviest component of the space station. The lightweight heat-storage panels are needed because in the outer-space application and perhaps in a terrestrial application, the reduction in the size and weight of this subsystem could greatly increase the efficiency of the overall solar-power system.

The developmental lightweight heat-storage elements consist mainly of porous carbon-fiber structures imbued with germanium, which melts at a temperature of 938 °C and serves as the phase-change material. Although metals have been considered for use as phase-change materials, they are not favored because the containment of molten metals at their high melting temperatures presents a formidable technical challenge. Germanium, on the other hand, has a relatively high latent heat of fusion and is chemically compatible with the carbon in which it is to be contained.



This **In-Plane, Carbon-Fiber Preform** is typical of the preforms used to make the experimental heat-storage elements. In this view, it has not yet been impregnated.

To begin the fabrication of experimental heat-storage elements, preforms were made of carbon fibers, using in-plane, "four-directional" construction. These preforms (see figure) were subjected to a single pitch-impregnation cycle to rigidify them without significantly reducing the porosity of the open as-woven fibrous structures.

The resulting carbon/carbon preforms were made into Ge/(C/C) composites by hot isostatic pressing in a thin envelope of Si_3N_4 applied by chemical-vapor deposition. Si_3N_4 was chosen because its coefficient of thermal expansion is close to that of C/C and because it can be deposited at temperatures below the melting temperature of germanium. A thin, dense undercoat of pyrocarbon was deposited prior to deposition of the Si_3N_4, to prevent chemical attack on the germanium by chlorine, which is used in the deposition of Si_3N_4.

The results of this experimental fabrication were encouraging. Although germanium does not wet carbon, the hot isostatic pressing forced the germanium to infiltrate even the fine interstices between filaments within a single carbon fiber.

Attempts were made to enhance the wetting characteristics of the germanium by adding 0.5 weight percent silicon to the germanium or by coating the internal surface of the C/C with a thin film of tungsten carbide. However, these measures did not affect the degree of infiltration.

Germanium contents of the order of 20 to 30 volume percent were achieved in C/C preforms, the original void contents of which were about 40 percent. The original porosities of the preforms were reduced (some of the pores were collapsed) by the high pressure applied during hot isostatic pressing. Higher germanium contents should be achievable by increasing the porosities of the C/C preforms through the use of three-directional, open-weave construction and by modification of the pressure-and-temperature cycle during hot isostatic pressing.

The thermal conductivity of the experimental Ge/(C/C) composites encapsulated in Si_3N_4 was found to be 10 W/m·K at a temperature of about 80 °C. This level of thermal conductivity is quite satisfactory for heat-storage systems.

This work was done by Philip Stark of Foster-Miller, Inc., for **Lewis Research Center**. *No further documentation is available.*
LEW-15307

High-Flow, High-Molecular-Weight, Addition-Curing Polyimides

Melt viscosities are reduced significantly.

Lewis Research Center, Cleveland, Ohio

In a recently developed series of high-flow PMR-type polyimide resins, 2,2′-bis(trifluoromethyl)-4,4′-diaminobiphenyl (BTDB) is substituted for 1,4-phenylenediamine in a PMR-II formulation. The substitution at 2- and 2′-positions of the biphenyl moiety in BTDB apparently forces the two rings to adopt a noncoplanar conformation, which in turn disrupts the crystal packing, and thus lowers the melting temperature of the oligomeric polyimides. The objective is to formulate high-molecular-weight polyimide resins (e.g., $n = 9$, where n is the number of repeating units), based on 2,2′-bis(trifluoromethyl)-4,4′-diaminobiphenyl (BTDB) and dimethyl ester of 4,4′-(hexafluoroisopropylidene)-bis-(phthalic acid) (HFDE), with either nadic ester (NE) or *p*-aminostyrene (PAS) end caps for addition curing. These series of polyimides are designated either as PMR-12F when nadic ester (NE) end caps are used, or as V-CAP-12F when *p*-aminostyrene end caps are used.

Figure 1 shows that the melt viscosities of imidized 12F polyimides are several orders of magnitude smaller than are those of the standard formulations. Isothermal aging studies show that the thermo-oxidative stabilities of these resins upon exposure to flowing air at a pressure of 1 atm (0.1 MPa) and temperature of 650 °F (343 °C) for 750 h are in the following order:

PMR-II-50 < PMR-12F-71 < V-CAP-75 < V-CAP-12F-71

Prepreg materials prepared from 12F resins can be easily processed into high-quality, low-void composites by either high-temperature compression molding or low-pressure autoclave molding. Figure 2 shows that the V-CAP-12F matrix resin provides significant improvements in composite thermo-oxidative weight loss compared to PMR-II and V-CAP-75, along with good retention of mechanical strength after exposure for 2,000 h to air at 650 °F (343 °C). The properties of composite materials made with V-CAP-12F are similarly improved over those of composites made with PMR-II-50 and V-CAP-75, according to similar tests that include exposure to air at 700 °F (371 °C).

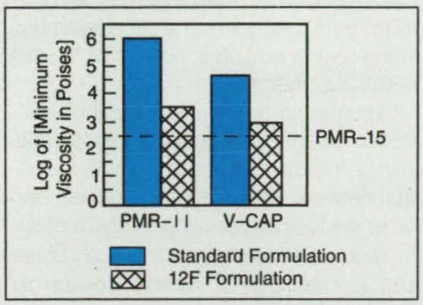


Figure 1. The **Melt Viscosities** of addition-curing polyimides of the 12F formulation are considerably smaller than are those of the standard formulation. Thus, the 12F resins are more processable.

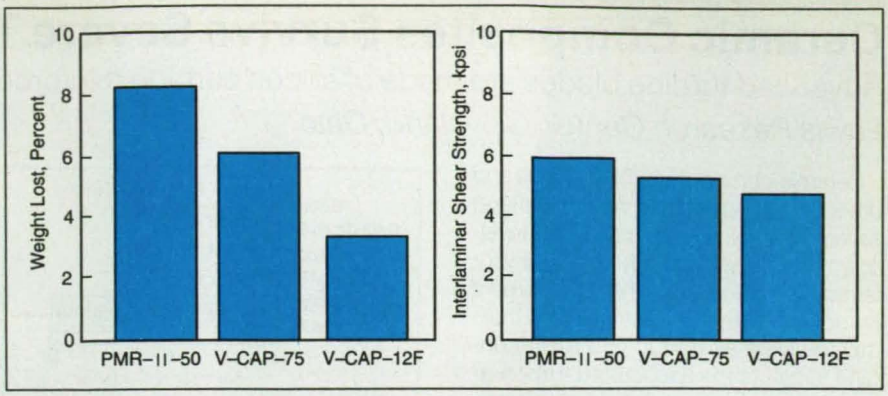


Figure 2. The **Weight Lost** by a laminate made of V-CAP-12F resin and G40-600 graphite fibers after exposure to air for 2,000 h at 650 °F is less than the weights lost by laminates made with two other resins and exposed similarly. The interlaminar shear strength of the laminate made with V-CAP-12F is almost as great as those of laminates made with the other two resins after similar exposure.

In summary, high-molecular-weight, addition-curing polyimides based on BTBD and HFDE are highly processable high-temperature matrix resins that can be used to make composite materials with excellent retention of properties during long-term exposure to air at 650 °F (343 °C) or higher temperature. Furthermore, these 12F addition-curing polyimides might be useful for electronic applications, inasmuch as fluorinated rigid-rod polyimides are known to exhibit low thermal expansion coefficients as well as low absorption of moisture.

This work was done by Kathy C. Chuang and Raymond D. Vannucci of **Lewis Research Center**. *For further information,* ***write in 12*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Lewis Research Center [see page 24]. Refer to LEW-15399.

Ceramic Composites Survive Severe Thermal Shocks

Advanced turbine blades are made of silicon carbide reinforced by continuous carbon fibers.

Lewis Research Center, Cleveland, Ohio

Ceramic-composite turbine blades and other components that must withstand severe thermal shocks are being developed for aerospace and, potentially, for terrestrial applications. The development is motivated by the fact that the thermal transient at startup of a rocket engine subjects the associated turbomachinery to a severe and sudden increase in temperature followed by an almost equally severe and sudden decrease in temperature during engine shutdown. Rates of heating and cooling in the fuel turbopump of the current main engine of the Space Shuttle are measured in thousands of degrees centigrade per second. Metallic components barely survive in this hostile environment and must be replaced frequently.

Almost a decade ago, research sponsored by NASA revealed the potential benefits of the use of ceramic materials in rocket engines, but also revealed that monolithic ceramics lacked toughness and were subject to brittle catastrophic failure. Since then, composite materials that consist of ceramic matrices reinforced by continuous fibers have been developed. These materials withstand high temperatures, exhibit high toughness, and fail gradually.

A unique hydrogen/oxygen rocket–engine test rig that simulates the severe thermal environment of the rocket–engine–starting transient has been used to test a number of fiber reinforced ceramic matrix composite bars. As illustrated by the example of Figure 1, the composites can withstand thermal shocks better than can monolithic ceramics. Incidentally, conventional superalloys would melt under the test conditions.

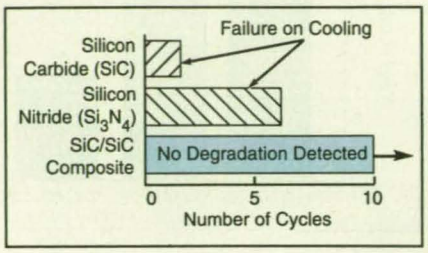


Figure 1. The **SiC/SiC Composite Bar** survived more thermal shocks at a rate of heating of 1,400 °C/s than did monolithic SiC and Si_3N_4 bars.

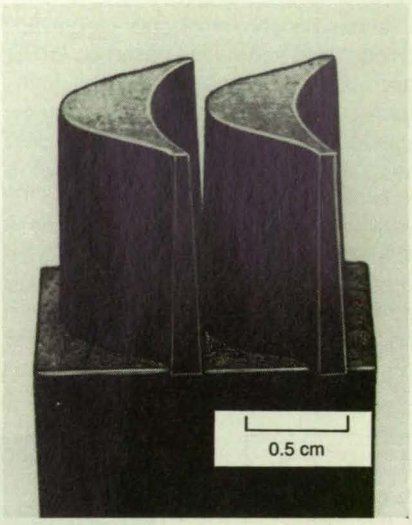


Figure 2. **One of These Turbine Blades**, which are made of SiC/C composite, survived more than 50 1-second thermal shocks from room temperature to 1,800 °C.

On the basis of the foregoing tests, a turbine blade made of silicon carbide reinforced by carbon fibers was fabricated (see Figure 2) and placed in the test rig. It survived more than 50 1-second thermal shocks from room temperature to 1,800 °C. Inasmuch as the maximum temperature in the proposed use in the rocket engine is only 1,100 °C, this result is significant.

Commercial applications for fiber-reinforced ceramic composites include brake linings for fast trains and aircraft, industrial heat exchangers, and nozzles and other devices for handling molten metals.

This work was done by A. J. Eckel and T. P. Herbell of **Lewis Research Center**. *For further information,* ***write in 48*** *on the TSP Request Card. Further information may also be found in NASA TM-103743 [N91-19235], "Ceramic Components for Rocket Engine Turbines," and NASA TM-103777 [N91-19295], "Thermal Shock of Fiber Reinforced Ceramic Matrix Composites."*

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-15493

Polymer Substrates for Lightweight, Thin-Film Solar Cells

These substrates would survive high deposition temperatures.

NASA's Jet Propulsion Laboratory, Pasadena, California

High-temperature-resistant polymers are candidate materials for use as the substrates of lightweight, flexible, radiation-resistant solar photovoltaic cells. According to a proposal, thin films of copper indium diselenide or cadmium telluride would be deposited on the substrates to serve as the active semiconductor layers of the cells, which would be parts of photovoltaic power arrays that would have exceptionally high power-to-weight ratios. The flexibility of the cells could be exploited to make arrays that would be rolled up for storage. In contrast, the materials upon which these semiconductors have been deposited heretofore include molybdenum-coated glass and such semiconductor substrates as GaAs and CdTe; these materials are neither lightweight nor flexible.

A polymer substrate of the proposed type must survive the cell-fabrication conditions without degradation: In the case of deposition of copper indium diselenide, the most demanding step is the selenization, which involves heating to a temperature of about 400 °C, in an atmosphere of hydrogen selenide and argon. This step lasts about 2 ½h, including warmup and cooldown. In the case of deposition of cadmium telluride, the most demanding step is the thermolysis of organometallic compounds in a stream of hydrogen gas at a temperature between 250 and 400 °C.

There are many families of polymers that do not soften (in glass-to-rubber transition), melt, or decompose, at the above-mentioned temperatures and other conditions. The polymer families that have desirable film-forming abilities in addition to the requisite thermal stability include the aromatic polyamides and ordered aromatic copolyamides, aromatic polyanhydrides, polybenzimidazoles, and polyquinoxalines. Other candidate materials include "ladder polymers," which have double-chain rather than single-chain backbones; these tend to exhibit very high thermal stability because breaking the backbone involves the cleavage of two chains instead of one.

Because most of these polymers are electrical insulators, it would be necessary to dope them with small amounts of graphite or other conductive materials for photovoltaic applications. Doping

of this type is well known in the synthesis of composite materials, and dopants have been added to Kapton polyimide for other photovoltaic applications. The precise thickness of a substrate film is not critical. In general, the thickness would depend on such physical factors as the density of the polymer, the tendency to form (or not form) pinholes, and mechanical strength; 50 microns is a suggested approximate value.

This work was done by Carol R. Lewis of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 4*** *on the TSP Request Card.*
NPO-18693

Solid Lubricant for Alumina

An outer layer of silver lubricates, while an intermediate layer of titanium ensures adhesion.

Lewis Research Center, Cleveland, Ohio

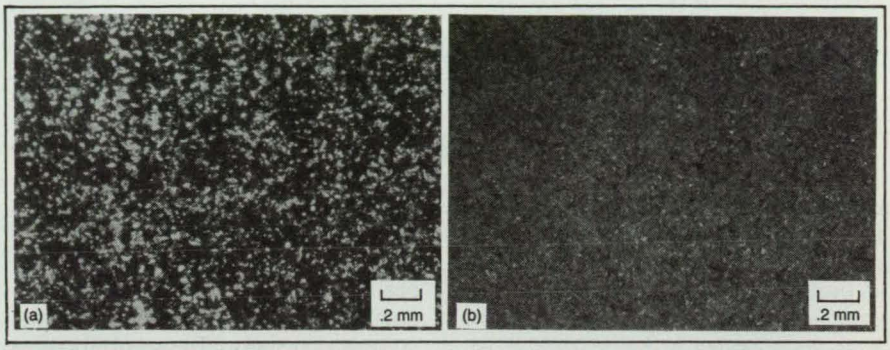
Lubricating outer films of silver deposited on thin intermediate films of titanium on alumina substrates have been found to reduce sliding friction and wear. The films may, therefore, provide effective lubrication for ceramic seals, bearings, and other hot sliding components in advanced high-temperature engines.

In experiments, alumina disks coated with silver/titanium films, alumina disks coated with silver (only), and bare alumina disks were tested in a pin-on-disk tribometer, in which they were slid against bare alumina pins under a 4.9 N load at a speed of 1 m/s. Data on coefficients of friction were collected during test periods that lasted from 30 to 90 minutes each. The silver/titanium films were found to reduce the coefficients of friction to an average value of 0.41 — about half that of bare alumina. These films reduced wear of the pins by a factor of about 140 and wear of the disks by an average factor of about 2.5.

The titanium and silver films were deposited by sputtering: titanium to a thickness of 250 Å, silver to a thickness of 1.5 μm. Some specimens with silver/titanium films were heat-treated in argon at a temperature of 850 °C (1,562 °F), before testing. These specimens retained their tribological properties; thus, it appears that such films can lubricate at temperatures that lie in a wide range. In contrast, a film of silver alone tends to dewet the alumina substrate and form small balls at temperatures greater than 500 °C (932 °F) (see figure). The titanium film thus serves as a bonding layer between the silver film and the alumina substrate while the silver surface film, because of its low shear strength, provides lubrication.

The predominant wear mechanism, according to analysis by scanning electron microscopy, is the pulling out of grains from the alumina substrate. This indicates a strong bond between the silver and titanium and between the titanium and alumina.

The secondary wear mechanism is gradual thinning of the silver film, resulting in a slow increase in the coefficient of friction. The film-and-substrate combination thus deteriorates gradually and can be monitored so that the lubricant film can be renewed or the alumina component replaced before a sudden catastrophic failure occurs.



These Optical Micrographs show the effects of heat treatment at 850 °C upon silver coats on alumina substrates. The silver dewets the alumina substrate, gathering into little ball-like clumps. However, in the presence of a thin interlayer of titanium, the silver does not dewet.

This work was done by Christopher DellaCorte, Stephen V. Pepper, and Frank S. Honecy of **Lewis Research Center**. *Further information may be found in NASA TM-103784 [N91-19224], "Tribological Properties of Ag/Ti Films on Al_2O_3 Ceramic Substrates."*

Copies may be purchased [prepayment required] from the NASA Center for AeroSpace Information, Linthicum Heights, Maryland, Telephone No. (301) 621-0390. Rush orders may be placed for an extra fee by calling the same number.
LEW-15495

Computer Programs

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

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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.

Mathematics and Information Sciences

Fault-Tree Compiler

FTC calculates the probability of the top event in a fault tree.

FTC, the Fault-Tree Compiler program, is a software tool used to calculate the probability of the top event in a fault tree. Gates of five different types are allowed in the fault tree: AND, OR, EXCLUSIVE OR, INVERT, and M OF N. The high-level input language is easy to understand and use. In addition, the program supports a hierarchical fault-tree definition feature, which simplifies the tree-description process and reduces execution time.

A rigorous error bound is derived for the solution technique. This bound enables the program to supply an answer precisely (within the limits of double-precision floating-point arithmetic) at an accuracy and number of digits specified by the user. The program also facilitates sensitivity analysis with respect to any specified parameter of the fault tree such as a rate of failure of components or the probability of a specific event by enabling the user to vary one probability or rate of failure over a range of values and plot the results.

The mathematical approach chosen to solve a reliability problem can vary with the size and nature of the problem. Although different solution techniques are utilized on different programs, it is possible to have a common input language. The Systems Validation Methods group at NASA Langley Research Center has created a set of programs that form the basis for a reliability-analysis workstation. The set of programs are the SURE reliability-analysis program (COSMIC program LAR-13789, LAR-14921); the ASSIST specification interface program (LAR-14193, LAR-14923), the PAWS/STEM reliability-analysis programs (LAR-14165, LAR-14920); and the FTC fault-tree tool (LAR-14586, LAR-14922). FTC is used to calculate the probability of the top event in a fault tree. PAWS/STEM and SURE are programs that interpret the same SURE language but utilize different methods of solution. ASSIST is a preprocessor that generates SURE language from a more abstract definition.

SURE, ASSIST, and PAWS/STEM are also offered as a bundle. Please see the abstract for COS-10039/COS-10041, SARA — SURE/ASSIST Reliability Analysis Workstation, for pricing details.

FTC was originally developed for DEC VAX-series computers running VMS and was later ported for use on Sun computers running SunOS. The program is written in PASCAL, ANSI- compliant C language, and FORTRAN 77. The TEMPLATE graphics library is required to obtain graphical output. The standard distribution medium for the VMS version of FTC (LAR-14586) is a 9-track, 1,600-bit/in. (630-bit/cm) magnetic tape in VMSINSTAL format. It is also available on a TK50 tape cartridge in VMSINSTAL format. Executable codes are included. The standard distribution medium for the Sun version of FTC (LAR-14922) is a 0.25-in. (6.35-mm) streaming-magnetic-tape cartridge in UNIX tar format. Both Sun3 and Sun4 executables are included. FTC was developed in 1989 and last updated in 1992.

DEC, VAX, VMS, and TK50 are trademarks of Digital Equipment Corp. UNIX is a registered trademark of AT&T Bell Laboratories. SunOS, Sun3, and Sun4 are trademarks of Sun Microsystems, Inc.

This program was written by Ricky W. Butler of **Langley Research Center** *and David P. Boerschlein of Lockheed Engineering & Sciences Co. For further information,* ***write in 36*** *on the TSP Request Card.*
LAR-14922

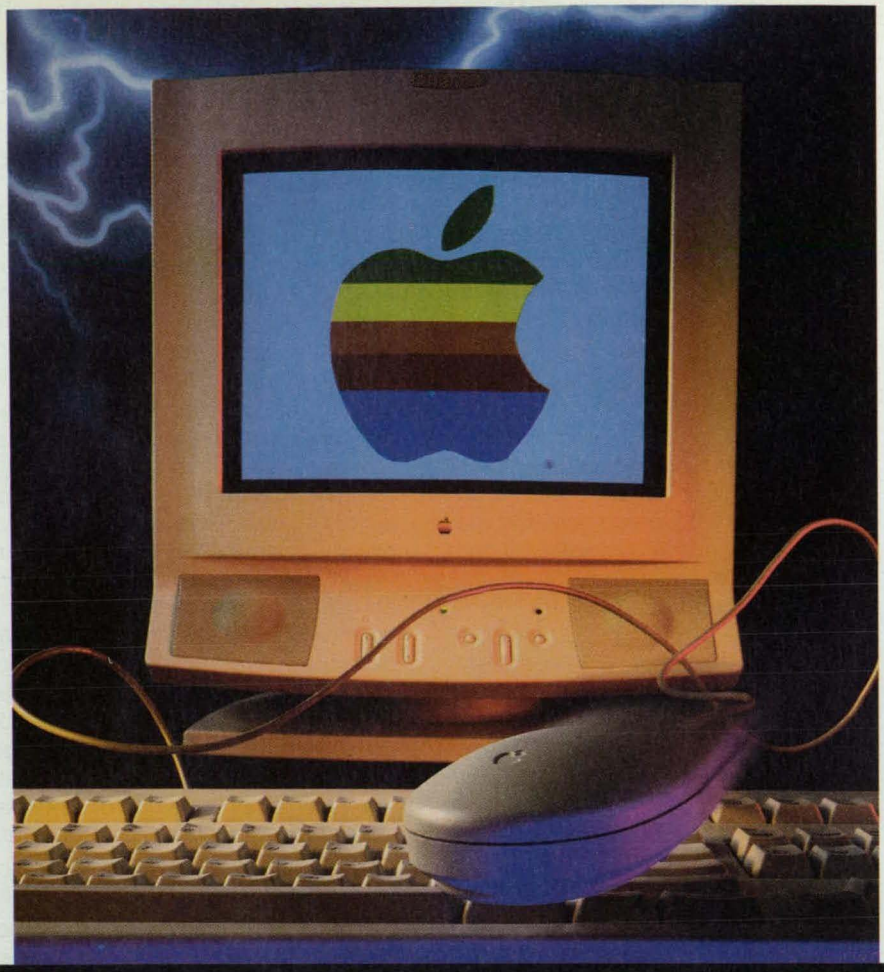
Program Facilitates Distributed Computing

KNET enables simultaneous use of two host computers and transfer of data between them.

The KNET computer program facilitates the distribution of computing between a UNIX-compatible local host computer and a remote host computer, which may or may not be UNIX-compatible. It is capable of automatic remote log-in. That is, it performs, on the user's behalf, the chores of handling selection of the host computer and of sending the user's name and password to the designated host computer. Once the log-in has been completed successfully, the user can communicate interactively with the remote host computer. Data output from the remote host computer can be directed to the local screen, to a local file, and/or to a local process. Conversely, data input from the keyboard, a local file, or a local process can be directed to the remote host computer.

KNET takes advantage of the multitasking and terminal-mode-control features of the UNIX operating system. A parent process is used as the upper layer for an interface with the local user. A child process is used for a lower layer for an interface with the remote host computer, and optionally one or more child processes can be used for the remote data output. Output can be directed to the screen and/or to the local processes under the control of a data-pipe switch. For KNET to operate, the local and remote host computers must observe a common communications protocol.

KNET is written in ANSI standard C language for computers running UNIX. It has been successfully implemented on several Sun-series computers and a DECstation 3100 computer and used to run programs remotely on VAX VMS- and UNIX-based computers. It requires 100K of random-access memory under SunOS and 120K of random-access memory under DEC RISC ULTRIX. An electronic copy of the documentation is



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provided on the distribution medium. The standard distribution medium for KNET is a 0.25-in. (6.35-mm) streaming-magnetic-tape cartridge in UNIX tar format. It is also available on a 3.5-in. (8.89-cm) diskette in UNIX tar format. KNET was developed in 1991 and is a copyrighted work with all copyright vested in NASA.

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This program was written by Joseph Hui of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 47*** *on the TSP Request Card.*
NPO-18634

Automated Estimation of Software-Development Costs

COSTMODL can reduce the risk of cost overruns and failed projects.

The cost of developing computer software consumes increasing portions of many organizations' budgets. As this trend continues, the capability to estimate the effort and schedule required to develop a candidate software product becomes increasingly important. COSTMODL is an automated software development-estimation tool that fufills this need. The assimilation of COSTMODL into the particular computing environment of any organization can yield significant reduction in the risk of cost overruns and failed projects. This user-customization capability of COSTMODL is unmatched by that of any other available estimation software tool.

COSTMODL accepts a description of a software product to be developed and computes estimates of the effort required to produce it, the calendar schedule required, and the distribution of effort and staffing as a function of the defined set of development life-cycle phases. This is accomplished by the five cost-estimation algorithms incorporated into COSTMODL: the NASA-developed KISS model; the Basic,Intermediate, and Ada COCOMO models; and the Incremental Development model. This choice affords the user the ability to handle projects ranging from relatively small and simple to relatively large and complicated.

Unique to COSTMODL is the ability to redefine the life-cycle phases of development and the capability to display a graphic representation of the optimum organizational structure required to develop the subject project, along with required staffing levels and skills. The program is menu-driven and mouse-sensitive with an extensive context-sensitive help system that makes it possible for a new user to install and operate the program easily and to learn the fundamentals of cost estimation without having prior training or separate documentation. The implementation of these functions, along with the customization feature, into one program makes COSTMODL unique within the industry.

COSTMODL was written for IBM PC-compatible computers, and it requires Turbo Pascal 5.0 or later and Turbo Professional 5.0 for recompilation. An executable code is provided on the distribution diskettes. COSTMODL requires 512K of random-access memory. The standard distribution medium for COSTMODL is three 5.25 in. (13.34-m) 360K MS-DOS format diskettes. The contents of the diskettes are compressed by use of the PKWARE archiving software tools. The utility to unarchive the files, PKUNZIP.EXE, is included. COSTMODL was developed in 1991.

IBM PC is a registered trademark of International Business Machines. Borland and Turbo Pascal are registered trademarks of Borland International, Inc. Turbo Professional is a trademark of TurboPower Software. MS-DOS is a registered trademark of Microsoft Corp.

This program was written by George B. Roush and William Reini of **Johnson Space Center** *For further information,* ***write in 21*** *on the TSP Request Card.* *MSC-22010*

Physical Sciences

Radiation-View-Factor Program

VIEW computes view factors for use in calculations of solar and thermal radiation.

The calculation of the exchange of thermal radiation between two gray, diffuse surfaces by the usual engineering method presents difficulties inasmuch as it requires a full and precise description of both surfaces. Often the major difficulty in calculating the transfer of heat rests with the accurate determination of the surface conditions. For multi-surface-enclosure problems, or for radiation between surfaces, the mutual views of which are obstructed, evaluation of view factors entails a major effort.

For many situations, as in spacecraft, or structures in outer space, solar receivers, or industrial furnaces, estimates made by use of graphical and numerical techniques are not adequate. Further, in structures in which the changing apparent position of the Sun leads to different surfaces becoming radiantly important at different times, accurate determination of the view factors for all surfaces is particularly important. The family of computer codes, VIEW, has been created to accomplish this task. VIEW is an interactive program that determines the view factors, graphically displays surfaces, and evaluates the solar irradiation of an assemblage of surfaces.

VIEWC and VIEWH compute the view factors between surfaces. These views may be obstructed either by other surfaces or by themselves. The view factors are generally computed by means of the contour-integration technique originally developed by Mittalas and Stevenson. When there is the possibility that the radiation between any two surfaces is obstructed, their view factor is calculated either by means of a double-area-integral technique, or by contour integration, applied to surface subelements (VIEWC), or by a pixel-projection method (VIEWH).

Structures are defined in VIEWC and VIEWH in terms of a collection of flat surfaces, each of which has three or four edges (i.e., a triangle or a quadrilateral). VIEWC can also compute view factors for two-dimensional surfaces. There are several ways to enter the data for VIEWC and VIEWH. One way is compatible with the usual finite-element-surface definitions and enables the use of finite-element mesh-generation programs to create input for VIEWC and VIEWH. The VIEWCI program eliminates excess common nodes in free-form data input, thus reducing the amount of storage required.

VIEWI is an interactive-graphics program for generating the surface information needed for VIEWC. The surfaces may be generated singly or in groups, and the user can manipulate them in a variety of different ways to create the structure desired. VIEWI can also be used to generate finite-element two-dimensional meshes. VIEWCM combines the output from two different VIEWI sessions to make a composite body. VIEWG provides interactive graphical display of the surfaces generated by VIEWI, with full removal of hidden lines and storage of the picture for high-speed processing (e.g., rapid rotation or perspective viewing of the structure).

VIEWO computes the solar radiation falling on an orbiting structure and the solar radiation reflected from the Earth.

The input to VIEWO is the same as that to VIEWC and VIEWH, with additional data on the position of the structure with respect to the Sun and Earth. VIEWO runs in either batch or interactive mode and computes the solar load as a function of orbital position. Output from VIEWO includes the solar view factor, the long-wave view factor of the Earth, the reflected solar view factor, and total solar load. VIEWS computes specular reflections from surfaces and can be used with VIEWO to track the progress of rays from the Sun as they are reflected throughout the assemblage of surfaces.

The VIEW programs are available in two machine versions. The IBM PC version (LAR-14217) is written in FORTRAN 77, C language, and assembly language. The graphical routines require the use of an EGA or VGA circuit card. The memory requirement for the program is 412K. The standard distribution medium is a set of eleven 360K diskettes in MS-DOS format.

The DEC VAX VMS version (LAR-14468) is written in FORTRAN 77. The graphical routines require a Tektronic 4010 display, a single-pen HP plotter or a VT 125 terminal. This version requires 1MB random-access memory. The standard distribution medium is a 1600 BPI (630 bits/cm)9-track magnetic tape in DEC VAX BACKUP format. The VMS version is also available on a TK50 tape cartridge in DEC VAX BACKUP format.

The VIEW programs were originally developed for the CDC 6000 and 7000 computers using the NOS operating system and for the DEC VAX computer.

Version 5.6.9 of the program was released for the IBM PC in 1991, and for the VAX in 1992.

This program was written by Ashley F. Emery of the University of Washington for **Langley Research Center**. *For further information,* ***write in 70*** *on the TSP Request Card.*
LAR-14217/14468

Thermal-Radiation Program

TRASYS solves equations of thermal radiation, especially for a spacecraft in orbit.

The Thermal Radiation Analyzer System (TRASYS) computer program is a software system that has generalized capability to solve the equations of the radiation-related aspects of thermal-analysis problems. TRASYS computes the total thermal-radiation environment for a spacecraft in orbit. The software calculates internode-radiation-interchange data as well as data on the rates of incidence and absorption of heat that originates from environmental radiant sources. TRASYS provides data of both types in a format directly usable by such thermal-analyzer programs as SINDA'85/FLUINT (available from COSMIC, program number MSC-21528).

One primary feature of TRASYS is that it enables users to write their own driver programs to organize and direct the preprocessor and processor library routines in solving specific thermal-radiation problems. The preprocessor first reads and converts the user's geometric input data into the form used by the processor library routines. Then the preprocessor accepts the user's driving logic, written in the TRASYS modified FORTRAN language. In many cases, the user has a choice of routines to solve a given problem. Users may also provide their own routines where desirable. In particular, the user may write output routines to provide for an interface between TRASYS and any thermal-analyzer program that uses the resistor-and-capacitor-network concept.

Input to the TRASYS program consists of options and edit data, model data, and logic-flow and operations data. Options and edit data provide for basic program control and capability for editing by the user. The model data describe the problem in terms of geometry and other properties. This information includes surface geometric data, documentation data, nodal data, block-coordinate-system data, form-factor data, and flux da-

ta. Logic-flow and operations data house the user's driver logic, including the sequence of subroutine calls and the subroutine library.

Output from TRASYS consists of data of two basic types: internode-radiation-interchange data, and incident- and absorbed-heat-rate data. The flexible structure of TRASYS allows considerable freedom in the definition and choice of the method of solution of a thermal-radiation problem. The flexible structure of TRASYS has also enabled TRASYS to retain the same basic input structure as the authors update it to keep up with changing requirements.

Among its other important features are the following: (1) capability of solving a problem that involves as many as 2,000 nodes, with shadowing by intervening opaque or semitransparent surfaces; (2) choice of diffuse, specular, or diffuse/specular radiant-interchange solutions; (3) a restart capability that minimizes recomputing; (4) macroinstructions that automatically provide the executive logic for generation of orbits that optimizes the use of previously completed computations; (5) a time-variable-geometry package that provides automatic pointing of the various parts of an articulated spacecraft and an automatic look-back feature that eliminates redundant form-factor calculations; and (6) capability to specify submodel names to identify sets of surfaces or components as an entity.

The current DEC VAX version (version P25) and the CRAY version (version P25) of TRASYS require installation of the NASADIG software library (MSC-21801 for DEC VAX or MSC-22001 for CRAY), which is available from COSMIC either separately or bundled with TRASYS. The NASADIG (NASA Device Independent Graphics Library) plotting software package provides a pictorial representation of input geometry, orbital and orientation parameters, and heating-rate output as a function of time. NASADIG supports Tektronix terminals.

The CRAY version of TRASYS (P25) is written in FORTRAN 77 for batch execution (only the plotting driver program is interactive) and has been implemented on a CRAY-XMP computer under UNICOS. The standard distribution medium for either MSC-21959 (CRAY version without NASADIG) or COS-10040 (CRAY version with NASADIG) is a 1,600-bit/in. (630-bit/cm), 9-track magnetic tape in tar format. Both versions are also available on a 0.25-in. (6.35-mm) streaming-magnetic-tape cartridge in UNIX tar format.

The DEC VAX version of TRASYS (P25) is written in FORTRAN 77 for batch execution (only the plotting driver program is interactive) and has been implemented on a DEC VAX 8650 computer under VMS. Since the source codes for MSC-21030 and COS-10026 are in VAX/VMS text library files and DEC Command Language files, COSMIC will provide only the following programs in the following formats: MSC-21030, TRASYS (DEC VAX version P25 without NASADIG), is available on 9-track, 1,600-bit/in. (630-bit/cm) magnetic tape in VAX BACKUP format (standard medium) or in VAX BACKUP format on a TK50 tape cartridge; COS-10026, TRASYS (DEC VAX version P25 with NASADIG), is available in VAX BACKUP format on either a 9-track, 1,600-bit/in. (630-bit/cm) magnetic tape (standard medium) or a TK50 tape cartridge. TRASYS was last updated in 1991.

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This program was written by Gordon Anderson of Lockheed Engineering & Sciences Co. for **Johnson Space Center**. *For further information,* ***write in 73*** *on the TSP Request Card.*
MSC-21959

Electron-Tunneling Pathways in Proteins

This program helps in modeling electron-transfer subprocesses of biological processes.

The key to understanding the mechanisms of many important biological processes like photosynthesis and respiration is a better understanding of the subprocesses in which electrons are transferred between metal atoms and groups of other atoms fixed within large protein molecules. Research is currently focused on the rates of transfer of electrons and such factors that influence these rates as the compositions of proteins and the distances between metal atoms. Current theoretical models explain the swift transfer of electrons over considerable distances by postulating bridges in the form of mediated-quantum-mechanical tunneling or other physical tunneling pathways made of interacting bonds in the medium around and between donor and acceptor sites. The computer program PATHWAYS is designed to predict the route along which electrons travel in the transfer processes.

The basic strategy of PATHWAYS is to begin by recording each possible path element on a connectivity list, including in each entry which two atoms are connected and what contribution the con-

nection would make to the overall rate if it were included in a pathway. The list begins with the bonded molecular structure (including the backbone sequence and side-chain connectivity), and then adds probable hydrogen-bond links and through-space contacts. Once this list is completed, the program runs a tree search from the donor to the acceptor site to find the dominant pathways. The speed and efficiency of the computer search offer an improvement over manual techniques.

PATHWAYS is written in FORTRAN 77 for execution on DEC VAX-series computers running VMS. The program receives input data from four sets of data and one structure file. The software was written to accept input in the form of BIOGRAF (old format) structure files based on x-ray crystal structures. The software puts out ASCII files that list the best pathways and BIOGRAF vector files that contain the paths. Relatively minor changes could be made in the input format statements for compatibility with other graphics software.

The executable and source codes are included with the distribution. The main memory required for execution is 2.6 Mb. This program is available in DEC VAX BACKUP format on a 9-track, 1,600-bit/in. (630-bit/cm) magnetic tape (standard distribution) or on a TK50 tape cartridge. PATHWAYS was developed in 1988. PATHWAYS is a copyrighted work with all copyright vested in NASA.

DEC, VAX, VMS, and TK50 are trademarks of Digital Equipment Corp. BIOGRAF is a product of Biodesign, Inc., Pasadena, CA.

This program was written by David N. Beratan, Bruce E. Bowler, and Jonathan Betts of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 27*** *on the TSP Request Card.*
NPO-18139

Mechanics

FASTRAN II

This program implements mathematical models of growth of fatigue cracks.

Predictions of the behaviors of growing fatigue cracks can be made with the help of the Fatigue Crack Growth Structural Analysis (FASTRAN II) computer program. As cyclic loads are applied to a crack that has a selected configuration and a selected initial size, FASTRAN II predicts the growth of the crack as a function of the history of the cyclic loads until either the crack attains a desired size or failure occurs.

FASTRAN II is based on plasticity-induced closure behavior of cracks in metallic materials and accounts for such load-interaction effects as retardation and acceleration, under variable-amplitude loading. The mathematical model of closure that is implemented by FASTRAN II is based on the Dugdale model with modifications to allow plastically deformed material to be left along the surfaces of the crack as the crack grows. Plane stress and plane strain conditions, as well as conditions between these two, can be simulated in FASTRAN II by using a constraint factor on tensile yielding at the crack front to account approximately for three-dimensional stress states.

FASTRAN II contains 17 predefined crack configurations (standard laboratory fatigue-crack-growth-rate specimens and many common crack configurations found in structures), and the user can define 1 additional crack configuration. The baseline crack-growth-rate properties (effective stress-intensity factor against crack-growth rate) can be given in either equation or tabular form. For such three-dimensional crack configurations as those of surface cracks or corner cracks at holes or notches, the fatigue-crack-growth rate properties can be different in the crack-depth and crack-length directions. Final

failure of a cracked structure can be modeled with fracture-toughness properties, using either linear-elastic fracture mechanics (for a brittle material), a two-parameter fracture criterion (for a brittle to ductile material), or plastic collapse (for an extremely ductile material).

The crack configurations in FASTRAN II can be subjected to either constant-amplitude, variable-amplitude, or spectrum loading. The applied loads can be either tensile or compressive. Several standardized aircraft flight-load histories, such as TWIST, Mini-TWIST, FALSTAFF, Inverted FALSTAFF, Felix-28, and Gaussian, are included as options. FASTRAN II also includes parts that implement two other methods that help the user enter spectrum load histories. The two methods are (1) a list of stress points and (2) a flight-by-flight history of stress points. Examples are provided in the user's manual. Developed as a research program, FASTRAN II has successfully predicted the growth of cracks in many metallic materials under various aircraft spectrum loading schemes

The computer program DKEFF, which is a part of the FASTRAN II software package, was also developed to analyze crack-growth-rate data from laboratory specimens to obtain the effective stress-intensity factor against crack-growth-rate relations used in FASTRAN II.

FASTRAN II is written in standard FORTRAN 77. It has been successfully compiled and implemented on Sun4-series computers running SunOS and on IBM PC-compatible computers running MS-DOS using the Lahey F77L FORTRAN compiler. Sample input and output data are included with the FASTRAN II package. The UNIX version requires 660K of random-access memory for execution. The standard distribution medium for the UNIX version (LAR-14865) is a 0.25-in (6.35-mm). streaming-magnetic-tape cartridge in UNIX tar format. It is also available on a 3.5-in. (8.89-cm) diskette in UNIX tar format. The standard distribution medium for the MS-DOS version (LAR-14944) is a 5.25-in. (13.34-cm) 360K diskette in MS-DOS format. The contents of the diskette are compressed by use of the PKWARE archiving tools. The utility to unarchive the files, PKUNZIP.EXE, is included. The program was developed in 1984 and revised in 1992.

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This program was written by James C. Newman, Jr., of **Langley Research Center**.

For further information on LAR-14865, ***write in 93*** *on the TSP Request Card.*

For further information on LAR-14944, ***write in 100*** *on the TSP Request Card.*

LAR-14865/ LAR-14944

Code Estimates Helicopter-Rotor Inflow and Wake Velocities

DOWN implements a flat-wake theory.

The prediction of inflow to a helicopter rotor and of the wake velocities below and behind is vital to the calculation of aerodynamic loads on the rotor blades. DOWN is a computer program that assists designers with such predictions. DOWN was created to implement a flat-wake theory, which provides a simple analysis for the calculation of inflow and wake velocities of helicopter rotors.

The analysis essentially treats the geometry of the wake as rigid, without interaction between induced velocities and the structure of the wake. The code predicts three orthogonal incremental components of flow velocity at any point in any plane parallel or perpendicular to the rotor disk. Input to the code is entered interactively through the computer key-

board. The coded version of flat-wake theory as implemented in DOWN provides vertical inflow patterns similar to experimental patterns for helicopter flight at speeds greater than 60 kn (111 km/h).

DOWN is written in FORTRAN 77 for IBM PC-series and compatible computers running MS-DOS. It requires 56K of random-access memory for execution. The DOWN software package includes sample executable codes that were compiled under Microsoft FORTRAN. The standard distribution medium for this program is one 5.25-in. (13.34-cm), 360K MS-DOS diskette in MS-DOS format. DOWN was developed in 1991.

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This program was written by Howard C. Curtiss and Robert M. McKillip of Princeton University and John C. Wilson of U.S. Army-AVSCOM for **Langley Research Center**. *For further information,* ***write in 74*** *on the TSP Request Card.*
LAR-14841

Autonomous Frequency-Domain System-Identification Program

AU-FREDI is a collection of routines that can be assembled to suit specific situations.

The Autonomous Frequency Domain Identification (AU-FREDI) computer program implements a system of methods, algorithms, and software that was developed for (1) the identification of parameters of mathematical models of the dynamics (usually, vibrations and/or rotations) of flexible structures (called "system identification" in the art) and (2) the characterization, by use of system transfer functions, of such models, dynamics, and structures regarded as systems. The structures that were contemplated in the development of AU-FREDI are flexible spacecraft and large platforms in outer space.

AU-FREDI was validated in the Large Spacecraft Control Laboratory, which is part of NASA's Jet Propulsion Laboratory. Because of the unique characteristics of the environment in this laboratory and the environment-specific nature of many of the routines in AU-FREDI, this software should be considered to be a collection of routines that can be modified and reassembled to suit system-identification and control experiments on large flexible structures.

The AU-FREDI software was originally designed to command the vibrational excitations applied to the experimental structures, to handle the subsequent transfers of input and output data, and to conduct system identification on the basis of the input and output data.

The principal features of AU-FREDI methodology are the following:

1. AU-FREDI provides on-line design of digital filters to support optimal design of input and optimal composition of data on orbit.
2. Experimental data in overlapping frequency bands are composed in such a way as to overcome constraints imposed by finite actuator power.
3. Recursive least-squares sine-dwell estimation accurately handles digitized sinusoids and low-frequency modes.
4. The orders of mathematical models are estimated automatically by use of a product moment matrix.
5. A sample-data-transfer-function parameterization supports digital control design.
6. Minimum-variance estimation is ensured by use of a curve-fitting algorithm with iterative reweighting.
7. Robust algorithms that solve for the roots of high-order polynomials factorize those polynomials accurately to estimate frequencies and coefficients of damping.
8. Characterization of the additive uncertainties of mathematical models in terms of output errors supports analysis of

robustness.

The research objectives associated with AU-FREDI were particularly useful in focusing the identification methodology for realistic on-orbit testing conditions. Rather than estimating the parameters of an entire structure, as is typically done in ground structural testing, AU-FREDI identifies only the key transfer-function parameters and uncertainty bounds that are necessary for on-line design and tuning of robust controllers (to control or suppress vibrations). The system-identification algorithms in AU-FREDI are independent of the specific laboratory environment for which they were developed and can easily be extracted and modified for use with input/output data files.

The basic approach of the system-identification algorithms in AU-FREDI is to identify nonparametrically the sampled data in the frequency domain by use of either stochastic or sine-dwell input, and then to obtain a parametric model of the transfer function by curve-fitting techniques. A cross-spectral analysis of the output error is used to determine the additive uncertainty in the estimated transfer function. The nominal estimate of the transfer function and the estimate of the associated additive uncertainty can be used for analysis and design of robust control.

The input/output data-transfer routines in AU-FREDI are tailored to the specific laboratory environment for which they were developed; this environment included a special operating system that served as an interface with the testbed. Input commands for a particular experiment (wide-band, narrow-band, or sine-dwell) were computed on-line and then issued to respective actuators by the operating system. The operating system also took measurements through displacement sensors and passed them back to the software for storage and off-line processing. To make use of the input/output data-transfer routines in AU-FREDI, a user would need to provide an operating system capable of overseeing such functions between the software and the experimental setup at hand.

The program documentation contains information designed to support the user in either providing such an operating system or modifying the system-identification algorithms for use with input/output data files. It provides a history of the theoretical, algorithmic, and software-development efforts, discusses operating-system requirements, and lists some of the special-purpose subroutines that were developed and optimized for Lahey FORTRAN compilers on IBM PC-AT computers before the subroutines were integrated into the system software. Potential purchasers are encouraged to purchase and review the documentation before purchasing the AU-FREDI software.

AU-FREDI is distributed in DEC VAX BACKUP format on a 1,600-bit/in. (630-bit/cm), 9-track magnetic tape (standard medium) or a TK50 tape cartridge. AU-FREDI was developed in 1989 and is a copyrighted work with all copyright vested in NASA.

This program was written by Yeung Yam, Edward Mettler, David S. Bayard, Fred Y. Hadaegh, Mark H. Milman, and Robert E. Scheid of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 46*** *on the TSP Request Card.* *NPO-18096*

Program for Two-Dimensional Thermoplastic Deformation

SOLAS contains a number of utility programs for use with finite-element simulations.

Prediction of the lifetimes of components that undergo plastic deformation requires accurate solution of relevant finite-element models of plastic behavior. The SOLAS computer program is designed to handle two-dimensional problems of quasi-static thermoplastic deformation.

SOLAS builds a mathematical model in ANSYS. SOLAS provides software tools for splicing and interpolation of temperature transients as well as for selection of load steps. Three computer codes that solve the equations of the model — namely, ANSYS, ABAQUS, and APSAC — can be used to compute the mechanical response of the deformed component. Because the bandwidth limitation of APSAC may preclude the use of a typically irregular computational mesh like that used in mathematical modeling of a deformed solid, PATRAN is used to minimize the bandwidth. SOLAS can be used to verify the solution; it can also be used to compare the resources needed by ANSYS, ABAQUS, or APSAC. Thus, SOLAS helps to select the code and type of element to be used in multiple-duty-cycle analyses.

SOLAS includes optional postprocessing software, independent of the solution codes, that generates a unified element-by-element list of the quantitative results of the computation, plus a file that contains the signed equivalent stresses, the equivalent strains, and the multiaxiality factor parameter. The signs of the equivalent quantities can be expressed either with respect to the maximum principal quantities or with respect to directions defined by the user.

Several stand-alone utility programs are included in the SOLAS software package:

1. set_anspar is used to set ANSYS parameters externally.
2. ansaba translates an ANSYS model to an ABAQUS model. Currently, only two-dimensional continuum elements are supported.
3. ansaps translates an ANSYS model to an APSAC model. Currently, only two-dimensional continuum elements are supported.
4. fix24 performs various functions to splice thermal-load files together, skip load steps, insert necessary commands to separate load steps, and specify time. In addition, a thermal-influence-function model can be applied to generate a new transient thermal field corresponding to a perturbation of the parameters of the system.
5. fix24_p inserts pressure-scaling commands to simulate the history of the pressure loading. The program writes pressure-scaling commands to a file to generate a linear increase and linear decrease of the pressure during the startup and shutdown transients, respectively.
6. postgen generates post-processing commands for ANSYS and ABAQUS from the element list written during the ANSYS-model-building phase.
7. dumpgen generates post-processing commands from the element list written during the building of the ANSYS model for APSADUMP.
8. summary reads the post-processing listing written by ANSYS, ABAQUS, or APSAC and generates a code-independent list. In addition, signing of the equivalent stress and the equivalent strain is also available. A plot file that lists the time, signed equivalent strain, effective stress, and multiaxiality factor is generated.

SOLAS is written in UNIX shell script and FORTRAN 77 for computers running the UNIX operating system. It requires input from ANSYS, ABAQUS, or APSAC. It has been successfully implemented on Sun-series computers running SunOS and CRAY-series computers running UNICOS. Several component programs, such as the translators, as well as utilities to set ANSYS parameters outside of ANSYS and to generate post-processing decks for ABAQUS and APSAC, and the code-independent-list-generating programs are written in FORTRAN. These can be used on non-UNIX systems; the operation of these programs has been verified on IBM PC and compatible computers with MS FORTRAN 5.0 and on CDC NOS-VE. The standard distribution medium for SOLAS is a 0.25-in. (6.35-mm) streaming-magnetic-tape cartridge in UNIX tar format. SOLAS was developed in 1991.

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This program was written by George E. Orient of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information,* ***write in 2*** *on the TSP Request Card. MFS-29934*

Data on Flow About a Compressor Blade in Cascade

Measured flow quantities can be used to test flow-computing software.

The development and testing of software to compute values of flow-field characteristics is greatly enhanced by using recorded experimental data to test the results of computations. The report "The Measurement of Boundary Layers on a Compressor Blade in Cascade" is a data base that provides detailed measurements of the boundary layer and wake in the flow field about double-circular-arc compressor blades in a cascade of such blades. The measurements were made at angles of incidence of 5°, –1.5°, and –8.5° and at a chord Reynolds number of 500,000. These data, taken together, represent a complex, well-documented flow field that can be used in the development and testing of flow-computing software.

The data were recorded at 11 or 12 locations on the pressure surface of the blade, 11 locations on the suction surface of the blade, and 3 or 4 wake locations. All the measurements in the boundary layer on the blade and in the part of the wake near the blade were made by use of a single-component laser Doppler velocimeter. The data are presented both in raw form and in reconstructed form, in which the effect of the normal pressure gradient caused by the curvature of the blade is removed. The data are organized into tables and grouped by angle of incidence and by location (pressure surface, suction surface, and wake).

The data, approximately 750K, were stored on a DEC VAX-series computer under VMS. These data are available in DEC VAX BACKUP format on a 9-track, 1,600-bit/in. (630-bit/cm) magnetic tape and are reprinted in the program documentation. The data were generated in 1991.

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This program was written by S. Deutsch and W. C. Zierke of Pennsylvania State University for **Lewis Research Center**. *For further information,* ***write in 8*** *on the TSP Request Card. LEW-15272*

Thermal-Hydraulic-Analysis Program

ELM models turbulent gas coolant flow in solid-core nuclear reactors.

The ELM computer program is a simple computational tool for modeling the steady-state thermal hydraulics of flows of propellants through fuel-element-coolant channels in nuclear thermal rockets. Written for the nuclear-propulsion project of the Space Exploration Initiative, ELM evaluates the various heat-transfer-coefficient and friction-factor correlations available for turbulent pipe flow with the addition of heat. In the past, these correlations were found in different reactor-analysis codes, but now comparisons are possible within one program.

The logic of ELM is based on the one-dimensional conservation of energy in combination with Newton's law of cooling to determine the temperature of the bulk flow and the temperature of the wall across a control volume. Since the control volume is an incremental length of tube, the corresponding pressure drop is determined by application of the law of conservation of momentum. The size, speed, and accuracy of ELM make it a simple computational tool for use in parametric studies of fuel elements.

ELM is a machine-independent program written in FORTRAN 77. It has been successfully compiled on an IBM PC-compatible computer running MS-DOS using Lahey FORTRAN 77, a DEC VAX-series computer running VMS, and a Sun4-series computer running SunOS UNIX. ELM requires 565K of random-access memory (RAM) under SunOS 4.1, 360K of RAM under VMS 5.4, and 406K of RAM under MS-DOS; a bulk of the RAM is a hydrogen-properties model. Because this program is machine-independent, no executable code is provided on the distribution medium. The standard distribution medium for ELM is one 5.25-in. (13.34-cm) 360K diskette in MS-DOS format. ELM was developed in 1991.

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This program was written by J. T. Walton of **Lewis Research Center**. *For further information,* ***write in 105*** *on the TSP Request Card. LEW-15423*

Shield Design for Protection Against Hypervelocity Particles

Installing multilayer insulation against primary Whipple bumper reduces pressure-wall damage.

Marshall Space Flight Center, Alabama

Impacts of space debris on orbiting spacecraft can result in severe damage including the total loss of the spacecraft. Space debris is usually composed of aluminum materials from satellites and launch systems. Dimensions of this debris can range from micron size particles up to meters in diameter. Impact velocities of up to 16 km/s can occur — for comparison, high-powered rifle projectiles have a maximum velocity of ~1 km/s. At these hypervelocities, unprotected spacecraft walls can be penetrated by aluminum particles as small as a few millimeters in diameter.

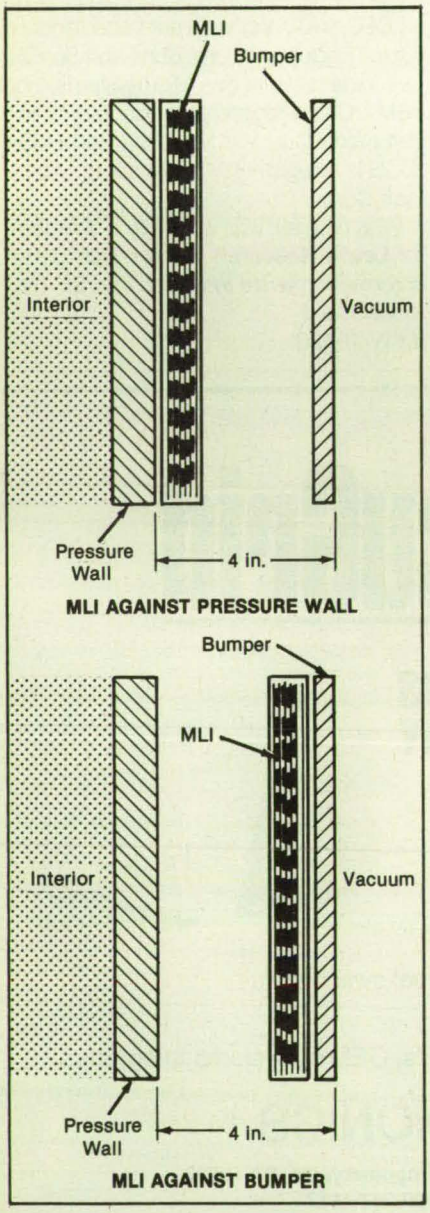


Figure 1. **Two Alternative Shield Designs** have been evaluated. The design on the bottom has demonstrated a sturdier protection against high-velocity impact.

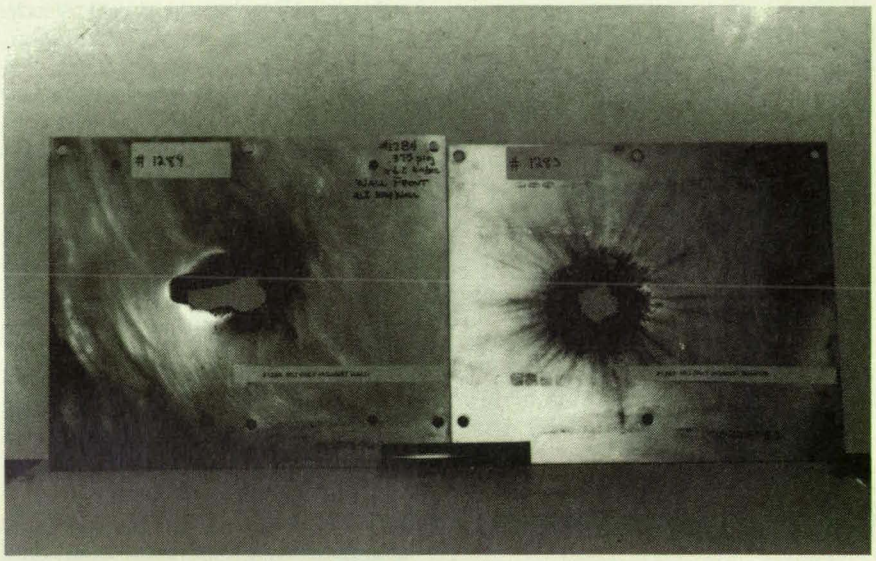


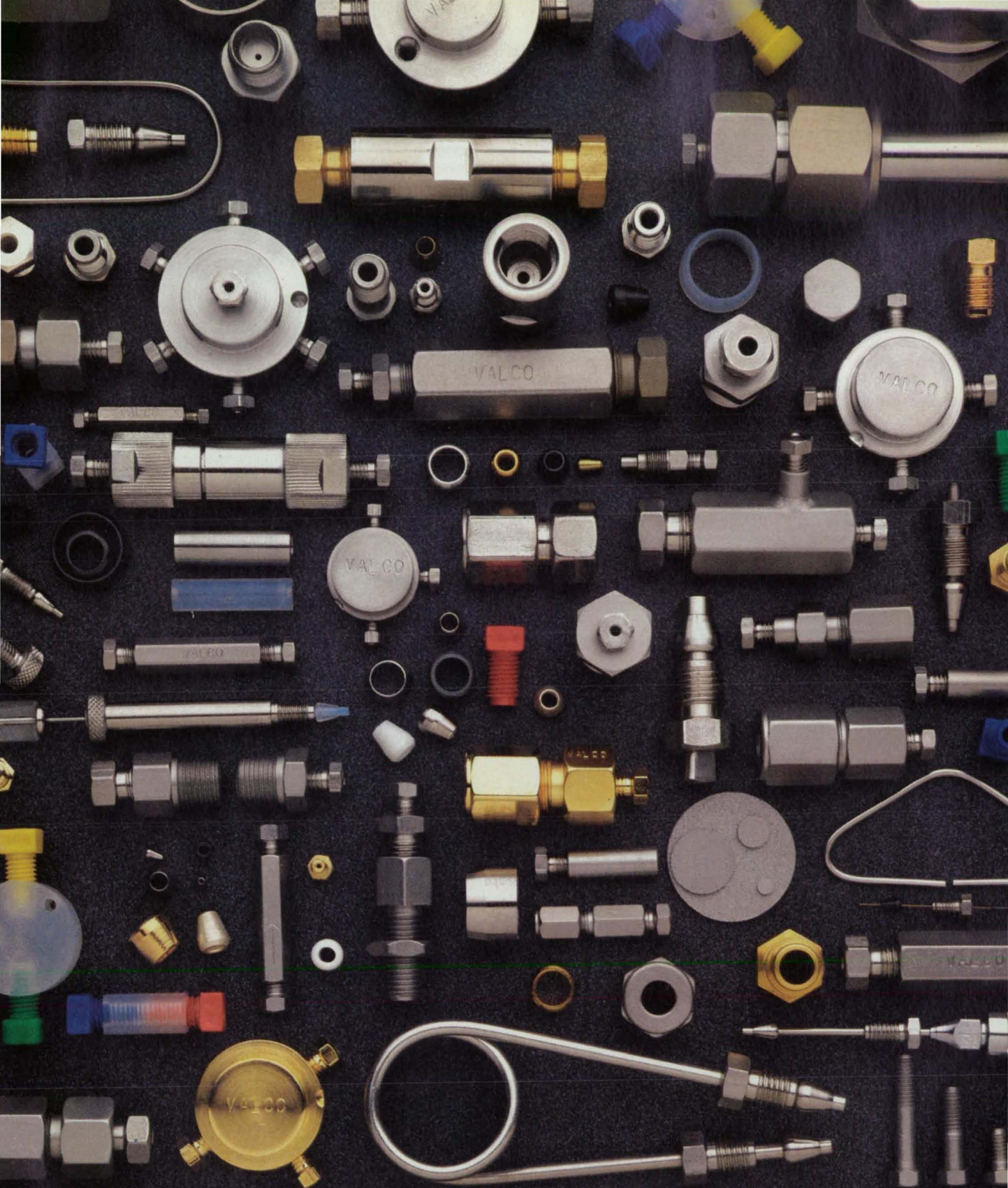
Figure 2. **Impact Damage** is different as shown in this side-by-side comparison. The panel on the left had MLI against the pressure wall; the panel on the right had MLI against the bumper. The impact projectile was a 1100 aluminum sphere 0.375 in. (9.52 mm) in diameter with a velocity of 6.2 km/s. The pressure wall is 2219-T87 [0.125 in. (3.18 mm)] aluminum, and the bumper is 6061-T6 aluminum [0.063 in. (1.60 mm)].

Protection to the Space Station is based on the Whipple bumper concept. Under this concept [also see *NASA Tech Briefs*, "Multishock Shields Containing Aluminum Mesh" (MSC-21792), Vol. 17, No. 11 (November 1993) p. 110], the debris particle impacts a bumper, which breaks up the projectile into smaller particles, liquid droplets, and gases and thereby minimizes damage to the spacecraft wall material.

A Whipple bumper consisting of an aluminum sheet ranging from 0.032 to 0.080 in. (0.81 to 2.03 mm) thick with a standoff of 4 in. (10 cm) is utilized to protect the Space-Station module pressure wall. If a bumper were not used, even millimeter size debris could easily penetrate the pressure wall of the Space-Station module. For example, a Whipple bumper of 0.063 in. (1.60 mm) thickness, with a 4-in. (10-cm) standoff, can prevent penetration of a pressure wall of 0.125 in. (3.18 mm) thickness by a projectile of ~0.3 in. (7.5 mm) diameter with an impact velocity of 6 km/s. In addition to the Whipple bumper, thermal insulation is required and is provided by a multilayered insulation (MLI) consisting of 20 layers (alternating) of double-aluminized Mylar® (or equivalent) and Dacron® (or equivalent) netting.

During the development testing of the bumper system for the Space-Station modules, it was discovered that the location of the MLI within the 4-in. (10-cm) standoff between the bumper and pressure wall has a significant effect on the pressure-wall damage. When the MLI is located against the pressure wall (see Figure 1), radial cracking occurs from the impact penetration outwards, increasing the spalling and generating petals. In comparison, in the test in which the MLI was located against the Whipple bumper, no radial cracking or petaling of the aluminum pressure wall occurred.

The actual physical mechanism causing the increased wall damage has not been totally evaluated. Further testing with other materials indicates that the increased damage to the pressure wall appears to occur whenever materials are placed against the wall. The debris cloud from the Whipple bumper disintegrates MLI material, generating more gases which create an increased pressure region localized in the impact zone (see samples in Figure 2). This increased pressure is



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relieved as the aluminum wall material "rips" open. When the MLI is located against the bumper, the material still disintegrates, but the extra space between the MLI and pressure wall allows the debris pressure cloud to expand so that the pressure cloud loading is reduced. In addition, the total amount of MLI material that is damaged is considerably less when placed against the Whipple bumper, which contributes to a decrease in the excess pressure and contents of the expanding debris cloud.

This work was done by R. J. Schwinghamer and A. Whitaker of **Marshall Space Flight Center**. *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 24]. Refer to MFS-28523.

Suppressing Oscillations in a Poppet Valve

A dashpot is added to damp vibrations and reduce wear.

Lyndon B. Johnson Space Center, Houston, Texas

A modification that involves the addition of a damping mechanism extends the life of a poppet check valve, especially one that carries a flow of gas. The mechanism, which is designed to fit a commercial spring-loaded in-line poppet valve, includes a dashpot that damps axial oscillations and helps to keep the poppet centered.

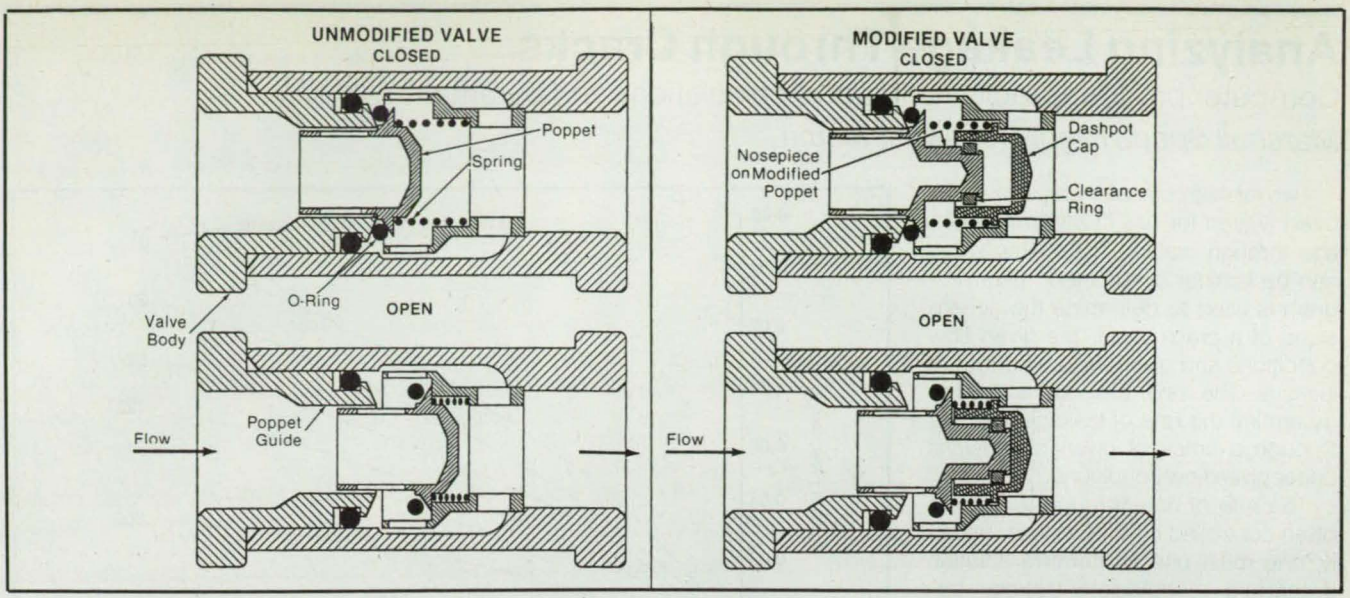
In the unmodified valve, the spring and poppet constitute a resonant system that can be set into sustained oscillations by the flow. These oscillations accelerate the wear of the poppet and poppet guide. A valve that would otherwise last for years can wear out in a few hours of vibration.

Moreover, wear increases the clearance between the poppet and its guide, allowing the poppet to tip increasingly as it moves toward the fully open position. Eventually, a surge in the flow can jam the poppet in the fully open position. In addition, wear creates particles that can clog downstream components.

To damp the vibrations, a dashpot cap that serves as a dashpot cylinder is added, and the original poppet is replaced with a new poppet equipped with a nosepiece that constitutes a dashpot piston (see figure). Because the nosepiece on the new poppet rides in the bore of the dashpot cap, the poppet is guided and centered at both ends as it strokes, and the tendency to tip is thereby suppressed.

During stroking, fluid flows into and out of the dashpot cavity. The resistance to flow, which is determined by the dimensions of the clearance ring and the bore of the dashpot, limits the speed of the poppet in both opening and closing directions, and thus damps out oscillations. The clearance ring is made of polytetrafluoroethylene or a similar low-friction material that is soft enough to help prevent jamming by particles, yet firm enough that it does not flex into a sealing position when pressure changes suddenly.

If the poppet becomes trapped in the dashpot cap by jamming of a particle between mating surfaces, the valve still functions as a check valve, albeit somewhat imperfectly. That is, reverse flow still closes the poppet, but in this condition the dashpot cap moves with the poppet because the cap is not anchored in the



Modifications of a Poppet Valve consist of the addition of a dashpot cap and the replacement of the original poppet with one of new design. The resistance of the gas or liquid in the dashpot damps poppet oscillations.

valve body (it is held against a shoulder in the body by the valve spring). With a trapped poppet, the cap and the trapped spring ride back and forth with the poppet as the direction of flow changes. The valve no longer seals tightly at low differential pressure, because in this condition, the spring is no longer effective.

The clearance between the clearance ring and the bore of the dashpot cap can be chosen to suit the conditions of the application — pressure, temperature, type of fluid, and size of valve — and thereby limit the speed of the poppet to a predetermined maximum. The operating characteristics of a given valve can be altered, if necessary, by retrofitting it with a different poppet, clearance ring, or dashpot cap.

This work was done by Brian G. Morris of **Johnson Space Center**. *For further information,* ***write in 41*** *on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center [see page 24]. Refer to MSC-21903.

Analyzing Leakage Through Cracks

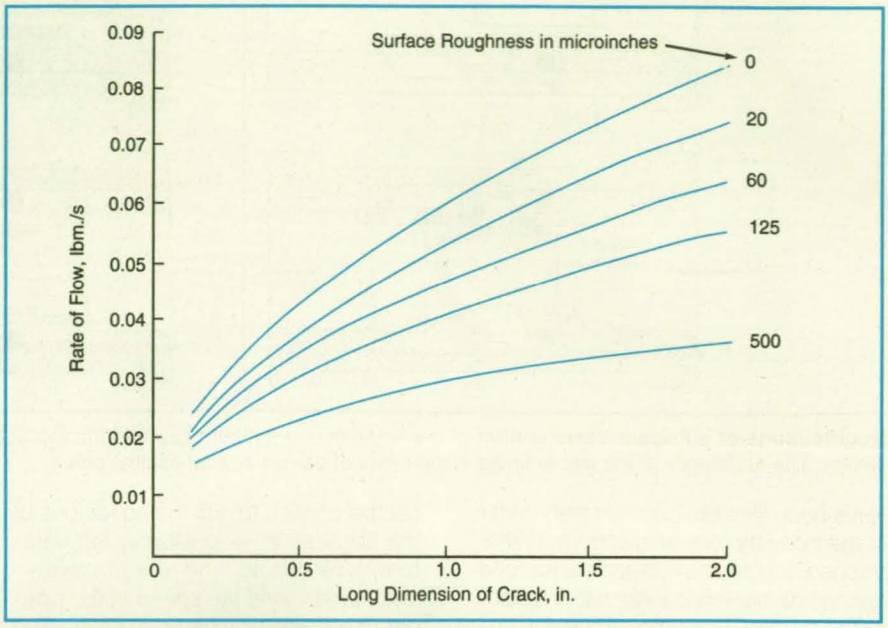
Computer programs facilitate iterative calculations and parametric analyses.

Marshall Space Flight Center, Alabama

Two related computer programs have been written for use in analyzing leakage through cracks. The leakage flow can be laminar or turbulent. One program is used to determine the dimensions of a crack under the given flow conditions and given measured rate of leakage. The other program is used to determine the rate of leakage of a gas through a crack of given dimensions under given flow conditions.

The rate of flow through a crack is often controlled by friction loss; usually, one must use an iterative solution procedure to calculate leakage because the rate of flow and the friction loss are interrelated. Heretofore, analyses of leakage have been performed manually, using simplifying assumptions, which gave rise to inaccuracy. Parametric analyses and iterations consume much time when performed manually.

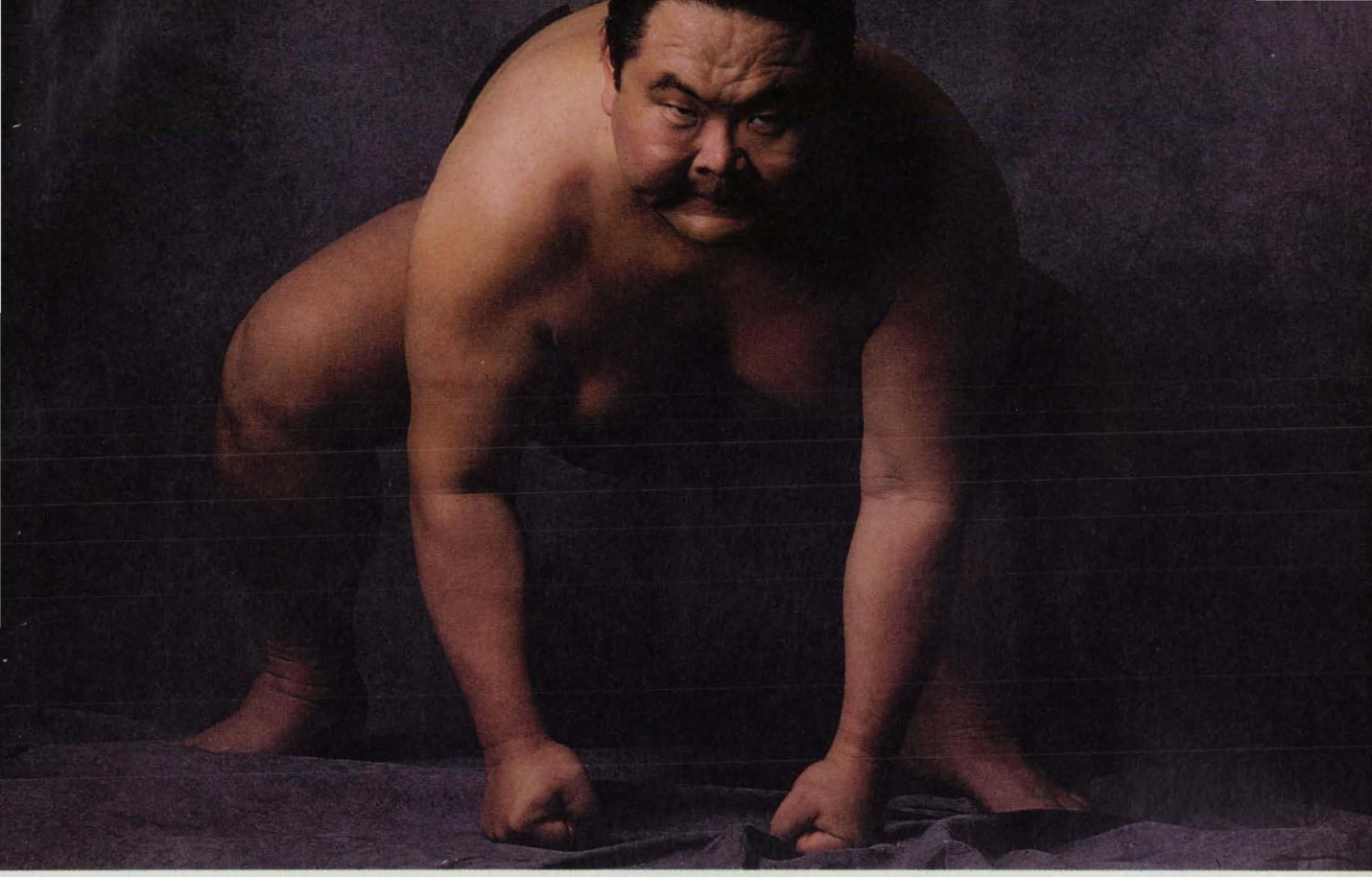
These computer programs, written in the BASIC language, accelerate and facilitate iterative calculations and parametric analyses. They solve the equations of Fanno flow, which is an idealized flow that is assumed to be one-dimensional (along a channel of constant cross section), steady, and adiabatic (the equations can be found in standard fluid-dynamics textbooks). The programs enable the rapid solution of the leakage problem, so that parametric analyses can be performed easily to determine the effects of unknowns. The major limitations and sources of error in these programs lie in the assumption of constant cross section, the need to estimate the surface roughness of the crack in some cases (see figure), the failure (because of the assumption of adiabaticity) to account for the transfer of heat, and the assumption that the leaking gas behaves like a perfect gas.



The **Rate of Flow** computed in an example of leakage from a pressurized supply of liquid oxygen was found to depend on the long dimension of the crack and on its surface roughness.

The first program, which applies to unchoked flow, implements the following iterative procedure to determine the effective rectangular cross section that the crack presents to the flow:

1. A value of the long dimension of the cross section is assumed, and the cross-sectional area is guessed. (From these two numbers, the program computes the width of the crack and the hydraulic diameter.) The user also enters depth of the crack and the measured rate of flow.
2. From the outlet pressure (e.g., ambient atmospheric pressure) and the



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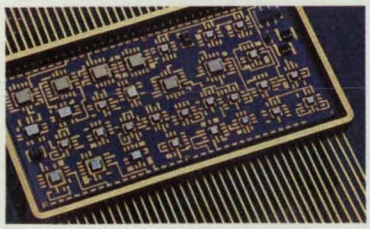

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dimensions of the crack, the outlet conditions (static temperature, density, velocity, speed of sound, and mach number) can be calculated. An iteration loop is needed at this stage of the computation because all of these computed quantities except the mach number are functions of the mach number and of other parameters that are known.

3. From the viscosity at the average temperature, the average Reynolds number is calculated. (Viscosity as a function of temperature is specified as input.) An iteration loop is required because the inlet static temperature to be used for determining the average temperature has not yet been calculated.
4. From the average Reynolds number, a friction factor and the frictional-loss term are calculated.
5. From the frictional loss and the outlet mach number, the inlet mach number is determined. This requires another iteration loop.
6. From the inlet mach number, the program calculates the static temperature, density, and velocity at the inlet.
7. From the static pressure, density, and velocity at the inlet, the program calculates upstream stagnation pressure.
8. This calculated stagnation pressure is compared with the measured stagnation pressure. The guessed cross section in step 1 is adjusted, and steps 2 through 7 are repeated until the calculated stagnation pressure at the inlet agrees with the measured stagnation pressure.

The second program applies to flow that is choked at the outlet. It implements an iterative procedure similar to that of the first program. One of the ways in which the second program differs from the first is that an initial guess is made for the static pressure at the outlet plane of the leak. This pressure must be at least ambient pressure and less than the maximum back pressure for which isentropic choking can occur. The outlet area can then be calculated. Then, using a procedure similar to that for unchoked flow, the inlet flow area is calculated. The outlet pressure is adjusted until the calculated inlet and outlet areas are equal.

This work was done by William D. Romine of Rockwell International Corp. for **Marshall Space Flight Center.** *For further information,* ***write in 50*** *on the TSP Request Card.*
MFS-29913

Algorithm Aligns Gyrocompass in Twisting and Swaying Vehicle

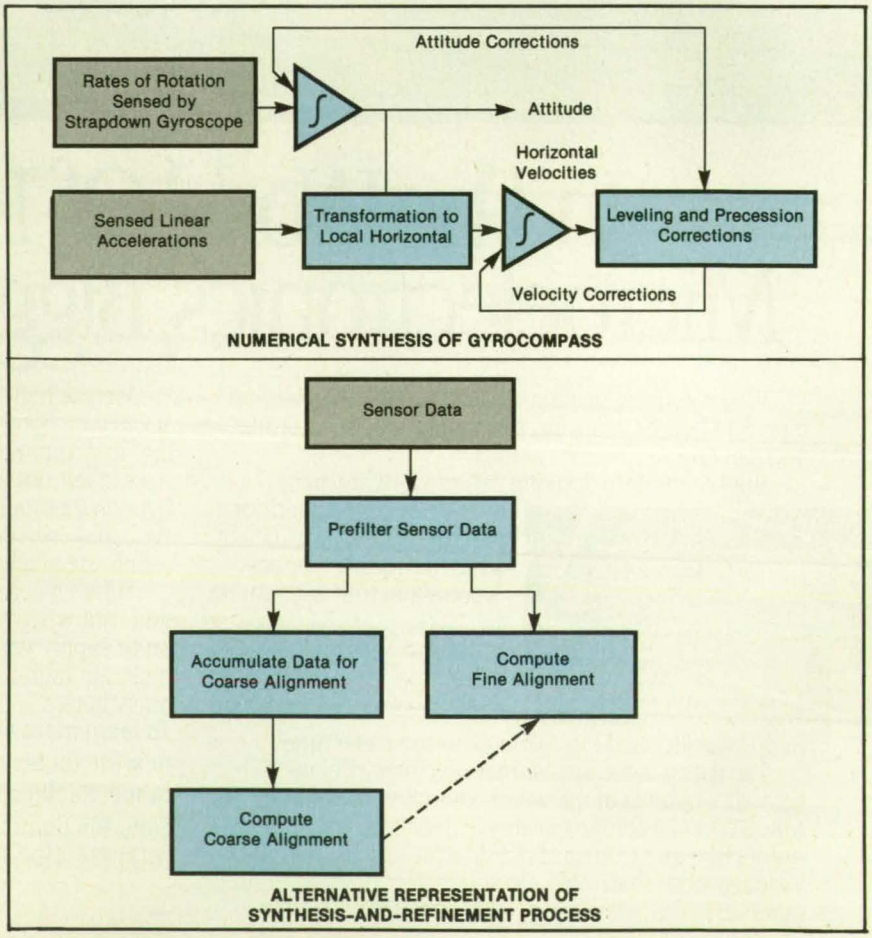
Alignment is refined repeatedly to maximize accuracy until moment of departure.

Marshall Space Flight Center, Alabama

An algorithm proposed for use with strapdown inertial sensors would synthesize a gyrocompass (that is, it would find true north in the local horizontal plane) and repeatedly refine the alignment of the synthetic gyrocompass to maintain accuracy until the time of departure. In the original application for which the algorithm was devised, the inertial sensors would be located in a spacecraft that twists and sways in the wind on the launching pad, and the time of departure would be the time of launch. It might be possible to devise a terrestrial version of the algorithm for use in an aircraft, ground vehicle, or vessel.

The algorithm (see figure) includes local-level-navigator, coarse-alignment, and fine-alignment subalgorithms. The coarse-alignment subalgorithm is the one that initially synthesizes the gyrocompass. The integrations in the algorithm are initialized by solving the analytic gyrocompass problem. This involves the determination of the coarse alignment from the transformation matrix that relates the gravitational and Earth-rotation-rate vectors in the vehicle coordinate frame to the known values of these vectors at the launchsite in a coordinate frame attached to the Earth.

The algorithm can be regarded as implementing a five-state navigation system; the five states represent the three degrees of freedom in attitude and two perpendicular components of horizontal velocity (the vertical velocity



A **Gyrocompass Would Be Synthesized Numerically** from outputs of inertial sensors plus geophysical and geographical data. The alignment of the synthetic gyrocompass would be refined repeatedly to maintain accuracy until shortly before launch.

is assumed to be zero initially). Once the integrations in the algorithm are initialized, the local-level-navigator subalgorithm computes the rates of rotation sensed by the strapdown rate gyroscopes to propagate the five navigation states to track the twisting and swaying motion caused by wind, with emphasis on computing the horizontal components of velocity.

The fine-alignment subalgorithm effects Kalman-filter corrections for each of the five navigation states. The computed horizontal components of velocity are compared with the corresponding measured values, and the results of the comparison are processed into corrections of the synthetic gyrocompass. These corrections are analogous to the application of leveling and precession torques to a spinning-wheel gyrocompass.

In the original spacecraft application, sensor data would be sampled at a rate of 50 Hz. The coarse alignment would be computed repeatedly after accumulating data during periods 30 seconds long. The coarse alignment would initialize the fine alignment, which would then be computed at intervals of 1 second. The process of repeated coarse and fine alignment would be continued until shortly before launch.

This work was done by Narotham S. Reddy and Jonathan Murray of Martin Marietta Corp. for **Marshall Space Flight Center**. *For further information,* ***write in 11*** *on the TSP Request Card.*
MFS-28671

Brush Seal Would Impede Flow of Hot Gas

The brush seal would be more durable, more tolerant of irregularities, and easier to install.

Marshall Space Flight Center, Alabama

A proposed brush seal would help to prevent a recirculating flow of hot combustion gases from reaching a bellows seal located deep in a gap in the wall of a combustion chamber. The barrier is needed because irregularities of surfaces at the gap can give rise to an uneven circumferential distribution of pressure, causing hot gases to flow circumferentially along the bellows seal. This flow can overheat the bellows seal, causing it to crack.

The gap and seal in question lie between a solid portion of the wall and a portion of the wall that consists of coolant tubes in the main engine of the Space Shuttle. However, brush seals like the one proposed here might also be helpful in impeding deleterious flows of hot gases in other combustion chambers — for example, those of furnaces and turbomachines.

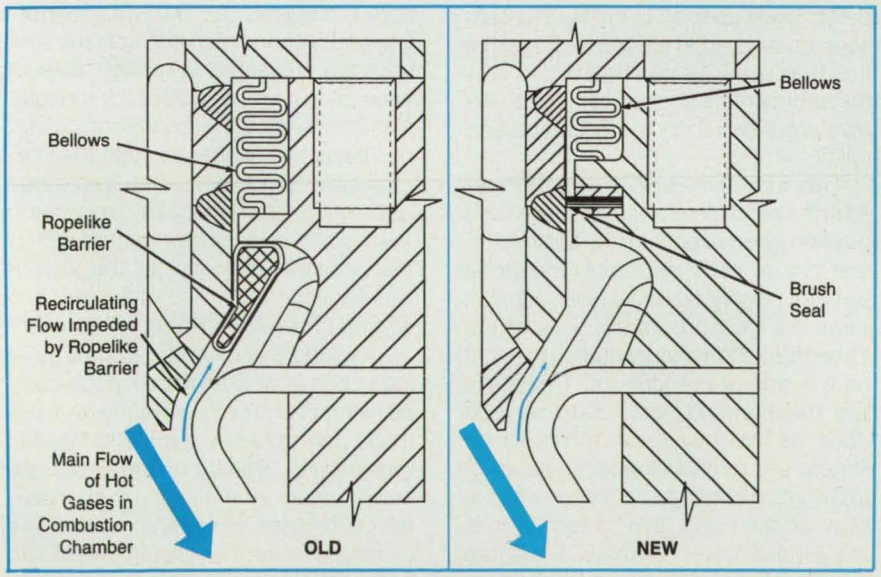
Previously, a ropelike barrier of braided fibrous refractory materials was placed in the gap to protect the bellows seal, as described in "Porous Barrier to Flow of Hot Gas" (MFS-29784), *NASA Tech Briefs*, Vol. 16, No. 6 (June 1992), page 61. The ropelike barrier is difficult to install; it also deteriorates over time, necessitating frequent inspection and replacement. In comparison with the ropelike barrier, the brush seal would be more durable, easier to install, and more tolerant of irregularities.

Heretofore, brush seals have been used primarily in rotating machines, in competition with labyrinth seals. Extensive test data on brush seals are available. The proposed brush seal would protect the bellows by providing high resistance to circumferential flow. Such flow would be redirected along the brush-seal bristles, which would be made of superalloys that withstand the operating temperature of about 1,500 °F (about 800 °C).

The brush seal would be installed at the position now occupied by part of the bellows seal (see figure). The only major disadvantage is that to make room for the brush seal, it would be necessary to reduce the height of the bellows seal, thereby reducing the amount by which the bellows seal could accommodate an increase in the gap. Tests to measure the effectiveness of the brush seal and to determine the effect of shortening of the bellows seal are planned.

This work was done by Paul F. Carroll and Barry P. Easter of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information,* ***write in 58*** *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 24]. Refer to MFS-29944.



The **Brush Seal Would Replace the Ropelike Barrier** in the new version. The bellows would be shortened to make room for the brush seal.

Compact Telerobot Hand

This electromechanical apparatus features relatively high strength and dexterity.

Marshall Space Flight Center, Alabama

A hand for a telerobot imitates motions of the human fingers and wrist in a lifelike and dexterous way. The hand incorporates recently developed pitch/yaw joints in the wrist and the head knuckles. Miniature linear actuators (MINNAC's) provide a high (with respect to power-to-weight ratio) load capacity. The hand is modular; for example, fingers are removable, interchangeable units. This feature simplifies servicing and maintenance, which must be done frequently in such a complex mechanism.

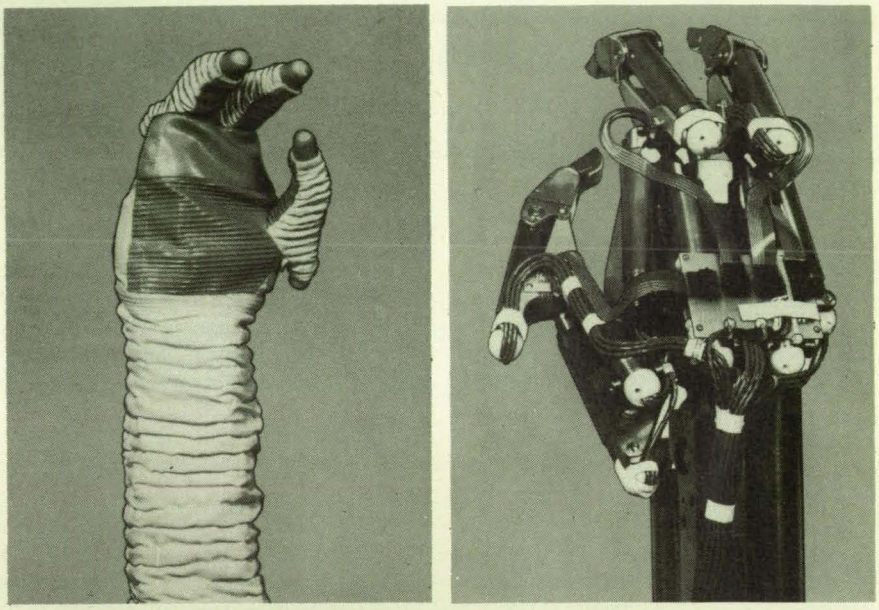
The wrist has a diameter of 4 in. (10.2-cm) and handles dynamic loads greater than 25 lb (111 N) (11.4 kilograms) with 90° pitch and yaw motion. Each of the three 1-in. (2.5-cm)-diameter fingers can sustain a load of 5 lb (22 N), with 90° of motion, and yaw motion limited like that of the human hand. The bandwidth of the associated electronic control circuitry is 4 to 5 MHz, and that of the motor is about 2 kHz.

Each finger is driven by a MINNAC via gears that cause motion of the outermost joint to be the same as that of the innermost joint. This action is similar to the prehensile effect in human finger.

The wrist ball-and-socket joint, knuckle ball-and-socket joints, MINNAC threads, sector gears, and sector-gear pivots are coated with a dry lubricant. Self-lubricating plastics like Delrin AF (or equivalent) are used in the MINNAC screws to reduce friction.

Special gear-manufacturing techniques were employed to increase the efficiency and smoothness of operation of the joints. Instead of conventional hobbling and shaping, wire electrical-discharge machining under computer numerical control was used to obtain a particularly smoothly running gear mesh.

Each MINNAC contains a custom-designed dc motor with integral encoder and gear head. Its output shaft is connected to a split screw that is preloaded to eliminated backlash. Double bearings on the motor housing support the screw; they make the MINNAC rugged and isolate it from shock loads. A 75:1 gear box boosts torque, and multistart threads on the screw help to increase speed. A finger MINNAC can exert 13 lb (58 N) of lift and travel 1 in. (2.5 cm) in about 2 seconds.



GLOVED HAND BARE HAND

The **Anthropomorphic Telerobotic Hand** contains actuators, joints, sensors, and complex wiring harnesses. A glove protects the interior components of the hand from dirt and damage.

The hand is instrumented with arrays of tactile sensors. Printed on highly flexible plastic, the sensors are integrated with their wire leads. Each sensor can detect loads up to 15 lb (67 N). The sensors are arrayed in a 5 × 5 matrices so that their readings can be used to infer the approximate shapes of objects. Arrays are located on the fingertips and palm.

Two wire harnesses are incorporated in the band: one to carry power to and position information from the MINNAC's, and one to carry data from the tactile sensors. Highly flexible power/position wires are routed from the base of the forearm to the wrist through an eyelet on the side of the forearm. The eyelet lets the bundled wires slide up and down as the wrist flexes. Wires to the fingers are routed alongside the wrist to minimize bending; as they rise to the back of the palm, they spread out to the various lower MINNAC's and are attached to them by miniature connectors. The upper motor cables are guided by an eyelet in the palm, between two fingers. Small clips hold the wires to the sides of the finger knuckles; this prevents entanglement and abrasion and minimizes stretching by holding the wires at the pivot points of the knuckles.

The wire harness for the tactile sensors is designed for quick disconnection and reconnection because the sensors are subjected to a high level of wear and must be replaced frequently. A cable, tied to the bundle of power/position wires passes through the forearm eyelet to the wrist then to a circuit board on the back of palm. The wires in the bundle lead to four connectors or the circuit board: one for the thumb, one for each of two other fingers, and one for the palm sensors.

The hand is sheathed in a fabric glove made of a polytetrafluoroethylene-coated blend of aromatic polyamid and aromatic polyamide — a material used in space suits. Panels of the fabric are sewn to an inner layer of spandex, which creates convolutions that are all flexing while maintaining a neat and compact exterior. Flaps give access to internal components. The glove protects

the electrical and mechanical components of the hand from debris, collisions, and other environmental hazards.

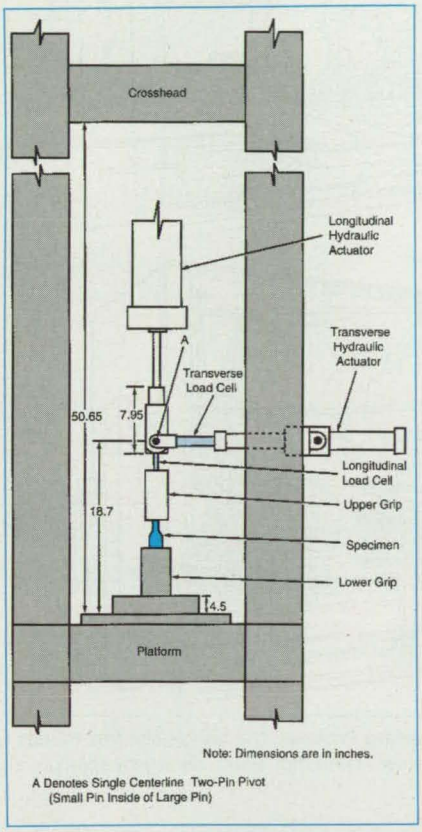
This work was done by Mark Rosheim of Ross-Hime Designs Inc. and Hans Trechsel of Automation Engineering Inc. for **Marshall Space Flight Center**. *For further information,* ***write in 66*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 24]. Refer to MFS-26213.

Testing Machine Exerts Longitudinal and Transverse Loads

Specimens can be tested in tension and bending simultaneously.

Langley Research Center, Hampton, Virgina



The **Load Frame Includes Pivots**, which isolates the longitudinal load from the transverse load. The longitudinal and transverse loads can be applied separately or in combination.

A hydraulic load frame for testing materials applies both longitudinal uniaxial tension and a transverse bending force simultaneously. This testing machine (see figure) includes axial and transverse hydraulic actuators that are mounted on pivots to eliminate coupling effects between the two loading modes.

The bottom end of a test specimen is held in a lower grip, which is fixed. The top end of the specimen is held in an upper grip, which includes a longitudinal load cell. The grip/load cell combination, the longitudinal hydraulic actuator, and the transverse load cell are all connected via a single centerline two-pin pivot (small transverse pin inside of a longitudinal pin). The transverse load cell is located between the transverse pin and the transverse actuator. Both hydraulic cylinders are connected to the frame via pivots. This design makes it possible to apply the longitudinal load to the specimen simultaneously with, and independently of, the transverse load.

The longitudinal and transverse motions can be either stroke-controlled (by use of position feedback from linear variable-differential transformers in the actuators) or load-controlled (by use of force feedback from the load cells). For example, a constant longitudinal tension load can be maintained by use of axial load control, while a cyclic transverse bending load is applied by use of transverse stroke control. The longitudinal actuator can pivot and stroke as needed while maintaining the constant longitudinal load.

This work was done by Mickey R. Gardner and R. Scott Young of **Langley Research Center** *and T. Kevin O'Brien of the U.S. Army Vehicle Structures Directorate. No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Langley Research Center [see page 24]. Refer to LAR-14848.

Machine Cleans and Degreases Without Toxic Solvents

This industrial appliance uses hot water and biodegradable chemicals to degrease and clean hardware.

Marshall Space Flight Center, Alabama

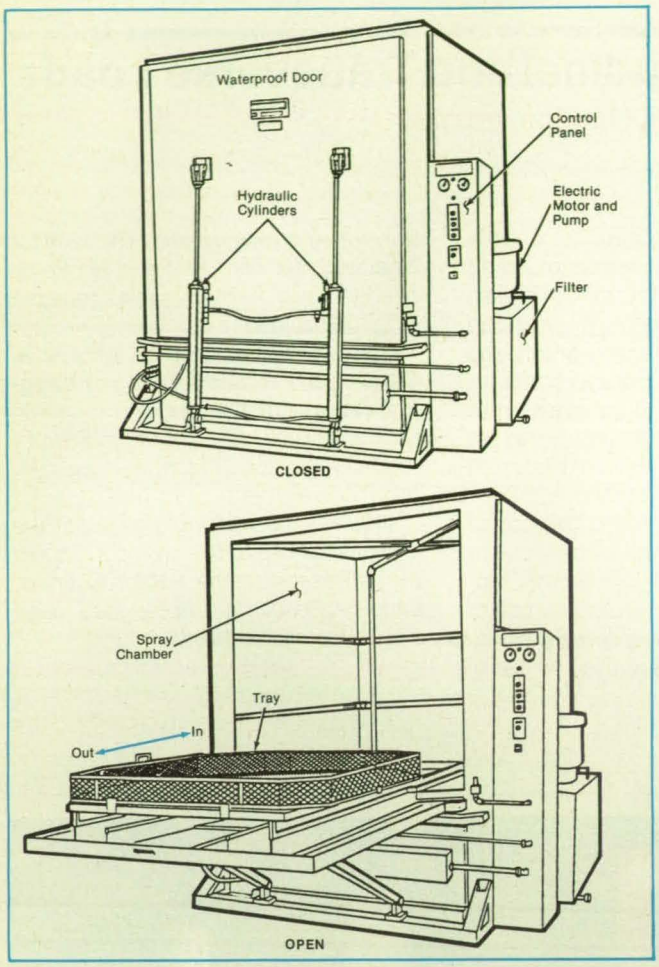


Figure 1. The **Spray Chamber** is essentially industrial-scale dishwasher. The front door tilts open, and the hardware to be cleaned is placed on the basket-like tray.

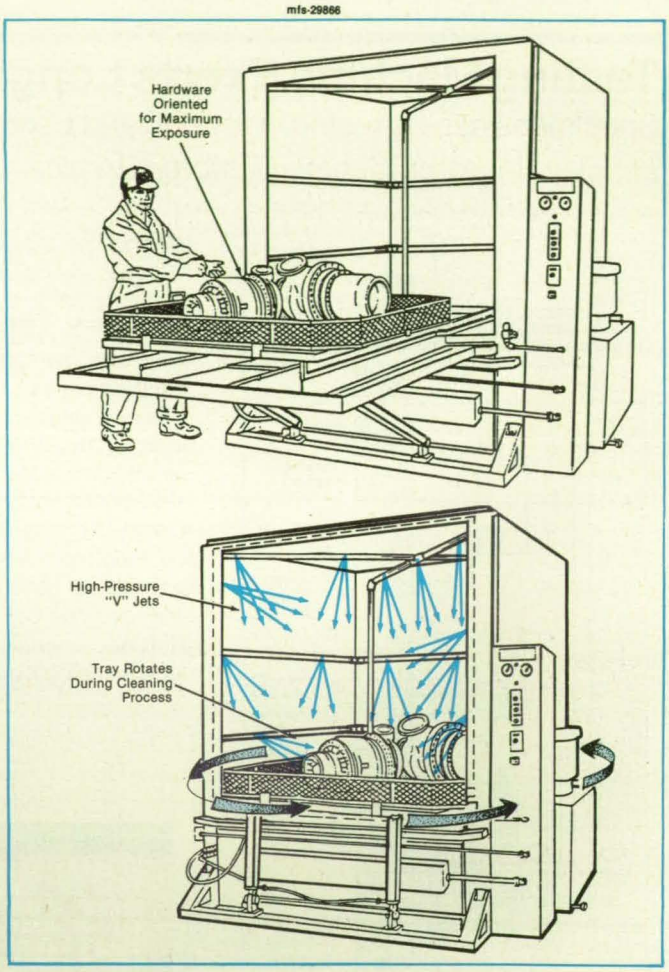


Figure 2. **During the Cleaning Process**, the basket-like tray rotates as high-pressure "V" jets deliver steam, hot water, detergent solution, and rust inhibitor as required.

An industrial-scale dishwasherlike spray chamber (see Figures 1 and 2) uses steam, hot water, and biodegradable chemicals to degrease and clean hardware that would otherwise have to be cleaned by use of toxic, volatile solvents that could be hazardous to those doing the cleaning and, when discarded, to other people and the environment.

As shown in the figures, the chamber includes a hydraulically actuated waterproof door that tilts open like the door of a dishwasher. The hardware to be cleaned is loaded on a basketlike tray and oriented for maximum exposure. The tray slides into the spray chamber before or as the front door is closed. In the washing process, the basket, rotates as high-pressure "V" jets deliver steam, hot water, detergent solution, and rust inhibitor as required. A control panel on the right side of the chamber controls the wash and rinse cycles, and the pressures, temperatures, and rates of flow of the sprays.

This work was done by Kamal S. Gurguis and Gregory A. Higginson of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*

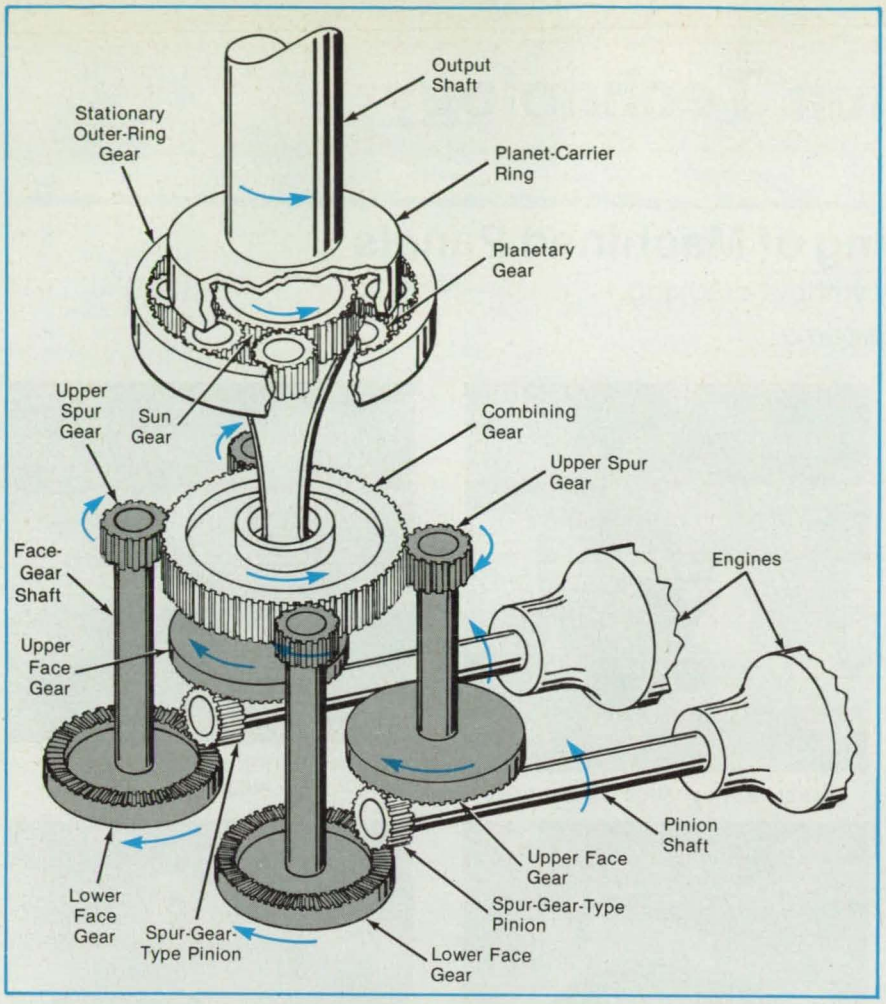
Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 24]. Refer to MFS-29866.

Lighter, More-Efficient Helicopter Transmissions

Redundant gearing transmits torque through an angle or angles.

Lewis Research Center, Cleveland, Ohio

An improved gear system intended primarily for use in a helicopter transmits torque from the horizontal or nearly horizontal shafts of two engines to the vertical output shaft that supports the rotor. The system apportions torques equally along multiple, redundant drive paths, thereby reducing the stresses on individual gear teeth, and it enables one engine to continue to turn the rotor when the other engine fails. The underlying design concept could also be applied to couple two airplane engines to a set of propellers in such a way that both propellers turn as long as at least one engine operates.



Torque From Each Engine is split and transmitted to the combining gear along two redundant paths. Should one engine fail, the other engine could still turn the output shaft.

The system exploits the special advantages of the geometry of the meshing of a spur-gear-type pinion with a face gear. In comparison with other gear geometries that have been used in helicopter transmissions, this one is much more forgiving of (1) errors in manufacturing and alignment and (2) thermal and vibrational changes in the sizes and positions of the meshing components. One of the benefits is a reduction of gear-tooth-contact noise and vibration. Another benefit is the possibility of achieving a high (> 4) speed-reduction ratio in a single, efficient mesh, and the consequent possibility of reducing the number of parts, the size, the cost, and the weight of the gear system. Of course, the reduction of the number of parts confers yet another benefit by increasing the reliability of the system.

The system is shown schematically in the figure. The output of each engine is coupled by a pinion shaft to a spur-gear-type pinion. Each pinion engages an upper and a lower face gear, and each face gear is coupled by a face-gear shaft to an upper spur gear. The upper spur gears feed torque into a large combining gear. The pinion end of each pinion shaft is lightly spring-loaded in a nominal lateral position and is free to shift laterally through a small distance to take up slack, compensate for misalignments, and apportion torques equally to the two face gears with which it is engaged.

The combining gear is splined to a shaft that flares outwardly to a sun gear. The sun gear operates in conjunction with planetary gears and a stationary outer ring gear. The torque is coupled from the sun gear through the planetary gears to the planet-carrier ring, which is mounted on the output shaft.

This work was done by Robert B. Bossler, Jr., of Lucas Western, Inc., for **Lewis Research Center**. *For further information,* ***write in 60*** *on the TSP Request Card.* *LEW-15158*

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Restraint Age Forming of Machined Panels

Panels can be bent permanently without cracking.

Marshall Space Flight Center, Alabama

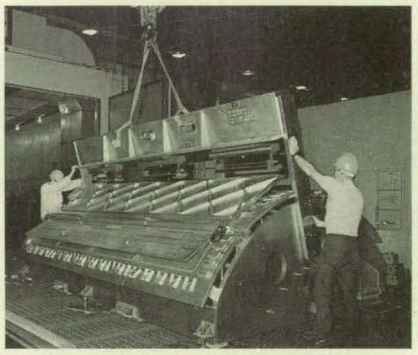
Complexly shaped, machined panels can be bent permanently into cylindrical or other desired shapes by restraint age forming. Panels that cannot be processed into desired shapes readily and reliably by other techniques can be processed by restraint age forming, which imparts a high degree of dimensional accuracy to the panels while imposing stresses that are very low in comparison with those of other forming processes like press-brake forming.

A panel to be formed could be, for example, a flat plate of precipitation-hardenable aluminum alloy that has been machined into a thinner plate with integral stiffening ribs in a waffle pattern. In restraint age forming, the panel is wrapped onto a mandrel that has the necessary curved contour, restrained on the mandrel clamps and vacuum, and heat treated. When the panel is released after the end of the heat treatment, the panel retains the contour of the mandrel except for a small springback. The process is repeatable: panels subsequently processed under the same mechanical and thermal conditions on the same contour emerge with the same final contour.

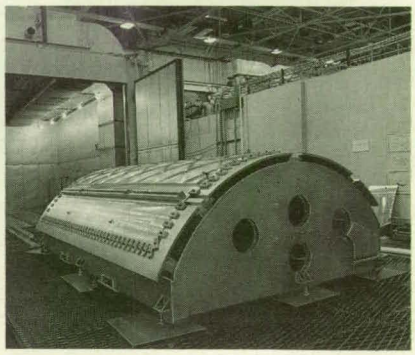
Restraint age forming has been used to form machined panels 13 ft (3.9 m) long, 8 ft wide, to a radius of curvature of 83 in. (2.1 m). Each panel includes skin sections with thicknesses of 0.190 in. (4.8 mm) and 0.125 in. (3.2 mm), waffle-pattern ridges about 0.81 in. (21 mm) high, and one or two longerons 4 in. (10.2 cm) high. Each panel was clamped to the aging mandrel tool with tooling pins (see figure). Vacuum was applied to the underside of the panel through the mandrel, and the mandrel and panel were heated in an oven for 18 hours at 350 °F (177 °C). When aging was complete, and the panel had cooled to room temperature, the vacuum was released and the clamps were removed. Measurements showed that the panels thus formed had nearly the required contour, and they could be pulled easily to the required contour by hand pressure.

PANEL BEING LOADED ON MANDREL

CONTINUATION OF POSITIONING OF PUSHER BAR



PANEL SECURED WITH TOOLING PINS: PUSHER BAR BEING POSITIONED



PANEL CLAMPED ONTO MANDREL READY FOR HEAT TREATMENT

A Flat Panel With Waffle Pattern is loaded on the restraint-age-forming mandrel. The panel is partially secured to the mandrel with pins. A bar pusher is used initially to bend the panel to the contour of the mandrel. The clamping of the panel is then completed with more pins, clamping vacuum is applied, and heat treatment is performed.

This work was done by Rebecca Wood of The Boeing Co. for **Marshall Space Flight Center**. *For further information,* ***write in 15*** *on the TSP Request Card.*

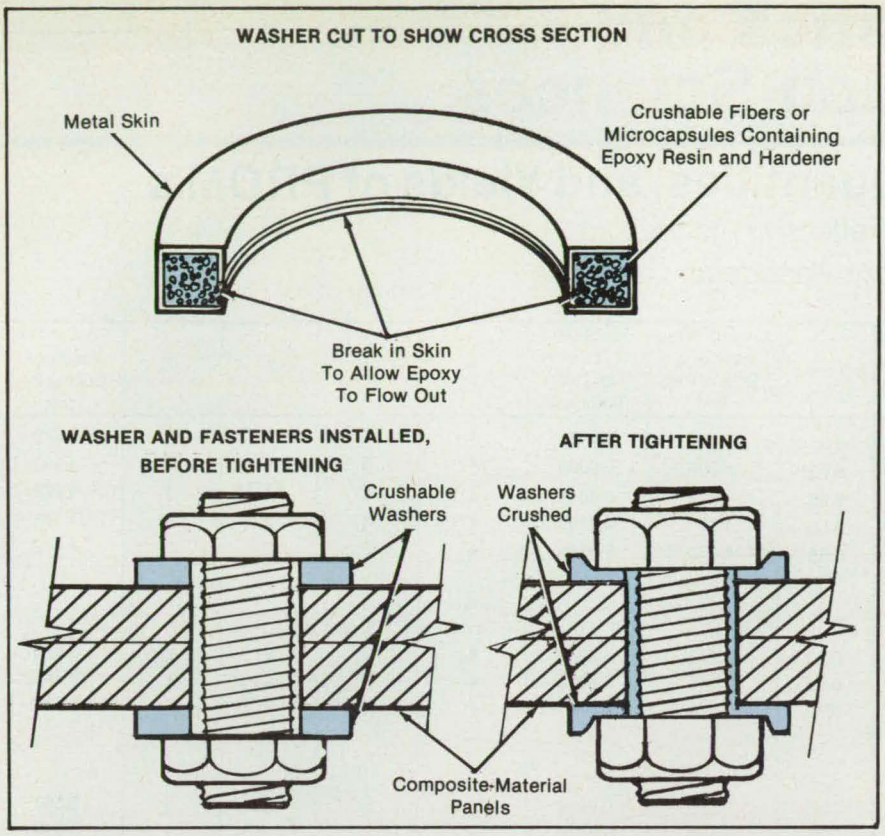
Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 24]. Refer to MFS-28703.

Crushable Washers for Bolting Composite Panels

The washers would yield to prevent overloads.

Marshall Space Flight Center, Alabama

Crushable washers have been proposed for use in protecting composite-material (matrix/fiber) panels against overloads applied by nut-and-bolt fasteners. The crushable washers are intended principally for use at drilled holes, where the strengths



The **Washer Would Be Crushable** at a predetermined compression. Microcapsules in one version of the washer would be broken during crushing, releasing their contents.

of composite panels are reduced by exposure of the ends of fibers.

A crushable washer could consist, for example, of a metal skin filled with microcapsules of epoxy resin and hardener. Alternatively, it could be filled with fibers that collapse under a given load (see figure). It would be placed in the customary manner at a fastener site. When the fasteners were tightened, the washer would be crushed, thereby absorbing any overload on the bolted composite panels. The crushing action would simultaneously fracture the microcapsules (if used), releasing the components of epoxy. These components would mix and fill the bolthole and fiber-reinforcement interstices. The epoxy would then harden, locking the fasteners in place.

This work was done by Alfred F. Daech of Martin Marietta Corp. for **Marshall Space Flight Center**. *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 24]. Refer to MFS-28597

Computing Costs, Quantities, and Yields of PROM's

Buying can be planned in a cost-effective manner.

NASA's Jet Propulsion Laboratory, Pasadena, California

A procedure and computer program have been devised for use in cost-effective estimation of the quantities of programmable read-only memories (PROM's) to be bought for use in subsequent iterative attempts to program them as part of a development project. More specifically, the procedure and computer program are designed to help answer the following question: Assuming that project timings allow for two or three programming iterations in arriving at each end-product PROM, how many PROM's should be started into each phase of development to achieve, most economically, an acceptably high probability of success (an acceptably high number of PROM's programmed successfully) in each state? The program reflects elements of contract pricing structure, historical unit production yields and costs, and probability theory. The program is based on the following equation for the probability $P(s,y,x,n)$ that when n devices are started into each programming sequence and the individual-device yield rate is y, a single iteration will yield x devices in each of s states:

$$P(s,y,x,n) = \left[1 - \sum_{k=0}^{x-1} C_k^n y^k (1-y)^{n-k}\right]^s$$

where

$$C_k^n = \frac{n!}{k!(n-k)!}$$

The procedure is as follows:

1. Calculate a large set of P's (for $s = 1$) and record them in the computer memory.
2. Weigh and combine the relevant P values to calculate the probability of success associated with multiple (usually, two) iterations of any given strategy $(m,a,b,c...)$ (where m is the number of devices started into the first iteration, a is the number of devices started into a second-iteration path that is required to produce three devices, b is the number of devices to be put into a second-iteration path that is required to produce two devices, and c is the number of devices to be put into a second-iteration path that is required to produce one device).
3. Including both part prices and lot charges, calculate the costs of two- and three-iteration strategies.
4. Order the computer to generate an ordered list of the calculated costs and the associated probabilities or frequencies of success (see figure). From this list, one would most likely want to choose the strategy that involves a combination of acceptably low cost and acceptably high probability of success.
5. From the $(m,a,b,c...)$ of the chosen strategy, compute the total number of devices to be ordered.

y	Cost of Three Iterations, Dollars Per Unit	Probability of Success of Two Iterations	m	a	b	c	Cost of Two Iterations, Dollars Per Unit
0.65	4,364	0.9658	4	4	4	3	4,279
0.65	4,365	0.9688	4	5	4	3	4,287
0.65	4,368	0.9615	4	3	4	3	4,272
0.65	4,375	0.9155	4	4	2	3	4,164
0.65	4,375	0.9185	4	5	2	3	4,172
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
0.70	3,978	0.9346	4	4	2	2	3,815
0.70	3,978	0.9113	4	4	4	1	3,757
0.70	3,978	0.9361	4	5	2	2	3,819
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
0.85	3,583	0.9939	3	3	3	3	3,568
0.85	3,583	0.9825	3	4	2	3	3,540
0.85	3,583	0.9951	3	5	3	3	3,571
0.85	3,585	0.9815	3	3	2	3	3,539
0.85	3,585	0.9827	3	5	2	3	3,542

This List Is Part of the Computer Printout obtained in a test case. Only a few of many variations are shown here. All values are computed for $s = 1$.

This work was done by Charles L. Bromberick and Stephen L. Sawyer of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 101*** *on the TSP Request Card.*
NPO-18555

Segmentation of Multifrequency, Multilook SAR Data

Two statistical models are incorporated into the segmentation scheme.

NASA's Jet Propulsion Laboratory, Pasadena, California

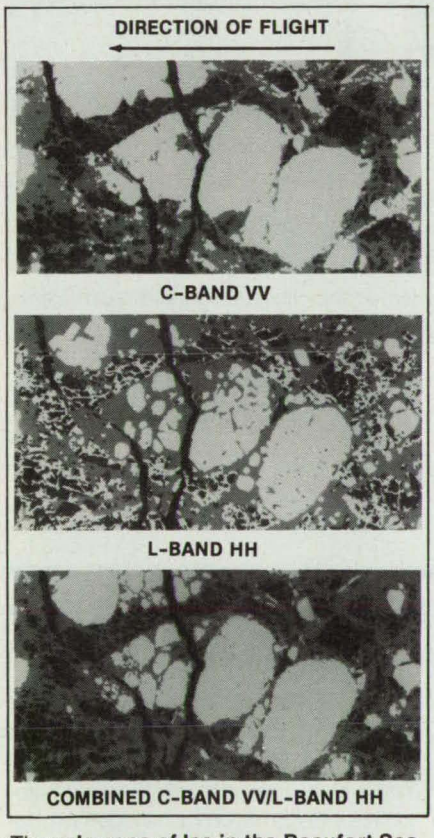
The segmentation of multifrequency, multilook synthetic-aperture radar (SAR) image intensity data into regions, within each of which the backscattering characteristics of the target scene are considered to be homogeneous, is enhanced by use of two statistical models. One of the models represents the statistics of the multifrequency, multilook speckled intensities of the SAR picture elements; the other represents the statistics of the labels applied to the regions into which the picture elements are grouped. Typically, each region represents a different type of terrain, terrain cover, or other surface; e.g., forest, agricultural land, sea ice, or water (see figure).

The development of the mathematical model of the statistics of multifrequency, multilook speckled intensities begins with the observation that as long as the widths

of the picture elements are about half the spatial resolution of the SAR equipment, that component of spatial correlation between the intensities at two points separated by two or more picture elements that is attributable to speckle is negligibly small. This observation justifies the representation of the joint probability distribution for the N-look-averaged, multifrequency intensities of M picture elements grouped together into a region as a product of probability distributions of intensities in the individual picture elements. Gamma distributions are used because they appear to be adequate approximations and the exact distributions are still to be determined. In this model, each region, l is characterized by two parameters for each frequency, f: an intensity, I_{lf}, which represents its radar brightness at that frequency; and its equivalent number of looks, N_{lf}, which represents the degree of variability of its brightness at that frequency.

The segmentation of the image into regions of neighboring picture elements is accomplished by a method similar to that described in "Algorithms for Segmentation of Complex-Amplitude SAR Data" (NPO-18524), *NASA Tech Briefs*, Vol. 17, No. 6 (1993), page 28. First, the scene is segmented tentatively, using the mathematical model described above, in a maximum-likelihood or other scheme in which the a priori probabilities of the regions are assumed to be equal and the region labels of neighboring picture elements are assumed to be independent. Thereafter, the region labels are assumed to be distributed across the scene according to a Markov random-field model, in which the probabilities of the region labels of neighboring picture elements affect each other. Then using Bayes' rule, the region labels are adjusted iteratively to obtain a maximum a posteriori probability distribution of the region labels. An excessive amount of computation would be needed to obtain the segmentation that yields the exact maximum a posteriori distribution. Therefore, the labels are adjusted according to the Iterative Conditional Mode algorithm, which yields a suboptimal result.

This work was done by Eric J. Rignot, Ronald Kwok, and Rama Chellappa of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 96*** *on the TSP Request Card.*
NPO-18592



These **Images of Ice in the Beaufort Sea** were generated from data acquired in simultaneous SAR scans at C-band in vertical transmitted/vertical received (VV) polarization and at L-band horizontal transmitted/horizontal received (HH) polarization. These images are four-region segmentation maps generated according to the method described in the text. The four regions represent, respectively, multiyear ice (white), rough first-year ice (light gray), smooth first-year ice (dark gray), and open water or frazil ice (dark).

Clinostat Delivers Power to Plant-Growth Cabinets

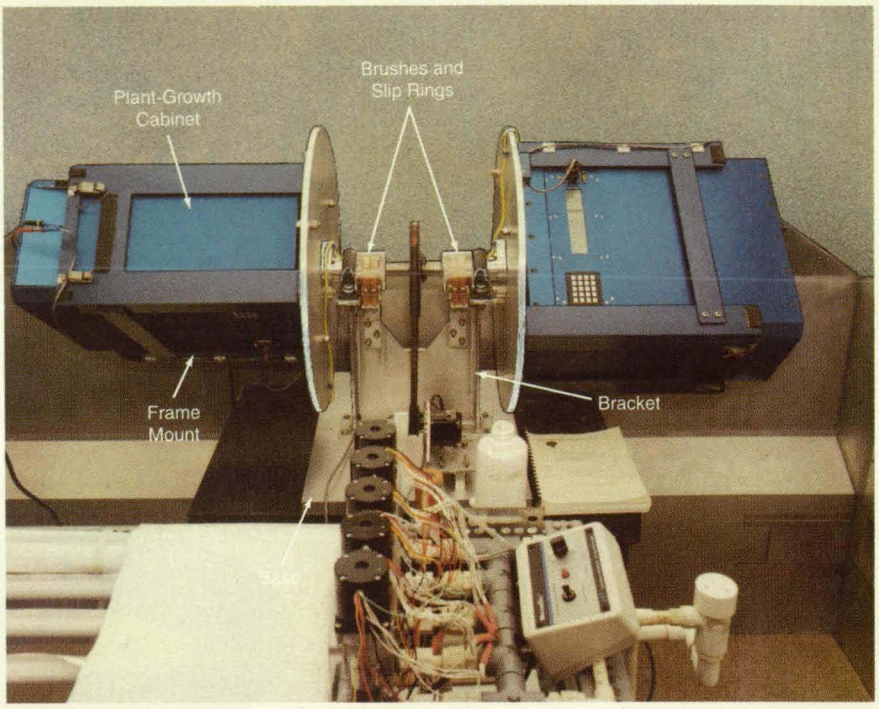
Rotation about a horizontal axis produces some of the effects of microgravity.

John F. Kennedy Space Center, Florida

A clinostat rotates a coaxial pair of plant-growth cabinets about a horizontal axis while supplying the cabinets with electric power for their built-in computers, lamps, fans, and auxiliary equipment, such as nutrient pumps. Each cabinet is a self-contained unit for growing plants in a controlled environment. By rotating the cabinets and their contents about a horizontal axis, scientists hope to simulate and study some of the effects of microgravitaty on the growth of plants.

The clinostat includes a vertical aluminum mounting bracket on a horizontal aluminum base. Bearings on the bracket hold a shaft with a V-belt pulley (see figure). At each end of the shaft, a circular plate holds a frame mount for a cabinet. Stationary brushes on the mounting bracket and sliprings on the shaft transfer 24-volt dc power for the cabinets. On the base, a variable speed dc motor with a V-belt pulley turns the shaft at about 1 revolution per minute (about 0.26 times the speed of the motor).

The cabinets, which weigh about 35 kg each, are secured in the frame mounts on the circular plates by use of clamps and bolted bars. Panels of the cabinets can be left off to facilitate access to the plant-growth chambers inside. Cables carry the 24-volt power from the commutators to the cabinets. The mounting plates can also be used to hold transparent sealed growth chambers described in the accompanying article, "Sealed Plant-Growth Chamber for Clinostat" (KSC-11538).



A **Pair of Plant-Growth Cabinets** are mounted on the clinostat. Sets of brush/slipring commutators deliver power to the rotating cabinets.

This work was done by Wilton E. Bushong and Ronald C. Fox of **Kennedy Space Center** *and Christopher S. Brown, Ronald R. Biro, and Thomas W. Dreshel of The Bionetics Corp. For further information,* ***write in 42*** *on the TSP Request Card.*

KSC-11537

Fluorescent-Antibody Measurement of Cancer-Cell Urokinase

Quantitation of urokinase levels may reveal the metastatic potentials of tumors.

Lyndon B. Johnson Space Center, Houston, Texas

A combination of laboratory techniques provides measurements of the amounts of urokinase in and between normal and cancer cells. The techniques include the use of fluorescent antibodies specific against different forms of urokinase-type plasminogen activator (uPA), fluorescence microscopy, quantitative analysis of images of sections of tumor tissue, and flow cytometry of different uPA's and deoxyribonucleic acid (DNA) found in suspended-tumor-cell preparations. These measurements may provide a statistical method for indicating or predicting the metastatic potentials of some invasive tumors. The need for such measurements arose from observations that cultured cells from several types of primary tumors produce abnormally high levels of uPA, whereas cells from metastases often produce subnormal levels. Assessments of metastatic potentials based on such measurements could be used, for example, in determining appropriate follow-up procedures after surgical removal of tumors.

The following molecular forms of urokinase are susceptible to analysis by use of specific fluorescent antibodies: a single-chain protein called "ScuPA," which is the inactive, proenzyme form; S2, the active high-molecular-weight form of urokinase that converts plasminogen to plasmin and hence is called a plasminogen-activator enzyme; and S1, the active low-molecular-weight form. Fluorescence microscopy and digital analysis of images of the fluorescence micrographs are used to measure the fluorescence from labeled uPA antibodies (of each of the three types) in cells. Fluorescence outside the cells is a measure of the uPA's secreted by the cells into the extracellular spaces. Only those cells that are actively invading or metastasizing con-

tain high levels of the uPA's or secrete large amounts of scuPA or active uPA. The fluorescence filters used in the digital imaging are selected to match the wavelengths measured in the flow-cytometric analyses precisely.

The same fluorescent antibodies are used in the laser-activated flow cytometer to measure the uPA content per cell of a large sample population from a biopsy specimen. By use of two-color fluorescence and anti-bromo-deoxyuridine (BDUr) or anti-iodo-deoxyurine (IDUr) antibodies, one can simultaneously measure the DNA contents of the cells. From timed studies, the rates of synthesis of uPA and DNA synthesis can be determined for statistically significant populations of normal and tumor cells. Also the time-phased relationship between abnormal synthesis of uPA and DNA can be determined by use of multivariate statistical analyses.

The data from these analyses can then be used in retrospective studies to establish a data base and statistical method for correlation of the production of uPA per cell with the occurrence or recurrence of metastatic tumors. Once this data base is sufficient, the data from the combined analyses can be used to predict the metastatic potential of those tumor cells that secrete abnormal amounts of uPA's.

This work was done by Dennis R. Morrison of **Johnson Space Center**. *For further information,* ***write in 28*** *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 24]. Refer to MSC-21715.

Sealed Plant-Growth Chamber for Clinostat

Products of photosynthesis and respiration can be measured conveniently.

John F. Kennedy Space Center, Florida

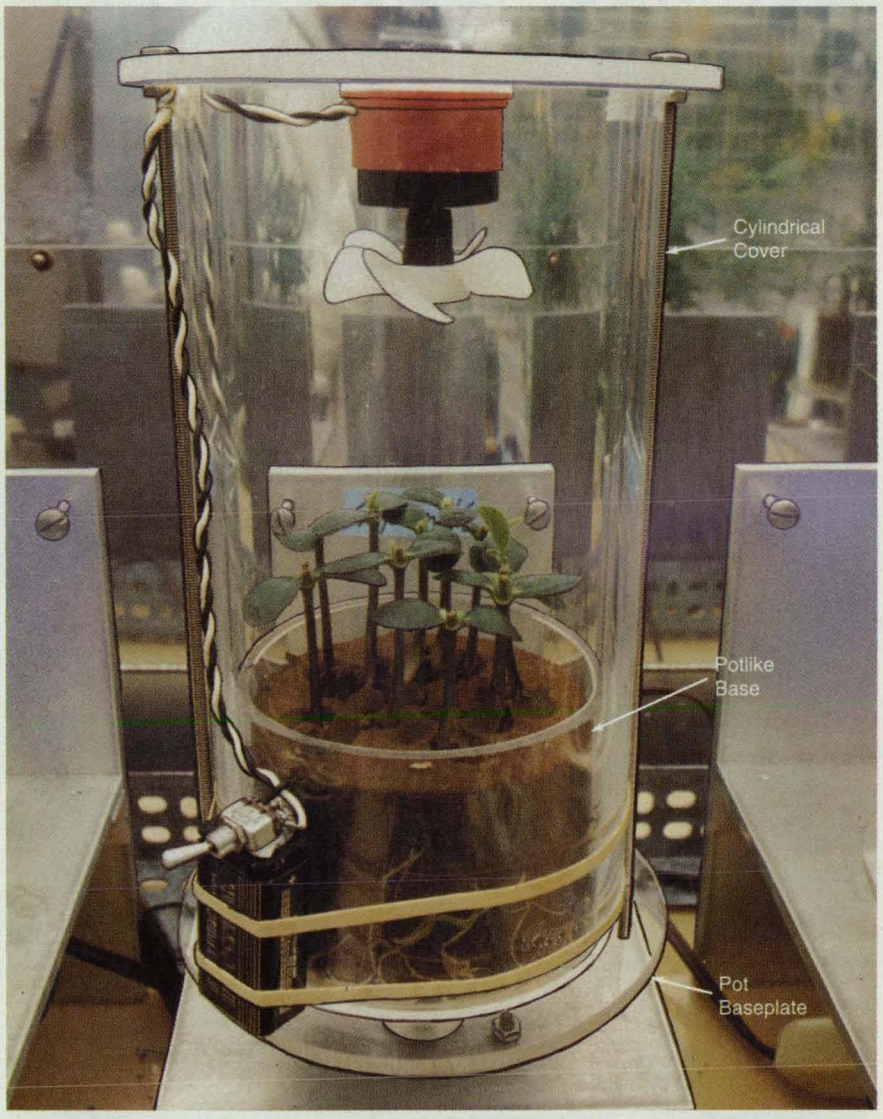
A laboratory chamber for growing plants is used to measure photosynthesis and respiration in simulated microgravity. The chamber holds plant specimens while they are rotated on a clinostat [see the accompanying article, "Clinostat Delivers Power to Plant-Growth Cabinets" (KSC-11537)]. The chamber provides a way of comparing gas-exchange rates of plants rotated horizontally on a clinostat with those of stationary or vertically rotated plants. (Continuous rotation around a horizontal axis produces some of the same effects on plants as does microgravity.) Gas can be extracted for analysis without stopping the clinostat.

The chamber includes a potlike base and a cylindrical cover, both made of transparent acrylic pipe (see figure). A gasket forms a seal between the cover and bottom plate of the base. The cover is bolted to the pot baseplate, which in turn is bolted to the clinostat.

A small fan in the cylindrical cover circulates air inside the chamber. A 9-volt external battery, strapped to the cover, supplies power to the fan; the battery leads are sealed in holes through the cover. A hole with a septum for sampling gas extends through the top of the cover.

Seeds are planted in a growth medium in the pot and allowed to germinate and develop uncovered while rotated on the clinostat. When the plant is in full leaf, the cover is installed and sealed onto the pot baseplate, and the fan is turned on. A series of gas samples is removed by use of a 1-mL gas-tight syringe during a measurement interval of 15 min. The cover is then removed and can be applied to another pot. It is not necessary to stop the clinostat to install or remove the cover or to take the gas samples.

The samples are injected into a gas chromatograph to measure the change in concentration of carbon dioxide with time. The increase or decrease in the concentration of carbon dioxide in the dark or in the light is a measure of the respiration or photosynthesis, respectively.



The Plant in the Sealed Chamber Can Be Illuminated through the transparent cover. The small fan distributes gases uniformly for accurate measurements of composition.

This work was done by Christopher S. Brown and Thomas W. Dreschel of The Bionetics Corp. for **Kennedy Space Center**. *For further information,* ***write in 18*** *on the TSP Request Card.*

KSC-11538

Books & Reports

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

Physical Sciences

Measurement of Thermal Conductivity of Molten LiF

A report discusses an experimental study of the thermal conductivity of molten lithium fluoride. The study was motivated by the consideration of this material for use as an energy-storage medium in solar power systems and by the fact that very little information on the thermal conductivity of molten lithium fluoride was available.

This work was done by Donald A. Jaworske of **Lewis Research Center** *and W. D. Perry of Auburn University. Further information may be found in NASA TM-102506 [N90-19373], "Hot Filament Technique for Measuring the Thermal Conductivity of Molten Lithium Fluoride."*

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-15182

Ballistic-Charge-Carrier Spectroscopy of $CoSi_2$/Si Interfaces

A report discusses experiments in which ballistic-electron-emission microscopy (BEEM) and related ballistic-hole and charge-carrier-scattering spectroscopies were used to investigate the transport of electric-charge carriers (electrons and holes) in the epitaxial $CoSi_2$/Si system. BEEM and the related spectroscopies are variants of scanning tunneling microscopy; the use of these techniques to characterize surface and near-surface layers of solid-state devices has been described in previous articles in *NASA Tech Briefs*.

Experiments like those described in the report are important because the $CoSi_2$/Si system is regarded, in the solid-state-physics and electronic-device communities, as a paradigm of metal/semiconductor systems. $CoSi_2$/Si structures are candidates for incorporation into metal-base and permeable-base transistors. The results of these experiments show the influence of the structures of electron-energy bands in the $CoSi_2$ metal layers, with important consequences for the performances of hot-electron devices that include $CoSi_2$/Si interfaces.

This work was done by Michael H. Hecht, William J. Kaiser, Robert W. Fathauer, Lloyd D. Bell, and Edwin Y. Lee of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Ballistic-carrier spectroscopy of the $CoSi_2$/Si interface,"* ***write in 16*** *on the TSP Request Card.* *NPO-18699*

Theory of Dewetting in a Filled Elastomer Under Stress

A report presents a theoretical study of (1) dewetting (and consequent formation of microvoids) between the elastomeric binder and the filler particles of a highly filled elastomer under multiaxial tension and (2) the resulting dilatation of the elastomer. A theoretical understanding of

these phenomena is desirable because the failure of a highly filled elastomer is caused by the coalescence of microvoids and the associated dilatation. Although the study was directed toward understanding and predicting the nonlinear stress-vs.-strain behavior (including failure) of a filled elastomeric rocket propellant, it is also applicable, for example, to rubber in a highly loaded tire or in a damping pad.

This work was done by Steven T. J. Peng of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Constitutive Equations of Highly Filled Elastomers With Volume Dilatation Under Multiaxial Loading Part I. Theory of Dilatation and Dewetting Criterion"* ***write in 29*** *on the TSP Request Card.* NPO-18871

Statistical Approach to Determination of Texture in SAR

A paper presents a statistical approach to analysis of texture in synthetic-aperture-radar (SAR) images. The objective of such analysis is to extract the intrinsic spatial variability of the distributed target from the overall spatial variability of the SAR image. For this purpose, it is necessary to remove the spatial variability from speckle and system noise.

This work was done by Eric J. Rignot and Ronald Kwok of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the paper, "Characterization of Spatial Statistics of Distributed Targets in SAR Data,"* ***write in 39*** *on the TSP Request Card.* NPO-18583

Electronic Components and Circuits

X-Ray-Diffraction Tests of Irradiated Electronic Devices: I

X-ray-diffraction tests were performed on aluminum conductors in commercial HI1-507A complementary metal oxide/semiconductor (CMOS) integrated-circuit analog multiplexers, both before and after the circuits were exposed to ionizing radiation from a ^{60}Co source, and after postirradiation annealing at ambient and elevated temperatures. These x-ray-diffraction tests were in addition to electrical tests that were performed to determine the effects of irradiation and of postirradiation annealing on the electrical operating characteristics of the circuits.

The idea was to investigate the feasibility of correlating data from the x-ray tests with data from the electrical tests of the circuits in the preirradiated, postirradiated unannealed, and postirradiated annealed conditions. More specifically, the investigators sought to determine whether there is a relationship between the effects of irradiation on the devices and physical stresses within the devices. X-ray diffraction is potentially useful for nondestructive measurement of stresses in that x-ray-diffraction patterns are related in a known way to the distances between atomic planes in crystalline materials, and these distances are known functions of stresses in the materials. Stating it from a slightly different perspective, one can use an x-ray-diffraction apparatus as a strain gauge.

This work was done by David C. Shaw, Lynn E. Lowry, and Charles E. Barnes of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Post Irradiation Effects (PIE) in Integrated Circuits,"* ***write in 9*** *on the TSP Request Card.* NPO-18803

X-Ray-Diffraction Tests of Irradiated Electronic Devices: II

A report describes research on the use of x-ray diffraction to measure stresses in the metal conductors of complementary metal oxide/semiconductor (CMOS) integrated circuits that have been exposed to ionizing radiation. Expanding upon the report summarized in the preceding article ["X-Ray-Diffraction Tests of Irradiated Electronic Devices: I" (NPO-18803)], this report presents data that further suggest a relationship between electrical performances of the circuits and the stresses and strains in the metal conductors.

This work was done by David C. Shaw, Lynn E. Lowry, and Charles E. Barnes of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Observation of Radiation Induced Changes in Stress and Electrical Properties in MOS Devices,"* ***write in 30*** *on the TSP Request Card.*
NPO-18825

Materials

Thermal-Control Coatings Evaluated

A report describes tests of a variety of thermal-control coating materials, including white paints, second-surface-metalized fluorinated ethylene propylene, aluminum anodized in sulfuric acid, and plasma-sprayed alumina. For the tests, all coatings were applied on aluminum substrates. They were tested for resistance to ultraviolet radiation in vacuum in the wavelength range from 200 to 400 nm and in the wavelength range from 100 to 200 nm, thermal cycling in vacuum, and atomic oxygen in a radio-frequency (RF) plasma asher.

This work was done by Joyce A. Dever of **Lewis Research Center**, *Wayne S. Slemp of Langley Research Center, Elvin Rodriguez of Cleveland State University, and Joseph E. Stoyack of LTV Missiles and Electronics Group. Further information may be found in NASA TM-104335 [N91-22367], "Evaluation of Thermal Control Coatings for Use on Solar Dynamic Radiators in Low Earth Orbit."*

Copies may be purchased [prepayment required] from the NASA Center of AeroSpace Information, Linthicum Heights, Maryland, Telephone No. (301) 621-0390. Rush orders may be placed for an extra fee by calling the same number.
LEW-15496

Thermal Conductivity and Expansion of Graphite/Copper

A report describes the fabrication of graphite-fiber/copper-matrix composite plates, measurements of the thermal conductivities of these plates at temperatures from ambient to 1,073 K, and measurements of the thermal expansions of the plates from ambient temperature to 1,050 K. Graphite/copper composites are promising lightweight, high-thermal-conductivity materials that have been proposed for use in heat exchangers and other heat-transfer components of power systems in spacecraft and hypersonic aircraft. Graphite/copper is also of interest as a model composite material, given the greatly differing thermal-expansion coefficients of copper and of graphite fibers and given that the graphite and copper do not react chemically with each other to form a compound, the only bond between the fiber and the matrix being a mechanical one.

This work was done by David L. McDanels of **Lewis Research Center** *and David L. Ellis of Case Western Reserve University. Further information may be found in NASA TM-105233 [N92-14120], "Thermal Conductivity and Thermal Expansion of Graphite Fiber/Copper Matrix Composites."*

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-15681

Release of Gaseous NH_3 From NH_4ClO_4 by HTPB-Bonding Agents

A report describes an experimental study of the rate of generation of ammonia and the total amount of ammonia generated by chemical reactions between bonding agents and grains of ammonium perchlorate in solid rocket propellants. The results of the experiments empirically define the ammonia-generation characteristics of several types of bonding agents, and thereby provide guidelines for tailoring a bonding agent to the other constituents of the propellant and to the process conditions used in making the propellant. The report also provides insight into the mechanisms of the chemical reactions between several types of organic amines with solid ammonium perchlorate.

This work was done by James C. McComb of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 51*** *on the TSP Request Card.*
NPO-18781

Mathematics and Information Sciences

Advances in Coding for Nearly Errorless Communication

A report surveys the state of the art of coding digital data for nearly errorless communication over long distances. The coding techniques described include mainly ones that have been or might be used to transmit imagery and/or other data from spacecraft to receivers on Earth.

This work was done by Kar-Ming Cheung, Leslie J. Deutsch, Samuel J. Dolinar, Robert J. McEliece, Fabrizio Pollara, Mehrdad M. Shahshahani, and Laif Swanson of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Recent Advances in Coding Theory for Near Error-Free Communications,"* ***write in 77*** *on the TSP Request Card. NPO-18510*

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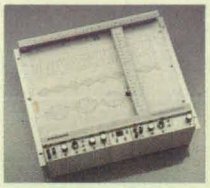

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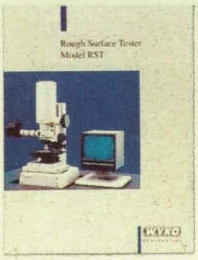


The WYKO RST rapidly measures roughness and step heights to 100 µm with a vertical resolution better than 0.3 nm (0.012 µin.) on surfaces such as textured aluminum and steel, etched silicon, plastics, magnetic tape and diskettes, ceramics, and even paper.

WYKO Corporation

For More Information Write In No. 303

AUTOMATED PRESSURE CONTROL SYSTEM

Fully Programmable Pressure Generation System, available in pressure ranges from vacuum up to 60,000 psi, interfaces to virtually any computer system. Software provided for IBM-PC Compatible Systems. Both electronic and mechanical over-pressure fail-safe systems with automatic pressurizing fluid refill system. For details call 607-257-5544. Toll free in USA and Canada: 1-800-APP-VALVE. Fax: 607-257-5639.

Advanced Pressure Products

For More Information Write In No. 304

COMPUTER CONTROLLED VALVES

Brochure describes company's line of remote and computer controlled on-off, metering and servo valves, pressure generators, automated pressure and flow control systems, pressure gauge calibration systems and capability for custom configurations. Pressure range from high vacuum to 60,000 psi. Tel: 607-257-5544. Toll Free in USA and Canada 1-800-825-5764. Fax: 607-257-5639. Address: 83 Brown Road, Bldg. 4, Ithaca, NY 14850.

Advanced Pressure Products

For More Information Write In No. 305

The Capattery is a high-reliability double layer capacitor used as a standby power source in memory back-up and bridge-power applications. It has virtually unlimited cycle life and over 20x the capacitance density of conventional capacitors. With a Perm-selective valve, patented by Evans, 33 Eastern Ave., East Providence, RI 02914-2107, Tel: 401-434-5600; Fax: 401-434-6908.

Evans

For More Information Write In No. 306

COATING TOUGHENS ALUMINUM PARTS

NEDOX® surface-enhancing anti-static coatings protect against wear, corrosion, sticking and galling. These harder-than-steel, dry-lubricated permanent coatings dramatically increase surface hardness, and chemical and moisture resistance,. They prevent static build-up without reducing electrical conductivity. Non-stick surface aids mold release, speeds sanitation cleanup, eliminates need for caustics.

General Magnaplate Corp.

1331 Route 1, Linden, NJ 07036. Tel: 908-862-6200

For More Information Write In No. 307

A NEW APPROACH TO SCIENTIFIC DATA ANALYSIS

Analysis Advisor is a free interactive analysis software tutorial that includes demonstrations of graphical and traditional programming methodologies for analysis. You can investigate Digital signal processing, Digital filtering, Windowing, Curve fitting, Signal averaging, Simulation, Interpolation, and Descriptive statistics. Requires Windows 3.1 and 8 MB of memory. Tel: 512-794-0100, 800-433-3488 (US and Canada); Fax: 512-794-8411.

National Instruments

For More Information Write In No. 308

PRODUCTS FOR TOOLING AND MANUFACTURING

This FREE catalog provides information on more than 1600 components for tooling and manufacturing. Dimensions, product photographs, prices and applications are included. Full line covers standarized tooling components for jigs and fixtures, and set-up and work clamping tools. A FREE TEMPLATE CATALOG will also be included. Contact Northwestern Tools, Inc., 3130 Valleywood Dr., Dayton, OH 45429. Tel: 513-298-9994. Fax: 513-298-3715.

Northwestern Tools, Inc.

For More Information Write In No. 310

VACUUM VALVES

VAT'S new 225 page hard-cover catalog contains detailed information and drawings on a comprehensive selection of gate, angle, all-metal, slit, fast-closing, throttle, and pressure control valves. Using innovative sealing technology, they are ideal for pump isolation, load-locks, beam lines, or other vacuum applications.

VAT

For More Information Write In No. 311

BREAK-THROUGH PORTABLE INSTRUMENTATION RECORDER

The Storeplex Portable Instrumentation Recorder is designed for highly efficient and accurate data acquisition in both laboratory and field use in the automotive, marine, medical, power and energy, defense and aerospace industries. Address: 15375 Barranca Parkway, Suite H-101, Irvine, CA 92178. Tel: 800-847-1226; Fax: 714-727-1774.

Racal Recorders, Inc.

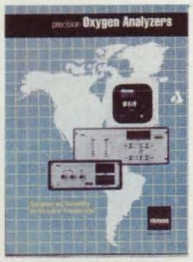
For More Information Write In No. 312

CATALOG DESCRIBES DATA ACQUISITION SYSTEMS

General and specialized data acquisition systems are described in this new catalog from Hi-Techniques. Modular in design, these products contain all the software for acquisition of signal data, calculation of data parameters, and output of finished documentation for research and routine test applications. Tel: 608-221-7500.

Hi-Techniques, Inc.

For More Information Write In No. 313



OXYGEN ANALYZERS

A full-color brochure introduces a complete line of oxygen analyzers for the laboratory or process line. They are ideally suited for monitoring the oxygen levels in all types of gas streams. Trace oxygen levels from ppb to 100% are accurately determined by these ruggedly constructed instruments. No periodic maintenance or special operator skills are required. Intrinsically-safe and battery-operated models are also available.

Illinois Instruments Inc.

For More Information Write In No. 314

PXS™ SERIES PORTABLE X-RAY SOURCES

Kevex X-Ray's PXS line of portable x-ray sources features the x-ray tube, high voltage power supply, control electronics and heat exchanger in a simple compact package. Each PXS unit is operable from a low level DC source, either 12 VDC or 28 VDC. An optional control and monitor target voltage and beam current.

Kevex X-Ray

For More Information Write In No. 315

MAINTAIN YOUR COOL

Barnstead offers a wide variety of cartridges and holders designed to provide deionized water for cooling systems. The presence of ions and oxygen can severely hamper the ability of your cooling system to work properly. We offer standard customized deionization systems to meet your cooling needs. Call now for more information, 800-446-6060, ext. 414.

Barnstead/Thermolyne Corp.

For More Information Write In No. 316

ANALYTICAL SERVICES—FAST TURN-AROUND

Brochure describes the wide range of materials characterization services that are provided by the firm's Analytical Services Division. Among those described in the brochure are surface area, pore and particle size distribution, density, permeability, chemisorption and pressure testing. Also available are instruments for sale or lease. Tel: 607-257-5544. Toll Free in USA and Canada: 1-800-825-5764. Fax: 607-257-5639.

Porous Materials Inc.

For More Information Write In No. 317

VERSATILE CAM RUNS WITH ANY CAD

Guaranteed CAD/CAM data translators, including IGES Version 5.1 with trimmed NURBS surfaces. Fast and accurate 3D surface design, model, NC programming and machining. Powerful DOS and 32-bit Windows version. Call 800-488-3615 or 818-361-5605; Fax: 818-361-1919.

Surfware, Inc.

For More Information Write In No. 318

SERVO CONTROL VALVES

Single and Dual Servo Valves from Advanced Pressure Products provide unmatched control of process parameters such as pressure, flow, temperature, fluid ratios and other process parameters. These are available for pressures ranging from high vacuum to 60,000 psi and flows from microliter to gallons per minute. Tel: 607-257-5544. From USA and Canada: 1-800-APP-VALVE. Fax: 607-257-5639. Cornell Industry Research Park, 83 Brown Road, Ithaca, NY 14850.

1-800-APP-VALVE

Advanced Pressure Products

For More Information Write In No. 319

ULTRA-HARD MATERIALS FABRICATION

Insaco's brochure describes the custom manufacture of components in sapphire, ruby, quartz, ceramics of all types including glass-ceramics, alumina, zirconia, carbides, and nitrides. The company routinely fabricates these materials for applications in optics, chemistry, vacuum, bearings, electronics, nuclear, space and medicine. Tolerances are measured in millionths of an inch with surface finishes in angstroms and flatness to fractions of a wavelength. Tel: 800-959-0264; Fax: 800-959-0267.

Insaco, Inc.

For More Information Write In No. 320

AUTOMATED PRESSURE GAGE CALIBRATION SYSTEM

Fully Programmable Automated Pressure Gage Calibration System, available in pressure ranges from vacuum up to 60,000 psi, interfaces to virtually any computer system. Window and DOS version Software provided for IBM-PC Compatible Systems. Both electronic and mechanical over-pressure fail-safe systems with automated pressurizing fluid refill system. Advanced Pressure Products. Tel: 607-257-5544. From USA and Canada: 1-800-APP-VALVE. Fax: 607-257-5639.

Advanced Pressure Products

For More Information Write In No. 321

OPTO-MECHANICAL PRODUCT GUIDE

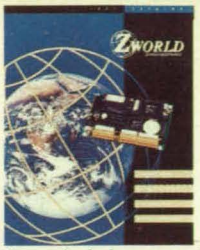
Daedal's new Opto-Mechanical catalog contains hundreds of laboratory bench optical mounts, positioning devices and optical hardware. Complete specifications, dimensions and pricing are included. All products listed can be ordered by phone or fax, can be charged to Visa or MasterCard, and are shipped free to anywhere in the continental US. Tel: 800-245-6903; Fax: 412-744-7626.

Daedal Division
Parker Hannifin Corporation
For More Information Write In No. 322

ADVANCED COMPOSITE WORKSHOPS —SINCE 1983

The brochure describes eleven different "hands-on" workshops in advanced composite materials technology. These workshops cover fabrication, repair, manufacturing, tooling, blueprint reading, adhesive bonding, engineering design for specialized repairs, and ultrasonic inspection of composites. Emphasis is placed on prepreg carbon and aramid fiber materials and processes, utilizing vacuum bagging and high-temperature curing methods in the oven and autoclave. REFRESHER WORKSHOPS OFFERED. Call toll-free 1-800-638-8441. Fax 702-827-6599.

Abaris Training Resources, Inc.
For More Information Write In No. 323



LOW COST MINIATURE CONTROLLERS

C-Programmable miniature controllers feature digital/analog I/O, serial communications (RS485/232), battery-backed memory, time/date clock, expansion I/O cards. LCD/keypads and more for data acquisition, test, or control. Prices from $159 Qty 1. Our $195 interactive Dynamic C™ makes software development easy. Tel: 916-757-3737, or fax 916-753-5141. For 24 Hr. Data Sheet retrieval from YOUR fax, call 916-753-0618.

Z-WORLD ENGINEERING
1724 Picasso Ave., Davis, CA 95616
For More Information Write In No. 324

THE SCRAMNet NETWORK

is a real-time shared-memory network designed to connect dissimilar computers (those with different backplanes). SCRAMNet avoids the limitations of physical shared-memory architectures and message passing LANs to deliver true and real-time speed, deterministic performance and positive system control with no software overhead. Features include data filtering, programmable byte swapping, and a sophisticated interrupt structure. Tel: 513-252-5601 or 1-800-252-5601.

SYSTRAN Corp.
For More Information Write In No. 325

FREE CATALOG! LINEAR MOTION COMPONENTS

All products ship within 24 hours.
- Ball Slides
- Crossed Roller Slides
- Positioning Slides
- Recirculating Bearings
- Shafts & Supports.

Call TOLL FREE: 1-800-447-2042, In CT: 203-790-4611, or Fax: 203-748-5147. **TUSK Direct, Inc.**, Clarke Industrial Park, P.O. Box 326, Bethel, CT 06801.

TUSK Direct, Inc.
For More Information Write In No. 326

CURRENT, VOLTAGE, POWER, AND FREQUENCY TRANSDUCERS

Catalog features a full line of stock, custom, military and industrial grade AC/DC transducers. Detailed electrical, mechanical and environmental specifications with product photos are provided. A convenient selection guide and options list allows for quick choice from almost 500 models. Several new, fast response, high current series are included.

American Aerospace Controls, Inc.
For More Information Write In No. 327

ELECTRONIC HARDWARE CATALOG

Broadest selection of hardware for electronic assemblies. 350-page free catalog includes a full range of standoffs, captive screws and nuts, chassis fasteners, handles, ferrules, spacers and washers. Special sections—new, unusual products, metric information and Mil-plating specifications. Full inventory, fast turnaround, samples. Tel: 1-800-237-0013; Fax: 201-661-3408.

Accurate Screw Machine Co.
For More Information Write In No. 328

GENERAL DEVICES FOR SPECIFIC SOLUTIONS

General Devices provides specific solutions for cabinets and racks, slides and accessories. Hundreds of standards Chassis Trak® telescoping slides, Vent Rak® cabinets and racks are designed for electronics and telecommunications. And, cooling modules, handles and pulls, shelves, drawers.

General Devices,
the Can Do! company
Indianapolis, IN. Tel: 1-800-626-9484.
For More Information Write In No. 329

PRECISION GEAR COMPONENTS

Featuring a wide variety of gear components in a variety of materials, this 151 page slim-line brochure is the latest from Berg. Designed to complement the Inch and Metric catalogs, it contains Precision Gears & Racks, Gear Assemblies (Inch & Metric), and an extensive technical section. Products include Spur, Helical Bevel & Worm Gears in various styles and are available in quantities of 1 to 50,000 directly off the shelf or custom made. Tel: 516-596-1700. Fax: 516-599-3274.

For More Information Write In No. 330

THERMOFOIL™ HEATERS

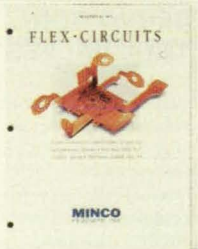
Bulletin HS-201 lists over 2000 sizes and resistances of etched-foil heating elements. Included are Kapton, silicone rubber, and mica insulated models for aerospace, medical, and industrial devices. The 32-page catalog offers complete technical specifications, custom design information, and application ideas to help the reader solve unique heating problems using Thermofoil technology.

Minco Products, Inc.
For More Information Write In No. 331

TEMPERATURE SENSORS AND TRANSMITTERS

108-page catalog lists resistance temperature detectors (RTDs), thermocouples, and transmitters for precision sensing in process control, machinery protection, and scientific applications. Included are flexible Thermal-Ribbon™ RTDs, laboratory standards, and new precision RTD probes rated to 850 °C. Hundreds of items are available from stock for immediate shipment.

Minco Products, Inc.
For More Information Write In No. 332



FLEX-CIRCUITS

Bulletin FC-301 describes precision single-layer, double-layer, multilayer, and rigid-flex circuits for aerospace, military, and medical electronics. Minco circuits are certified to MIL-P-50884C for critical applications. The 8-page bulletin includes design options, quality provisions, capabilities, and flex-circuit benefits.

Minco Products, Inc.
For More Information Write In No. 333

GPS TIMING FOR PC AND VMEbus

This information folder from Bancomm describes new PCbus and VMEbus board-level Global Positioning System (GPS) Satellite Receivers. These products provide worldwide precision time (100 nanosecond) and frequency (1 part in 10E7) references inside the host computer.

Bancomm

For More Information Write In No. 334

TECLAB ESD WORKSTATION CATALOG

Kalamazoo Technical Furniture's 8-page 4/color brochure details the *Teclab* line of static protective workbenches, workstation ystems, and ESD controlled vorkstation accessories. Included are color options, product specifications, and various levels of ESD protection available. *Teclab* also offers a Free Planning and Design Service. *Teclab*, the "professional's bench." Tel: 1-800-832-5227. Fax: 616-372-6116.

Kalamazoo Technical Furniture

For More Information Write In No. 335

WORKMANSHIP STANDARDS MANUAL

Workmanship Standards were developed by Martin Marietta to use as guidelines in manufacturing electro-mechanical and electronic systems that perform to exacting government defense requirements. Photographs and clear instructions provide the individual with a clear definition of what is required on the production line and in training programs. Tel: 407-356-4769. Fax: 407-356-6288.

Martin Marietta Information Systems

For More Information Write In No. 336

A GUIDE TO INNOVATIVE TECHNOLOGY

Nicolet is recognized worldwide as a leader in technologically advanced quality instruments. This short form catalog describes the Nicolet range of high resolution digital oscilloscopes, multi-channel transient analyzers, fiber optic isolation probes and software capabilities.

Nicolet Instruments Corp.

For More Information Write In No. 337

OPTICAL FILTERS AND COATINGS

Andover introduces it's new 1993 OPTICAL FILTER GUIDE. This extensive 56 page guide features a general and technical section which contains a large amount of information regarding the usage and performance of interference filters and optical coatings. The products section lists Andover's complete line of standard and custom interference filters and optical coatings.
Send for your FREE copy.

ANDOVER CORPORATION

For More Information Write In No. 338

FRICTION FREE SLIDES & STAGES

Del-Tron's new 40 pg. OEM Linear bearing design guide describes over 200 models of linear bearings, positioning stages, subminiature ball slide assemblies, and high precision crossed roller slides and tables. Del-Tron slides are used by designers of automated equipment in the medical, electronics, and robotics industries and anywhere that frictionless, repeatable, linear movement is required. Tel: 800-245-5013. Fax: 203-778-2721

Del-Tron Precision Inc.

For More Information Write In No. 339

ZIRCAR PRODUCTS INC.

Manufacturers and fabricators of high performance, high temperature fibrous ceramic thermal, electrical and structural insulation products. Fiber types include: Zirconia, Alumina Silica and other Refractory Oxide compositions. Product forms include: Bulk, Fiber, Powders, Cements, Hardeners, Felts, Cloths, Papers, Boards, Cylinders, Ceramic Composite Shapes and Engineering Insulation Assemblies in standard and custom shapes.

Zircar Products Inc.

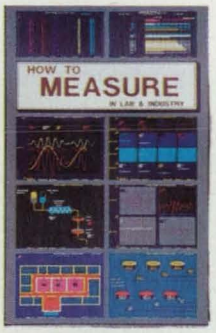
For More Information Write In No. 340

CAPABILITIES BROCHURE

Over thirty years of experience summarized to show RdF's success in providing quality temperature sensors to the aerospace, military, nuclear, and commercial markets. RdF offers a combination of standard and custom designed RTDs, T/Cs, Heat Flow Sensors, Foil Heaters, and more. Phone: 800-445-8367. Address: PO Box 490, Hudson, NH 03051-0490.

RdF Corporation

For More Information Write In No. 341



HIGH RESOLUTION DATA ACQUISITION

FREE booklet shows many ways to automate data collection using your personal computer. It comes with a FREE Instatrend Real-Time Graphics Demo Disk. Dianachart, Inc., 101 Round Hill Drive, Rockaway, NJ 07866. Tel: 201-625-2299.

Dianachart, Inc.

For More Information Write In No. 342

DUAL-LOOP INFRARED TEMP CONTROLLER

Use 1 or 2 infrared sensors coupled to feature-rich ANAFAZE multi-loop PID controllers to remote sense temperature & control machines, devices, processes, etc., accordingly. Applications are anywhere anything is moving, soft, sticky, or delicate. Call today for info! ANAFAZE, 334 Westridge Drive, Watsonville, CA 95076. Phone: 408-724-3800. Fax: 408-724-0320.

ANAFAZE

For More Information Write In No. 343

MULTI-SCREEN DISPLAY FOR WORKSTATIONS AND PCS

ComputerWall™ magnifies and splits computer imagery across a 2 x 2 or 4 x 4 array of projectors. Analog interface automatically synchronizes to workstations or PCs. Compatible with all software. Exactly duplicates real-time, true color images up to 1280 x 1024 pixels including text, graphics, animation or full-motion video. Built-in routing switcher in ComputerWall+ displays split or single screen images from six sources.

RGB Spectrum

For More Information Write In No. 345

THE LINK BETWEEN COMPUTER GRAPHICS AND VIDEO

RGB/Videolink™ video scan converters transform images from a computer, radar, or FLIR sensor to broadcast standard video (NTSC or PAL) for taping, projection or teleconferencing. Video can be overlayed with computer-generated graphics. Applications include training, simulation, archiving and signal transmission. GSA Contract #GS03F203A

RGB Spectrum

For More Information Write In No. 346

NEW FEA DESIGN AND ANALYSIS SOFTWARE

WeCan 5.0 is an integrated engineering design analysis package running on PCs and workstations. It is a full-featured, 3-D package developed by Westinghouse Electric Corporation over a 20 year period and used to simulate and visualize a wide range of static, dynamic and thermal design problems. FREE INFORMATION KIT; FULL WORKING DEMO AVAILABLE. CALL 412-826-3470.

Aegis Software Corporation

For More Information Write In No. 347

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For as little as $125,000 run your larger engineering problems, those that do not run well on today's cache-based RISC architectures, by adding a Cray Research EL92 deskside supercomputer to your network. FOR MORE INFORMATION CALL 1-800-BUY-CRAY.

Cray Research

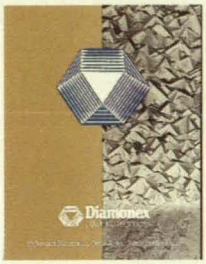
For More Information Write In No. 348

INFRARED IMAGING AND MEASUREMENT SYSTEMS

The broad range of Inframetrics IR systems software, capabilities and applications is described in this full-color brochure. Inframetrics manufactures IR imaging temperature-measurement systems that are in use worldwide in nondestructive testing, predictive maintenance, research and development, electronics design and manufacturing, medical, and law enforcement environments. Tel: 508-670-5555.

Inframetrics, Inc.

For More Information Write In No. 349

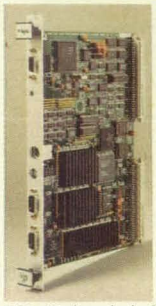


DIAMONEX® DIAMOND PRODUCTS

Diamonex's new brochure describes their Polycrystalline and Amorphous Diamond-coated products for manufacturers using advanced technology. Polycrystalline Diamond enhances the performance of high-power FET heat spreaders, hybrid multichips, and laser diodes. Amorphous Diamond coatings for medical implantables, surgical implements, medical packaging, thermal printheads, hard disks and magnetic tapeheads enhance the lifetime and wear of products.

Diamonex, Inc.

For More Information Write In No. 350



VIGRA VGS VME GRAPHICS SERVER

Processor: 33 Mhz MIPS R3000 compatible w/FP coprocessor. **Resolution:** Programmable up to 1280 x 1024. **Memory:** 8 Mbyte DRAM, 2 Mbyte VRAM, 1 Mbyte overlay RAM. **Graphics Interface:** X11R5 standard, others available. **I/O:** Keyboard, dual serial, sound generator. Vigra, Inc. Tel: 619-597-7080.

Vigra, Inc.

For More Information Write In No. 351

FREE ENGINEERING FINDINGS 93/94 CATALOG

320 pages of components, materials and precision tools in this NEW catalog. Hard-to-get items in small quantities such as: stainless steel hypodermic tubing, Tygon® and PEEK tubing, st/st luer connectors, Vibration and Noise Insulators, and a wide variety of st/st fasteners, inch & metric sizes.

Cover: 1993 winner of U.S. FIRST Competition

Small Parts Inc.

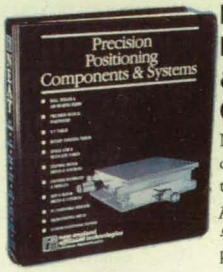
For More Information Write In No. 352

CAD/CAM Routing/Milling

XR® robotic machining system accepts CAD/CAM parts programs to rout and mill large and complex parts. Among the many features: automated machining in five axes, machine-tool accuracy throughout 60' x 16' x 8' work envelope. PaR Systems, Inc. 899 Hwy. 96 W, Shoreview, MN 55126.

PaR Systems, Inc.

For More Information Write In No. 353



PRECISION POSITIONING & MOTION CONTROL

NEAT's 1993 catalog, includes the latest additions to our family of *precision positioning components and systems.* Our expanded product line includes: single-axis, multi-axis, rotary, high-vacuum, and air-bearing stages; plus a complementary line of stepping, servo, and linear motor drives and controls. Our fully automated CAD/CAM machining facility enables us to provide custom turnkey solutions. Tel: 1-800-227-1066.

New England Affilliated Technologies

For More Information Write In No. 354

INSTRUMENTS CATALOG

The 1993-1994 Cole-Parmer catalog features over 1500 full-color pages and describes more than 35,000 products covering instruments, equipment, and supplies. The catalog features 32 pages of new products, special technical data and conversion factor sections, a newly-organized fittings section, and an expanded chemical resistance chart. Tel: 800-323-4340.

Cole-Parmer Instrument Co.

For More Information Write In No. 355

CAATS -

Compact Airborne Automatic Tracking System provides automatic tracking of video images for aircraft and helicopters fitted with TV and IR cameras. Video auto-tracking relieves aircrew from the exacting task of following video targets manually. Features include automatic scanning/search, target detection and acquisition. The equipment is easily integrated with existing or new camera systems. Contact Gordon Cain, Octec Ltd., Western Road, Bracknell, Berks, RG12 1RW, England. Tel: +44 344 861051. Fax: +44 344 860983

Octec Limited

For More Information Write In No. 356

AUTOMATIC VIDEO TRACKERS AND POSITION ANALYZERS

Octec's line of advanced, real time, video image automatic tracking systems can be integrated into TV/IR camera platforms and fixed position cameras where single or multiple object position data are provided for subsequent analysis. Octec systems serve the Surveillance, Behavior Research, Outside Broadcast, Process Control and Defense fields. Contact Gordon Cain, Tel: +44 344 861051. Fax: +44 344 860983.

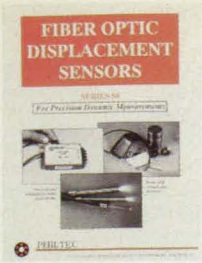
Octec Limited

For More Information Write In No. 357

FFE SOLVES FEA PROBLEMS SO FAST... IT'S SHOCKING.

Watch COSMOS/FFE analyze complex design problems up to 100 times faster than conventional FEA programs and you'll be impressed. But see it solve supercomputer-sized problems on a PC and you'll be shocked. Solve complex 100,000 DOF design problems on a PC in minutes at a fraction of the disk space at a fraction of the cost. Call 310-452-2158 in West or 412-635-5100 in East for more information.

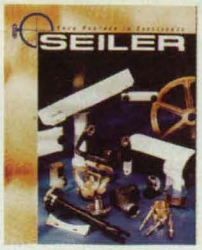
Structural Research and Analysis Corp.
For More Information Write In No. 358



FIBER OPTIC MOTION SENSORS

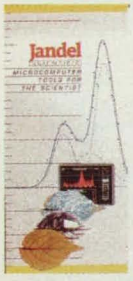
Catalog dated 6/93 describing sensors for precision dynamic measurement on non-conductive and conductive materials. Non-contact sensors described in catalog include reflectance dependent and reflectance compensated models. Applications include dimensional measurements and motion analysis of vibrating or rotating targets. From $595. Tel: 410-757-4404; Fax: 410-757-8138. Box 359, Arnold, MA 21012.

Philtec Inc.
For More Information Write In No. 359



Seiler Instrument offers state-of-the-art machining and product assembly. Automated CNC machining centers work with steel, aluminum, brass, copper, and stainless steel. In-house R&D and quality control departments guarantee compliance to strict specifications. For our complete capabilities brochure call 1-800-489-2282. Fax: 314-968-2637.

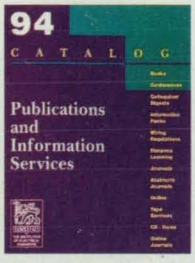
Seiler Instrument & Manufacturing Co., Inc.
For More Information Write In No. 360



SCIENTIFIC SOFTWARE

Jandel Scientific develops PC and Mac software tools for scientists and engineers. Our products include SigmaPlot (scientific graphing), SigmaStat (statistics), TableCurve (curve fitting), SigmaScan/Image (measurement software), and more. Call 1-800-874-1888 or 415-453-6700 for a free catalog.

Jandel Scientific
For More Information Write In No. 381



INSPEC AND THE IEE COMBINE CATALOG

INSPEC Publications and Services, Abstracts Journals, Online Database, Tape Services, CD-ROM, IEEE/IEE Periodicals On-disc (IPO) are featured along with the Books, Conference Proceedings, Professional Journals and Distance Learning (Video and CBT) materials of the Institution of Electrical Engineers (IEE). Tel: 908-562-5553; Fax: 908-981-0027.

IEE/INSPEC
For More Information Write In No. 361

DATAMYTE QUANTUM SPC SOFTWARE

This brochure, "Important Questions to Consider When Configuring a Networked SPC System," serves as a guide to purchasing a PC-based data collection system. It also outlines the features of DataMyte's Quantum SPC/DC™ data collection software, and Quantum SPC/QA™ quality analysis software, both designed to run on Windows™. Tel: 612-935-7704. Fax: 612-935-0018.

DataMyte
For More Information Write In No. 362

THERMOCOUPLE MONITOR/ SCANNER

The SR630 is a 16 channel thermocouple monitor for B, E, J, K, R, S, and T type thermocouples. Temperature can be read with 0.1 degree resolution, or each channel can monitor DC voltage with 1 mV resolution. Any or all channels can be scanned and alarm limits can be set for monitoring temperature deviation. RS-232 and GPIB (IEEE-488) computer interfaces as well as a Centronix printer port are standard. SR630 Thermocouple Monitor US List Price $1495. Tel: 408-744-9040.

Stanford Research Systems
For More Information Write In No. 363

COSMOS/M EXPLORER

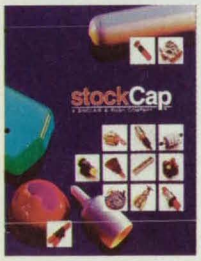
The EXPLORER features a state of the art geometric modeler, graphic pre- and postprocessor, linear and nonlinear statics and dynamics, advanced dynamics, heat transfer, fluid flow and optimization in one fully integrated package. With this wide array of capabilities EXPLORER provides tremendous value at a remarkably low price. By breaking down the barriers to FEA, EXPLORER is opening the door to a whole new world of productivity. Tel: 310-452-2158 or Fax 310-399-6421.

Structural Research & Analysis Corp.
For More Information Write In No. 364

POLYMERS & ACRYLIC MONOMERS

A new, 12-page four-color brochure titled "Engineering Polymers and Acrylic Monomers." Included are polymers and monomers family of products, including Rilsan® 11 and 12 polyimides; Rilsan® powder coatings, Pebax® thermoplastic elastomer resins; Platamid® and Platherm® hot melt adhesives; Platilon® hot melt film; and acrylic monomers. Product description, background, and a sampling of applications are also provided.

Elf Atochem North America, Inc.
For More Information Write In No. 365



CAPS, PLUGS, AND MASKING AIDS

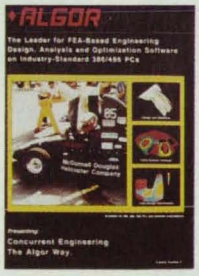
stockCap closures, masks, caps, plugs & flange covers for use in the electrical, aerospace and automotive industries. Mask, insulate, seal and protect threads, pipes, tubes, and fittings. Selection includes round & rectangular caps, plus plugs and hi-temp materials. In-stock or custom. For samples and catalog, stockCap, (800) 827-CAPS.

Sinclair & Rush, Inc.
For More Information Write In No. 366

REAL-TIME MULTI-PROCESSOR SYSTEMS

Comprehensive 4C brochure and MAXION™ data sheets provide complete product specifications on Concurrent's new standards-based real-time open computing systems. This system incorporates a revolutionary crosspoint multiprocessing architecture which eliminates performance bottlenecks encountered in traditional bus architectures. Call today: 1-800-631-2154.

Concurrent Computer Corporation
For More Information Write In No. 367



DESIGN OPTIMIZATION SOFTWARE WITH FEA ENGINEERING BUILT-IN

Free catalog. See why Algor is a world leader in engineering design optimization in which FEA analysis is tightly integrated. Includes solid and surface modeling. Enables engineers to finalize designs before the CAD documentation phase. All popular FEA analyses, including nonlinear. For DOD and UNIX. Adds value to all CAD, CAM and CAE setups. Tel: 412-967-2700; Fax: 412-967-2781.

For More Information Write In No. 368

New on the Market

The EnviroMac™ **environmental monitoring and control system** for the Macintosh is available from Remote Measurement Systems, Seattle, WA. EnviroMac allows users to monitor temperature, air quality, and energy use while continuously evaluating external conditions and automatically issuing commands to control electrical devices.

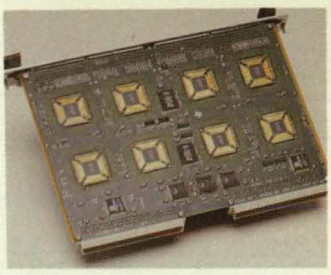
For More Information Write In No. 712

InfraCAM™, a palm-size focal plane array **infrared camera** in a self-contained package, is available from Inframetrics Inc., North Billerica, MA. The portable, high-resolution camera measures 5.3" x 9.7" x 2.5", weighs 3 lbs, and includes a battery, viewfinder, and interchangeable lens with focal lengths of 25, 50, or 100 nm.

For More Information Write In No. 709

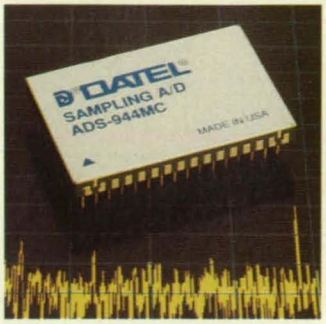
A 16 MB **memory module** from Dense-Pac Microsystems Inc., Garden Grove, CA, measures 0.56" x 0.80" with a height of 0.29"—an 85% reduction in board space covered by thin, small-outline packages. The DPD16MX8PH4 DRAM STACK module stacks eight ceramic carriers, each with a 4 MB x 4 MB DRAM die, and offers 128 MB of DRAM in a single 34-pin gull-wing, plastic package.

For More Information Write In No. 706



Mizar Inc., Carrollton, TX, has introduced the first eight-processor **DSP board** to require no daughtercards. The MZ 7772 single-slot 6U VME card is mounted with eight TI TMS320C40 processors, each capable of 50 MFLOPS, which permits 2.2 BOPS. Each DSP is configured with six 20 MB/sec communications ports and a six-channel direct memory access co-processor.

For More Information Write In No. 710

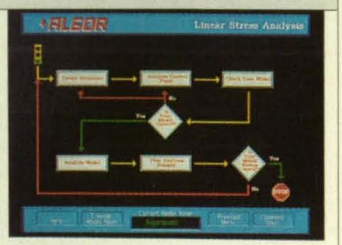


DATEL Inc., Mansfield, MA, has released a high-performance 14-bit, 5 MHz **A/D converter** in a 32-pin, triple-wide, ceramic dual-in-line package that consumes a maximum of 3.0 W. The ADS-944 contains a fast-setting sample/hold amplifier, a subranging A/D converter, an internal reference, timing and control logic, and error-correction circuitry.

For More Information Write In No. 711

The MicroFlow I **fume removal** system from HEMCO Corp., Independence, MO, uses four-stage filtration to absorb hazardous vapors, gases, and noxious fumes. The ductless hood includes a recessed work surface to contain spillage, a clear viewing shield, and a dual-speed blower with indicator lamp. The durable and lightweight systems are available in 120 V AC/60 Hz and 220 V AC/50 Hz configurations.

For More Information Write In No. 701



Algor Inc., Pittsburgh, PA, has introduced Roadmaps, the first **task-oriented educational human interface software**, available as an enhancement to the company's mechanical design and analysis program. Using a series of on-screen flow charts and interface control diagrams for each task, Roadmaps guides users through the design engineering and optimization process.

For More Information Write In No. 700

Aremco Products, Ossining, NY, has announced an **automotive engine repair putty** to bond, seal, and patch cracked manifolds, headers, and exhaust systems. The ceramic/stainless steel-filled Pyro-Putty™ PP2400 bonds well to cast iron, carbon steel, and stainless steel to 1093 °C and resists fuels, oils, and other corrosives. The putty cures in place by running the engine for ten minutes.

For More Information Write In No. 705

New on the Market

Microstar Laboratories, Bellevue, WA, has announced two **data acquisition processors** that combine 16-bit resolution with onboard intelligence in a PC board. Both the DAP 1216e™ and DAP 2416e™ feature a dedicated multi-tasking real-time operating system that runs on the DAP's processor and communicates with whatever software is running on the host PC.

For More Information Write In No. 707

An **image-based fault location and failure analysis** system from Schlumberger Technologies, San Jose, CA, allows users to debug a device without knowing its functionality. The system acquires logic-state snapshots across several vectors from both a good and bad device, comparing them to highlight the failure path. This new technique, known as Continuously Gated Fault Imaging, allows rapid image acquisition without test program modification and with acquisition times independent of program length.

For More Information Write In No. 713

PolyFEM polynomial-type **finite element analysis** software from CADSI, Coralville, IA, enables rapid linear static, dynamic, and thermal analyses. Easily integrated with CATIA, PolyFEM features a p-solver method for automated mesh generation and solution algorithms for performance speeds ten to 30 times faster than existing products, according to the manufacturer.

For More Information Write In No. 704

The MAXION **multiprocessor system** from Concurrent Computer Corp., Oceanport, NJ, enables real-time application builders to design systems with faster data processing, higher volume I/O, and scalability. MAXION's novel architecture replaces the system bus with a crosspoint switch and one global memory system with distributed local memory. The familiar global memory programming model is preserved, while the crosspoint switch overcomes performance limitations often encountered in other systems and allows the CPU to work in isolation on a single task.

For More Information Write In No. 702

The TMS 40™ **tool management** system from SPS Technologies, Newtown, PA, monitors air tools and controls the complete fastening cycle each time a tool is operated, detecting and reporting any defects. It can be used to reject defective assemblies or trigger repair operations and provides an alternative to transducerized air or electric tools.

For More Information Write In No. 703

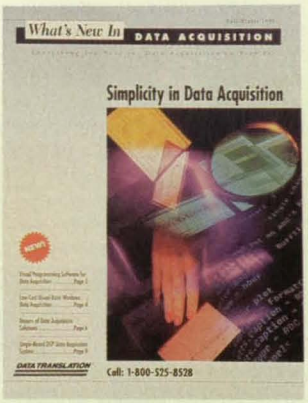
Belobox Systems Inc., Irvine, CA, has unveiled a scaleable **real-time symmetrical multiprocessing** (RT-SMP) system using COTS VME hardware and an unmodified UNIX SVR4. The BELOBOX® features a PSI module for sub-microsecond preemptive hardware scheduling. The request-driven system combines UNIX connectivity with real-time application, defining how a set of tasks is executed across multiple computers in response to synchronous and random events.

For More Information Write In No. 708

New Literature

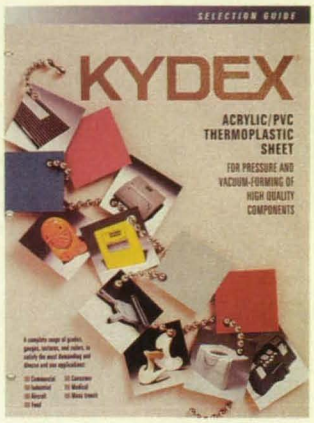
A **power protection** catalog from Best Power Technology, Necedah, WI, helps electronics users solve problems such as surges, sags, spikes, noise, brownouts, blackouts, and lightning strikes. The catalog includes tips for problem analysis, guidelines for purchasing a UPS/SPS, and a review of advanced UPS communications software.
For More Information Write In No. 718

G6G Consulting Group, Santa Monica, CA, has released the second volume of its **intelligent software** directory, a comprehensive listing of software and hardware products that can infer, recognize patterns, or make decisions on incomplete criteria. The publication contains information on fuzzy logic products, neural network development systems, Hypermedia and Hypertext software, voice and speech systems, natural language systems, knowledge-based development advisory tools, and virtual reality systems.
For More Information Write In No. 716



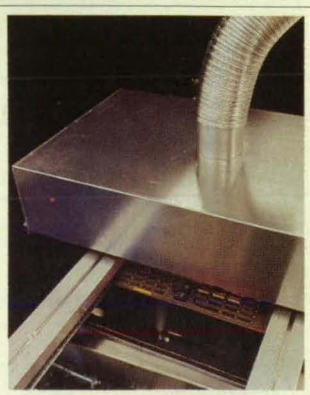
Data Translation, Marlboro, MA, has announced two shortform catalogs that highlight its **data acquisition and imaging products**. One describes visual programming software, data acquisition boards, and Windows™ programming tools; the second focuses on image analysis software for Windows, frame grabbers, and low-cost imaging boards and software.
For More Information Write In No. 719

A 128-page handbook from Conversion Devices Inc., Brockton, MA, describes the company's standard **DC/DC converters**. New products have ultra-wide input ranges, miniature single in-line packaging, and 8000 Vpk input/output isolation. Standard features include input Pi filters, indefinite short circuit protection, output overvoltage protection, six-sided continuous shielding, and ultra-high MTBFs.
For More Information Write In No. 717



A selection guide from Kleerdex Co., Aiken, SC, showcases grades, gauges, textures, and colors of the Kydex® extruded acrylic/PVC **thermoplastic sheet** for pressure- and vacuum-forming of high-quality components. The sheet, which can be thermoformed at temperatures between 165 °C and 200 °C, offers uniform wall thickness, high extensibility, and tear-resistance. Kydex can be pressed, cut, drilled, sawed, machined, or joined to other materials by fastening or welding.
For More Information Write In No. 715

An update of *Software for Science*, a catalog of **scientific and technical software**, has been published by SciTech International Inc., Chicago, IL. The free 64-page book describes more than 750 products for DOS, Macintosh, Windows, and UNIX, and offers information on buying complex software.
For More Information Write In No. 720



AT&T Network Systems, Princeton, NJ, has published a brochure describing the LSF-2000 series **low solids fluxer** for cleaning printed circuit boards. The unit's self-cleaning nozzle deposits a user-selected quantity of flux uniformly across a board's surface. The LSF-2000 is installed inside or adjacent to existing wave-soldering equipment, and releases no CFC emissions.
For More Information Write In No. 714

POSITIONS WANTED

Highly experienced, motivated professional engineer with Ph.D in metallurgical engineering. Seeking staff augmentation/contract work in the documentation, analysis, and preparation of reports for R&D programs, in-service inspections, proposals, or other technical projects. Has consistently demonstrated abilities to solve a wide range of technical problems, analyze voluminous and complex data using statistical methods, and to communicate results.
Box number 55B

BSME and MBA with 26 years P&L experience in international project management including engineering, design, construction management, procurement, start-up, and O&M seeks senior position in project/venture management. Responsibilities have included services within A/E, utility, IPP, industrial, government, and institutional sectors for energy, desalination, and environmental projects. Tel: 215-640-2045.
Box number 56B

Self-starting entry level BSME with 2.5 years experience in chemical process and aerospace industries seeks employment in design research consulting firm. Have experience in design, project, test, and process engineering along with good hands-on & communication skills. Honors graduate, willing to relocate.
Box number 58B

Electrical/computer engineer. MSEE, MSCS. Broad background in power system R&D, analog/digital circuit, computer hardware/software. Had three years experience in academics and industry. Experiences include C, C++, Pascal, MS-DOS, 80x86 assembly, power system software development. Hard working, self-motivated. Will locate for 40K/yr. Mr. Mingning Gu. Tel: 408-973-8920.
Box number 59B

High energy, innovative HVAC&R engineer looking for permanent position with high-tech, creative engineering or industrial organization. 19 years experience beginning as helper, working through AAS & BET degrees as an accomplished technician, then providing engineering, design, and construction management to industry, including 2nd law analysis, life cycle costing, and contract/supplier negotiations.
Box number 60B

Seeking part-time or temporary assignments raising capital for startup and young companies. Experience with debt and equity capital for such companies. Experience with debt and equity financing, mergers, and other business, IPOs, high-tech, biotech, and pharmaceutical investor, and public relations. Robert Schechter, 212-421-3186.
Box number 61B

Government quality assurance specialist—seven years Q/A and procurement. Commodities in aerospace, ammunition, materials, rubber, explosives, and propellants, MIL-Q-9858, MIL-I-45208, NHB 5300.4 (2B-1), STANAG 4107, MIL-STD-1520. Programs—Dragon Gen I & II, Hellfire, TOW2A, SMAW, M69 & M79 Grenade, Tank & APC wheels. Formal education in detonation physics and sonic/supersonic materials dispersion. Michael M. Taylor, Tel: 216-351-3425.
Box number 62B

Results-oriented, multidisciplinary, internationally-renowned, senior-level engineer (Ph.D in chemistry) with demonstrated expertise in semiconductor packaging and emerging technologies. Consultant to executives and an effective communicator and motivator. Recognized by IBM Corp. for achieving exceptional leadership. Five technical publications and 95 invention disclosures and issued patents leading to many successful IBM products. Tel: 914-298-3296.
Box number 63B

Supervising project engineer with substantial experience in conceptual design and fabrication of automated manufacturing and material handling systems. Knowledgeable in PLC programming and instrumentation. Project cost estimation, proposal development, customer presentation skills, accountability for scheduling, time/budget management, and report preparation. Field experience in installation, training, and problem solving.
Box number 64B

Highly self-motivated, self-directed team leader/player would like to put his experience—in surface engineering/metallurgical R&D, anti-wear engineering, and quality assurance relating to FAA-certified high-temperature alloy, gas turbine engine component repair—to work for you. M.Met.E. and MBA degrees, variety of patents and publications. Prefer full-time but would consider temporary or part-time. Voice mail at 908-370-8870.
Box number 65B

Ceramic engineer, Ph.D. Skilled in the development of technical ceramics from fine-grained powders (alumina, chromia, zirconia) using spray drying, and isostatic and dry pressing techniques. Also skilled in the fabrication of continuous fiber composites using filament winding and sol-gel techniques. Management experience. Will relocate/travel. Tel: 804-525-6934.
Box number 66B

BSME with experience in product design, testing, and stress analysis, as well as project coordination, scheduling, and supervision seeks an entry level opportunity to contribute to a research/development/design organization. Have used several CAD packages and many DOS and Windows applications. Registered EIT. Willing to travel and relocate.
Box number 67B

Design engineer: MSME plus seven years experience in product design, creation of component and assembly drawings with manufacturing specifications and tolerances, CAD customization, CNC tool path programming, and selection and integration of mechanical devices. Project engineering from conceptual drawings to manufacturing, through to final acceptance testing. Willing to relocate.
Box number 68B

Ph.D, agricultural engineering. Major: food engineering. Background: heat transfer, fluid flow, and non-Newtonian rheology. Highly innovative, result-oriented, and self-motivated. Extensive work with liquid crystal and electronic temperature sensors. Experience in image analysis, process control, computer languages (FORTRAN and BASIC), and PC-DOS. Tel: 614-291-0509.
Box number 69B

MS in astronautics, BS in engineering physics, seeking entry-level research or engineering position. Strong background in orbital mechanics, atmospheric physics, and spacecraft design. Experience modeling Venus atmosphere from Magellan data, and design/ repair of remote sensing instruments. Excellent problem solving and communications skills. Computer experience includes: Unix, VMS, Fortran, Basic, IDL, C, AutoCAD.
Box number 70B

Graduate engineer (MS, 7/93) seeks junior level product development/testing/R&D position. Thesis in traction studies, developed new soil testing device, project on pre-product testing. Two years as product engineer (auto): concept to prototype design, engine & components, QC/QP teams, management. SAS, WP 5.1, Qtro-Pro, Fortran, AutoCAD. Available now.
Box number 71B

Industrial chaplain. Human stress management. Work well with all people. 21 years military experience: naval aviation electronics technician, army chaplain in Vietnam, TexARNG, and reserve chaplain, colonel (1988). Doctor of ministry, MA, MDiv, BA. Pastored eleven years. Taught on college level 5½ years. Media experience.
Box number 72B

Recent Ph.D in applied mathematics, MS, BS engineering degrees. Extensive experience as senior system engineer for a major satellite program. Strong analytic and computer science skills. Have directed small project teams. Possess presentation skills, knowledge of marine systems, knowledge of military services requirements, have held clearances.
Box number 74B

Microwave engineer with three years experience in antenna design and production seeking professionally challenging career in northeast US. Strengths include involvement with numerous projects (100 MHz-65 GHz) as well as management experience. Strong communication/customer relation skills.
Box number 75B

Highly experienced, motivated professional seeking a return to NASA-based project. My 10+ years of NASA projects includes OGO-ETDRSS, AEES & SARSAT. Tasks supporting NASA projects include: S/W manager, project engineer, scientific programmer/analyst. Skills include competence with most S/W languages and business packages, writing, and meeting goals.
Box number 76B

To submit an ad for inclusion in this column, send a copy of your resume and a 50-word summary to: *NASA Tech Briefs*, 41 East 42nd St., New York, NY 10017, ATTN: Gregg McQueen.

To Request Resumes:

To obtain resumes corresponding to the above **Positions Wanted Ads**, fill out this form and mail to: *NASA Tech Briefs*, 41 East 42nd St., New York, NY 10017. ATTN: Gregg McQueen, or call 1-800-944-NASA and ask for Gregg McQueen.

Send resumes for the following box numbers (limit 5):

Box_____ Box_____ Box_____

Box_____ Box_____

Name: _____

Company Name: _____

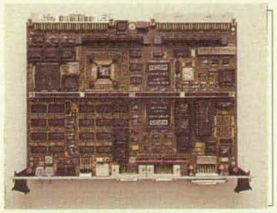
Street Address: _____

City/State/Zip: _____

HIGH-TECH PRODUCT NEWS

SPARCclassic™ Board

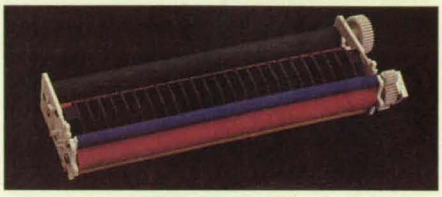
The SPARC CPU-3CE™ VME board for SPARCclassic workstations from FORCE COMPUTERS, Inc., San Jose, CA, provides maximum performance and functionality at a relatively low cost. The compact CPU-3CE has an on-board memory capacity for 8, 16, 32, or 64 MB of DRAM, and easily supports SBus memory and I/O devices. Software support is available to meet a broad range of application needs. **Write In No. 119**



Two Channel Function Generator

The YOKOGAWA Model FG120 Function Generator provides fully independent 2-channel operation. DDS technology is employed producing a frequency range of 1 µHz to 2 MHz with a frequency accuracy to 1 ppm. Both a single and two channel version are offered. **Write In No. 117**

Conductive Polyurethanes for ESD Management



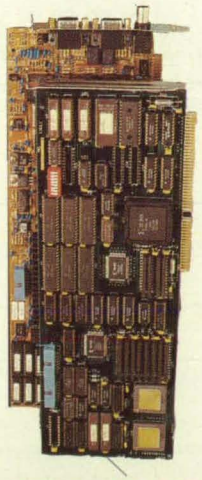
Mearthane® Polyurethanes can be used for many applications such as silicon wafer transport assemblies and laser printers where electrostatic dissipation or tribocharge management is required. Mearthane PU compounds utilize 0.5% to 5% of a proprietary liquid conductive additive which does not affect the material's physical properties or service life, and provides stable bulk resistivity. The compounds are custom formulated to provide hardness in Shore D, A, OO and Pandux, and demonstrate improved thermal conductivity. **Write In No. 118**

Battery-Powered Digital Gage Offers High Accuracy at Low Cost

The PG-2000 digital pressure gage from PSI-TRONIX incorporates a semiconductor strain gage pressure transducer as the sensing element, conditioned by hybrid electronics. It requires very low power consumption, resulting in a battery life of 5 years in typical use. The large 3½ digit display and ± 0.25% full scale accuracy allow it to replace much larger gages. **Write In No. 100**

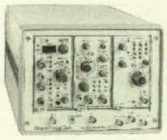
REAL-TIME Image Processing Users!

Univision's Eagle brings a full range of REAL-TIME image processing capabilities to your IBM PC/AT or compatible. The Eagle includes a true VGA compatible display output with a built-in Frame Grabber, so images can be transferred, processed in REAL-TIME at 30 frames per second, and then displayed on a standard VGA monitor. The Eagle's special architecture performs a variety of REAL-TIME image processing functions. Contact 617-221-6700 or fax to 617-221-6777. **Write In No. 131**



Use "Tek7" Diff Amps with any Scope

The ASM7 mainframe from Oregon Analog Tools adds "analog" measurement capability to any digital scope or ATE system. The mainframe provides power and signal interface for one, two, or three TEKTRONIX 7000 Series plug-in amps. DC Current-probe amp support is optional. Adding ASM7-supported amps gives your scope a major capability boost for very little cost. Please call (503) 591-9445. **Write In No. 121**



Microprocessor-Controlled Process Oxygen Analyzer

The Platinum Series analyzer has a large display for good visibility in plant and laboratory environments. Available in a wide dynamic single trace and percent ranges with improved accuracy and resolution, the analyzer's sensor uses a **non-depleting electrode technology** that is factory calibrated to NIST traceable standards. **Write In No. 126**

QuickStart™ Software Cuts Development Time

QuickStart™ software from Berkley Process Control eliminates development costs associated with machine control system startup and configuration, motor tuning, and hardware diagnostics by providing these standard functions on powerup. Designed for the multi-axis Bam™ Series-64 Machine Controller, QuickStart's facilities can provide intuitive touch screen operation for a wide range of industries. **Write In No. 128**

Precision High Voltage DC Power Supplies

Farnell Hivolt manufactures precision, regulated high voltage DC power supplies for applications including Electron and Ion beam, X-Ray, photomultipliers, and lasers. Models range from miniature PCB mountable modules to multi-Kilowatt rack mounted assemblies. Call 216-349-0755 for information. **Write In No. 132**

New Line Of Vacuum Valves

Balzers has introduced a new line of vacuum valves designed for accurate, easy-to-use gas flow control. Balzers' viton-sealed EVN 116 vacuum gas dosing and shutoff valve delivers faster response and excellent reproducibility to 10^{-8} torr. For UHV applications, the manual UDV 040 all-metal gas dosing valve is used as a controlled gas inlet in vacuum systems and the automatic UDV 140 with controller RGB 050B controls either total or partial pressure or gas flow via a pressure sensor. Multi-volt vacuum angle valves offer small power consumption and no induction spikes. For more information, contact: Mr. Craig Lazinsky, Balzers High Vacuum Products. Tel: 603-889-6888. Fax: 603-889-8573. **Write In No. 129**

Cleaning With Supercritical CO_2

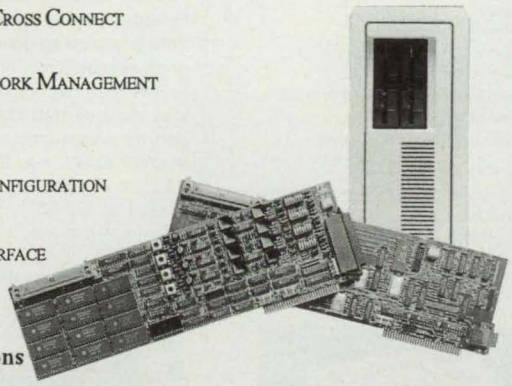
EnviroPro Technologies offers a complete line of cleaning systems utilizing CO_2 as the cleaning agent. This process replaces conventional CFC, Solvent and Aqueous-based cleaning processes. The use of CO_2 eliminates the need for a drying operation and provides extremely low operating cost. For more information call EnviroPro Technologies at 1-800-458-0409. **Write In No. 130**

HIGH-TECH PRODUCT NEWS

μDACS™

PC-Based T1 Digital Access Cross Connect Switch

- PC-BASED
- LOWEST COST DS0 CROSS CONNECT AVAILABLE
- INCORPORATES NETWORK MANAGEMENT
- 9 ALTERNATE MAPS
- SF AND ESF
- EVENT DRIVEN RECONFIGURATION
- REMOTE CAPABILITY
- USER-FRIENDLY INTERFACE



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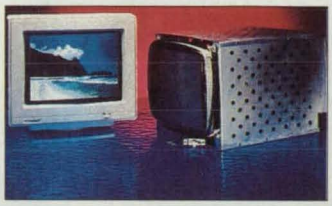

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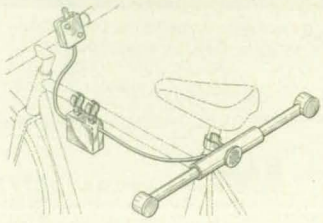

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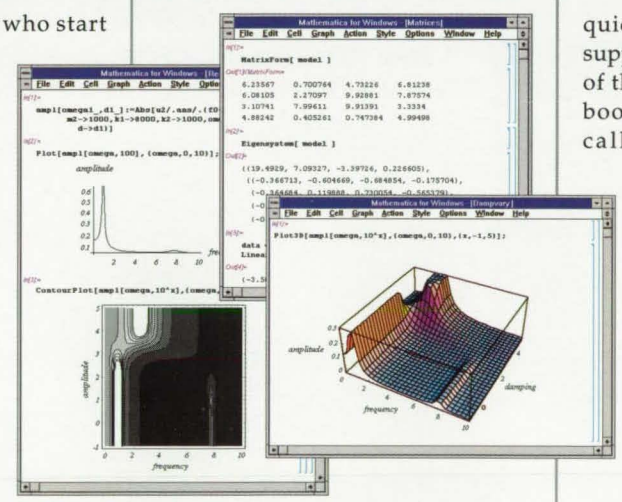

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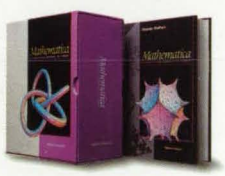

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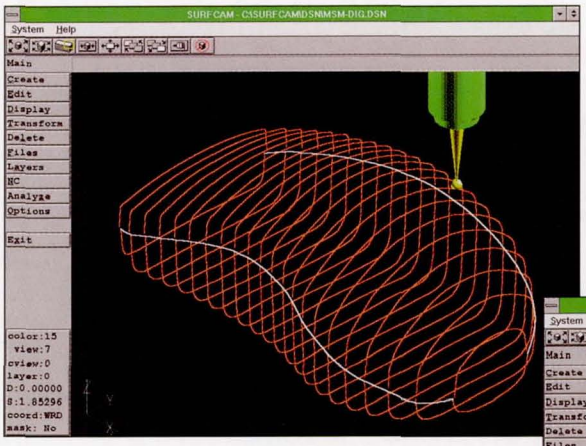
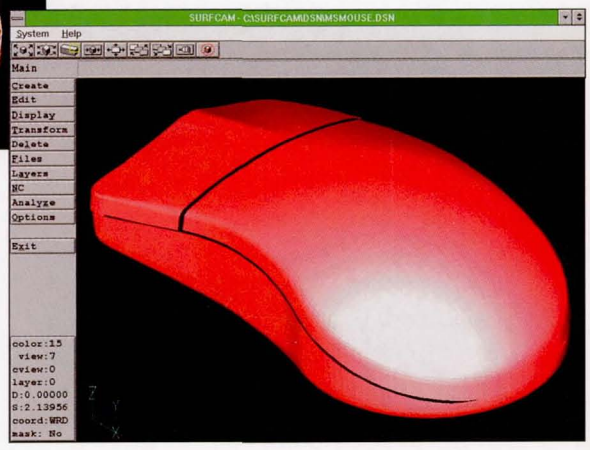
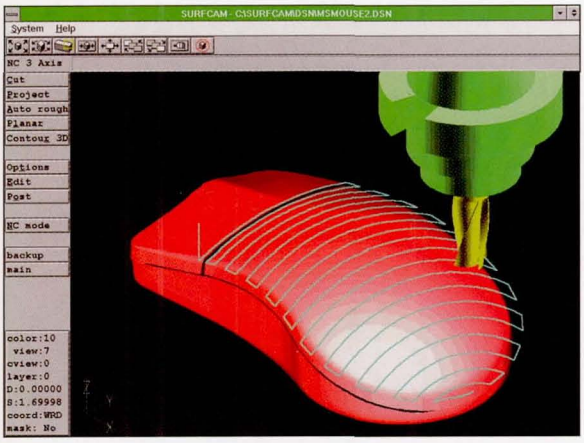


Step #1: Microsoft's industrial designers hand-carved mouse models, which were extensively tested for comfort and then digitized with a coordinate measuring machine. From the CMM data, 3D computer models were created in SURFCAM to replicate the physical model.

Step #2: Adjustments were made in the computer model, such as lowering the hump in the middle, creating the raised surface between the key surfaces, and experimenting with different variable fillet radii around the edge of the case.





Step #3: CNC toolpaths were generated in SURFCAM to machine the final models for ergonomic verification. The same data was then used to create the electrodes for the injection molding tools. Western Industrial Tooling, Inc., of Redmond, WA, was both the model builder and the fabricator of the injection molds.

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