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November 1988
Volume 12 Number 10

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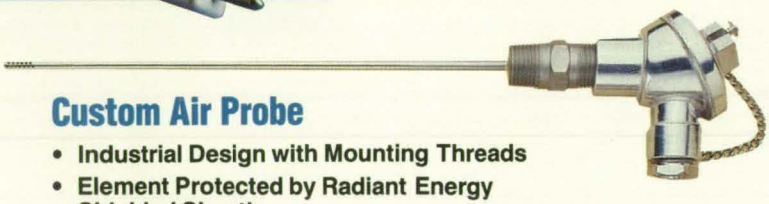

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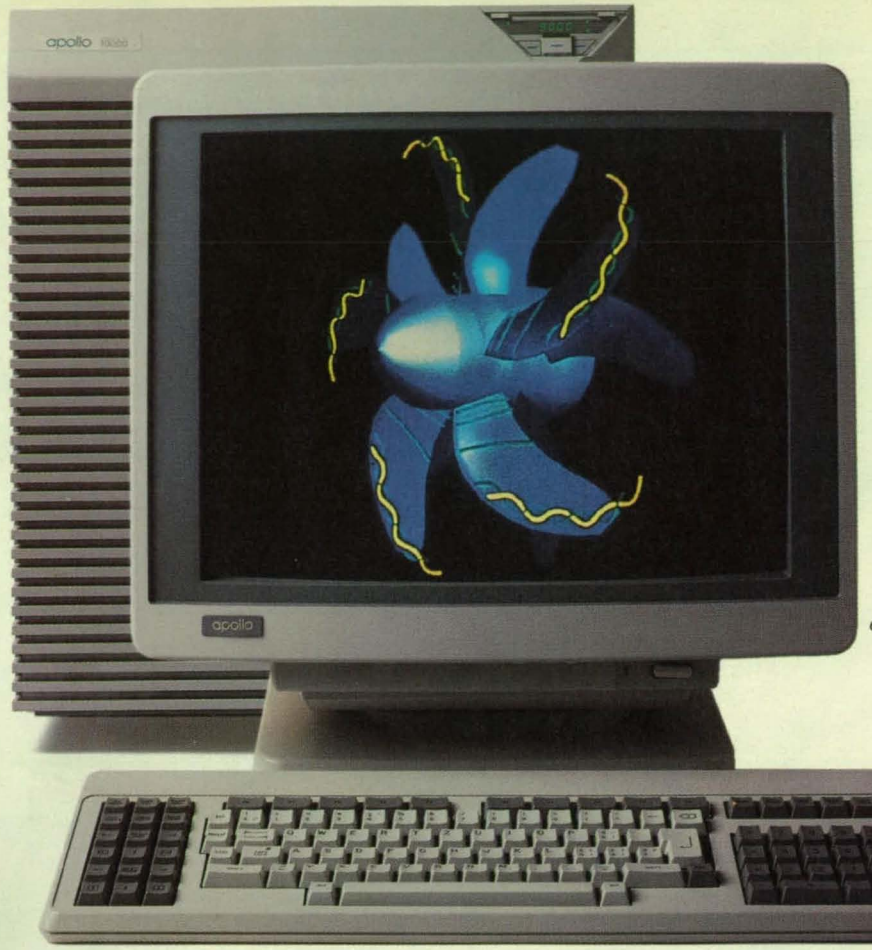

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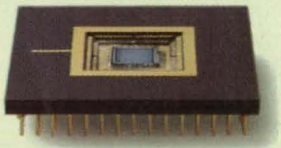
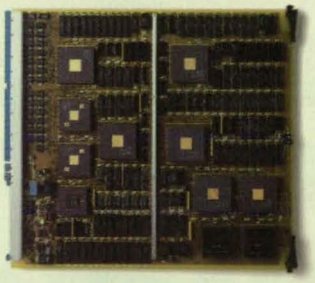
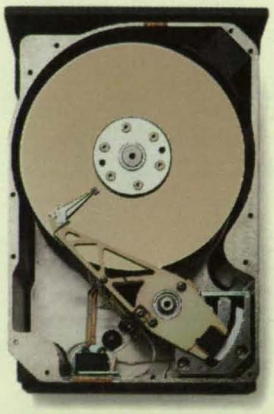


Faster Chips for Faster Processing: Advanced CMOS and ECL semiconductor technology are used throughout to improve performance.

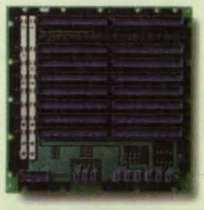


A Power Plant for Performance: Each system can have up to four CPUs, delivering performance 100 times that of a VAX® 11/780.



Where There are Discs There are Data: Disc striping, a concept previously limited to supercomputers, provides fast access to as many as four high capacity ESDI drives.

Clever Compilers for Data Flow: So none of this power goes to waste, sophisticated compilers map existing applications to match the CPU architecture and maximize application throughput.



A High Speed Bus: Our system bus passes information between CPUs and main memory at 150 million bytes per second.

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apollo

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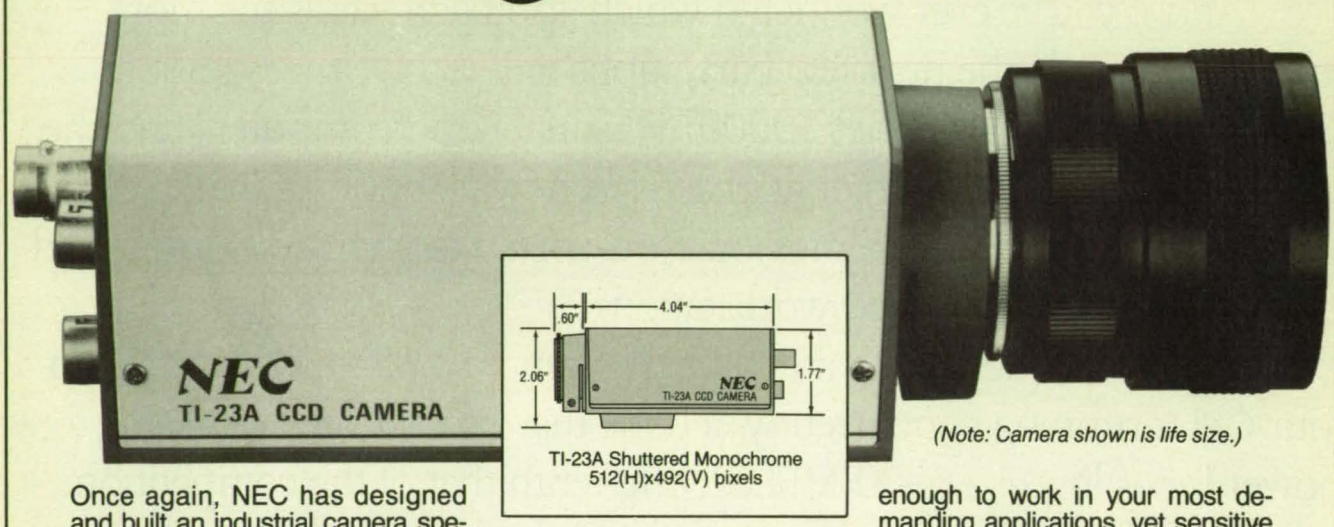

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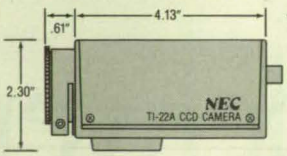

TI-22AII Monochrome
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TI-24A High-Resolution
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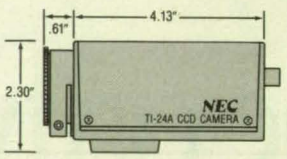

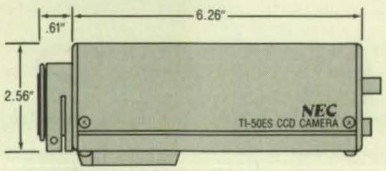

TI-50ES High-Speed
Shuttered Monochrome
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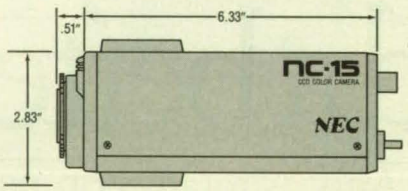

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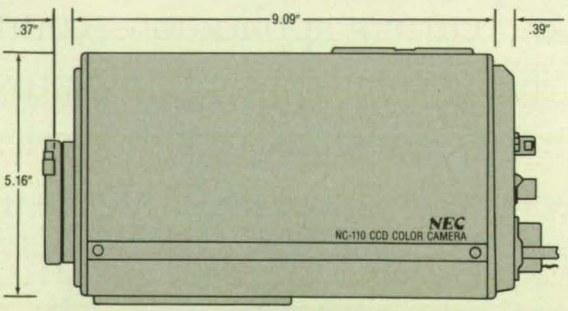

NC-110 Color, RGB Available
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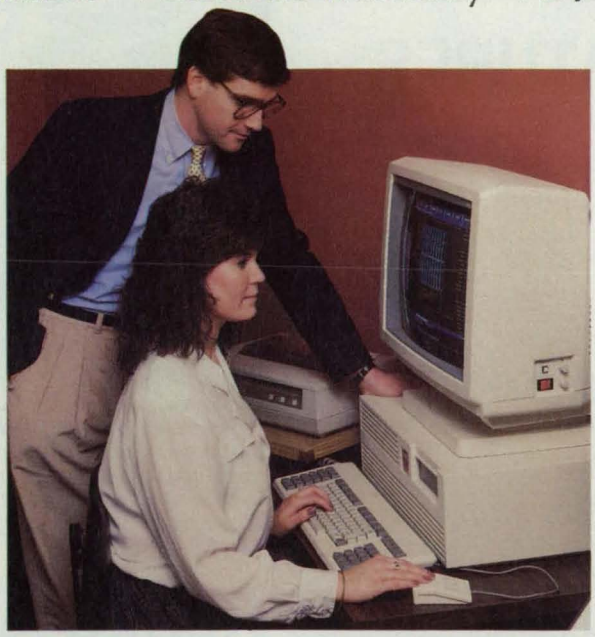

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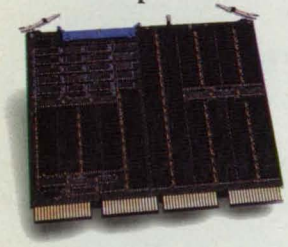

The **DCME-M30/32** quadruples the density offered by DEC. Available in 8, 16 and 32 MB boards, Clearpoint's design combines the winning features of greatest density, competitive pricing and unparalleled support.

MicroVAX 2000-Compatible

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MicroVAX II-Compatible

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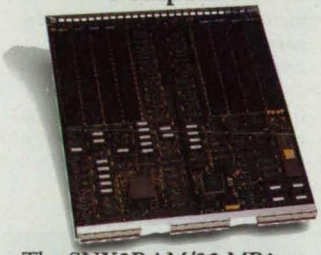
Sun 3/2XX and 4/2XX-Compatible



The **SNX2RAM/32 MB***, delivers 32 MB on a single board for the Sun 3/2XX and 4/2XX. Plus, take advantage of the microprocessor-managed "on-board hotline" for local and remote system-independent diagnostics.

Sun 3/1XX-Compatible

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SIMMs for Sun 3/60, 4/1X0 and 386i

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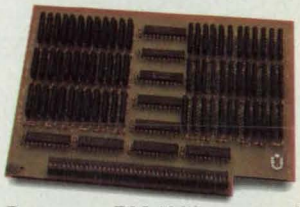
DN 4000-Compatible



Bring your DN 4000 up to its 32 MB capacity with the **DNX4RAM***. Available in 8 MB boards, Clearpoint's cost-effective memory provides Apollo-equivalent performance with lifetime product support.

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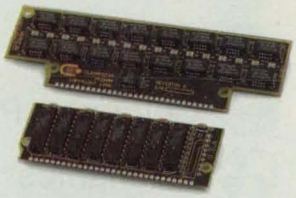

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National Aeronautics and Space Administration

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Volume 12 Number 10

SPECIAL FEATURES

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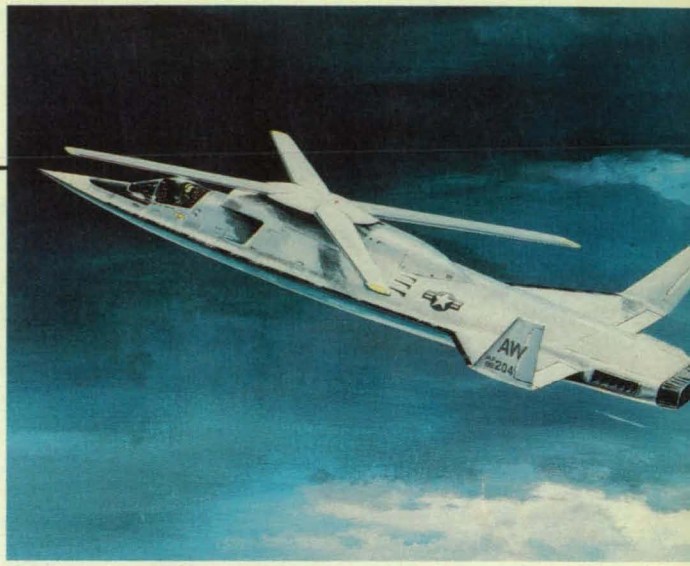

This conceptual drawing shows an X-wing rotorcraft with convertible gas-turbine engines. Now being tested at NASA's Lewis Research Center, the hybrid engines can produce any combined thrust and shaft power continuously at full speed and could save 20 percent in rotorcraft operating costs. See page 68. *(Photo courtesy NASA)*

DEPARTMENTS

On The Cover: A supercomputer simulation of airflow within a jet engine reveals the hot streaks from combustion that surround the turbine's rotor and stator blades, shown in black. Turn to page 12. *(Photo courtesy NASA)*

Imaging techniques originally developed for NASA satellite photos are now being used by doctors to view the workings of the human heart. See Mission Accomplished, page 92. *(Photo courtesy Philips Medical Systems, Inc., Shelton, CT)*

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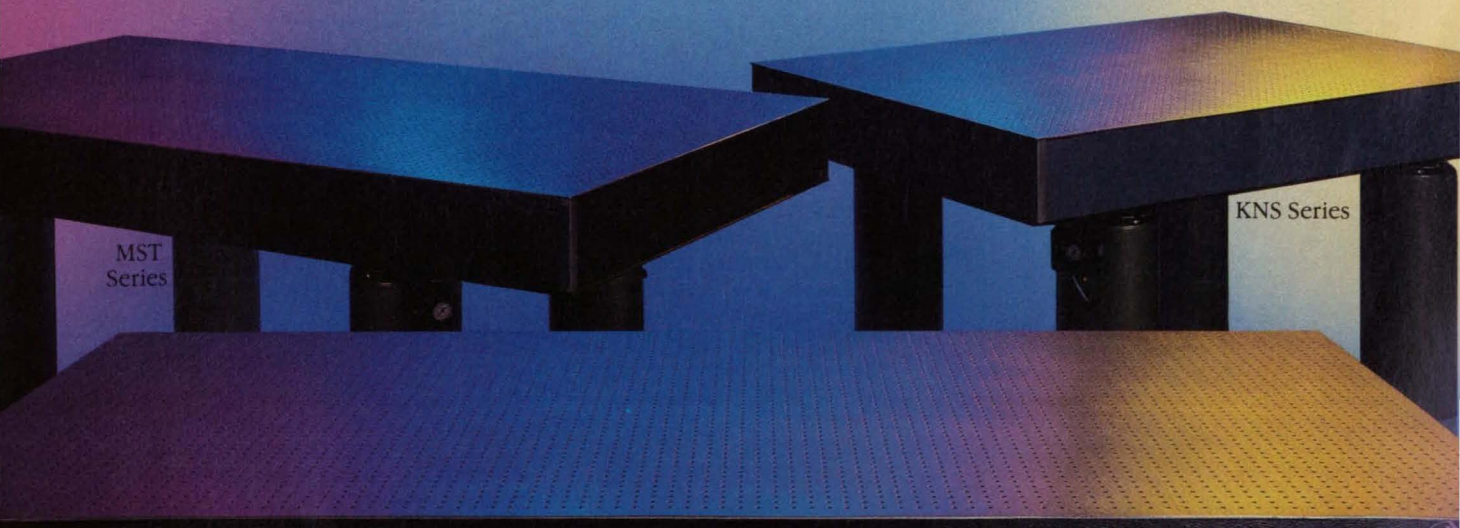

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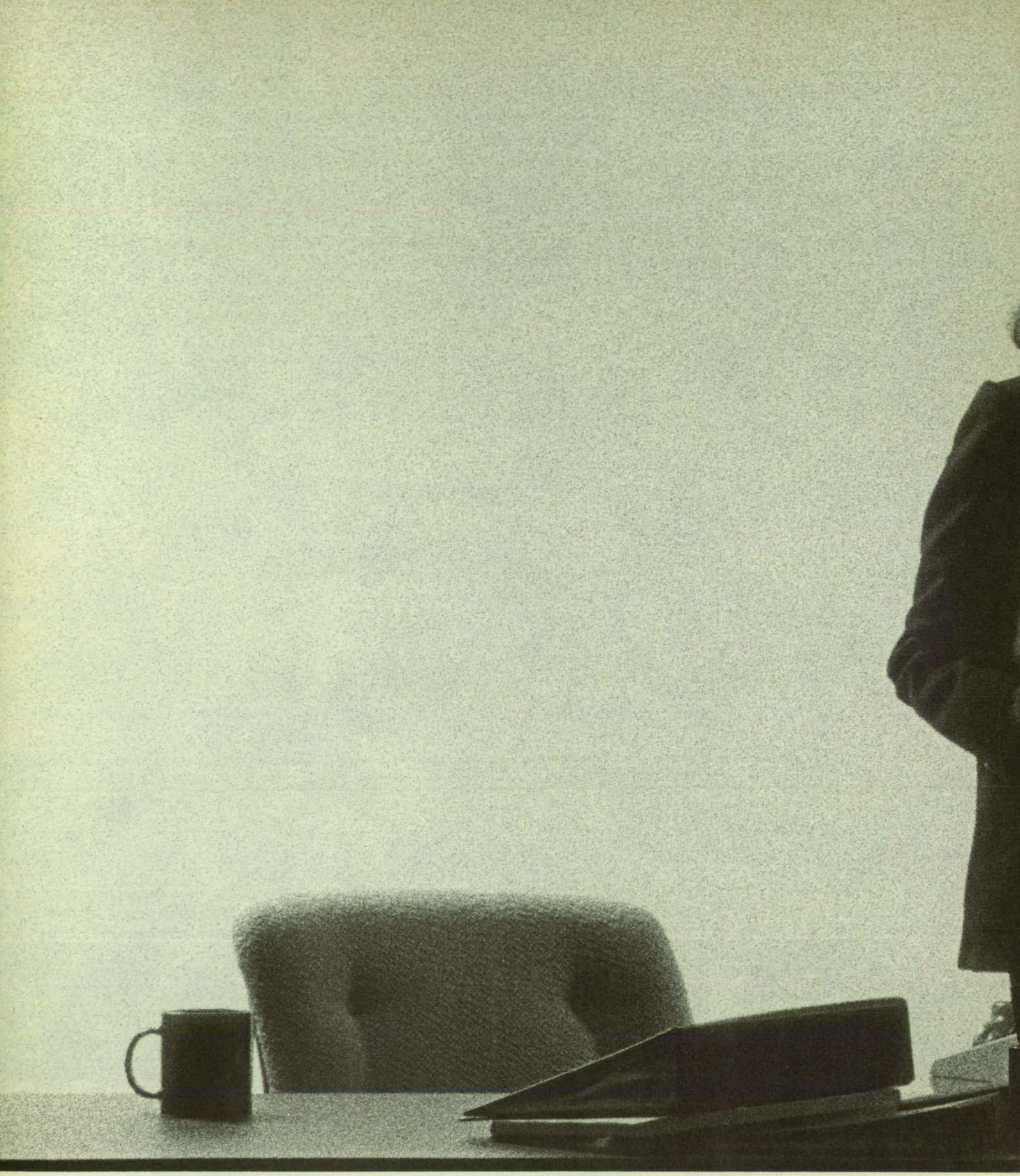

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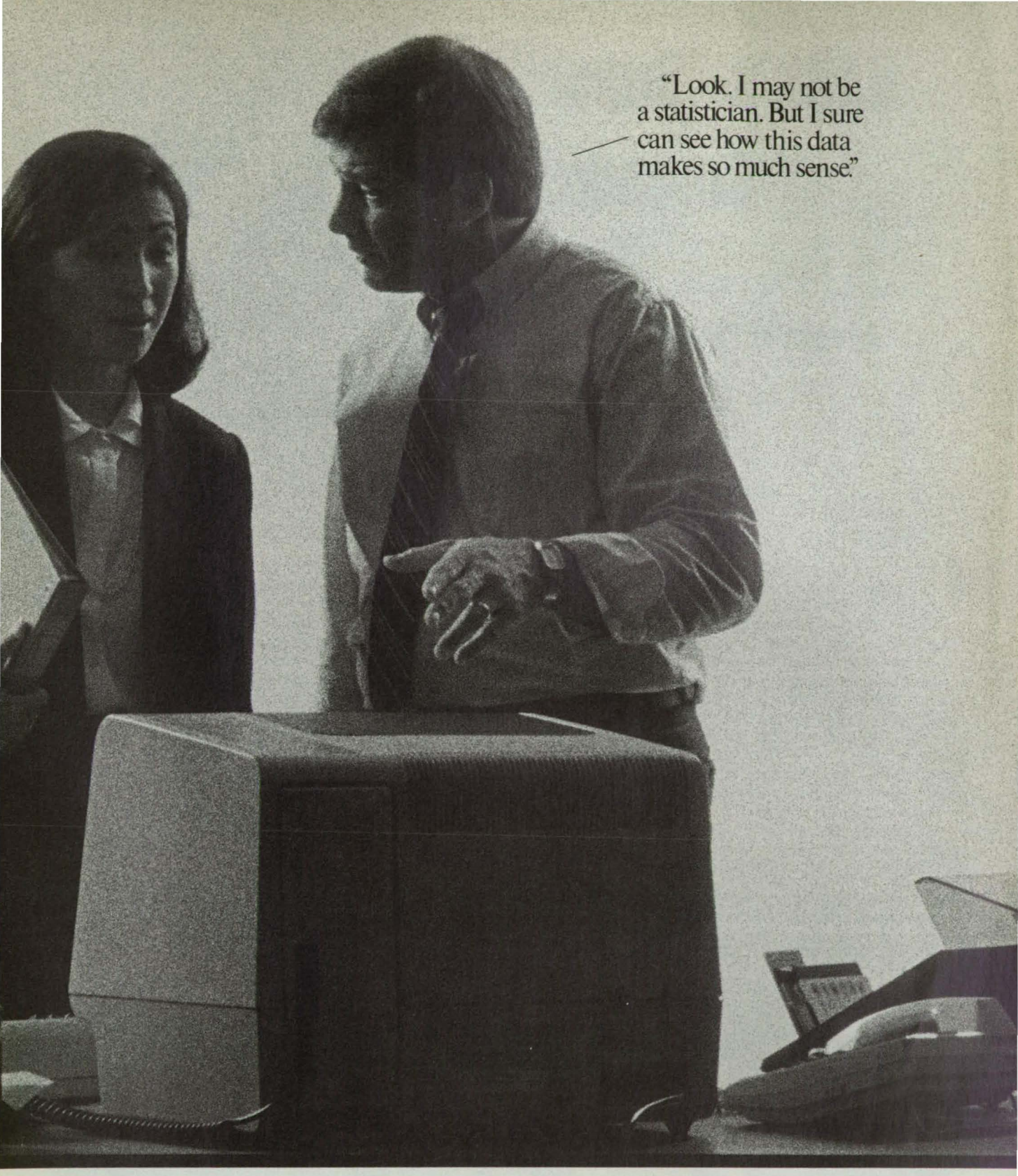

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NASA's "Super" Computer Model

Advanced Simulation Technique To Aid Engine Design

In one of the most complex computer simulations ever attempted, involving 22 trillion calculations, NASA researchers have recreated to a new degree of precision the unsteady airflow within jet engine turbines and compressors. Hailed by space agency scientists as a "pathfinding" achievement in computational fluid dynamics, the computer model should help engine manufacturers to develop smaller, more efficient, and longer-lasting power plants, leading to multimillion dollar savings for the United States aviation industry.

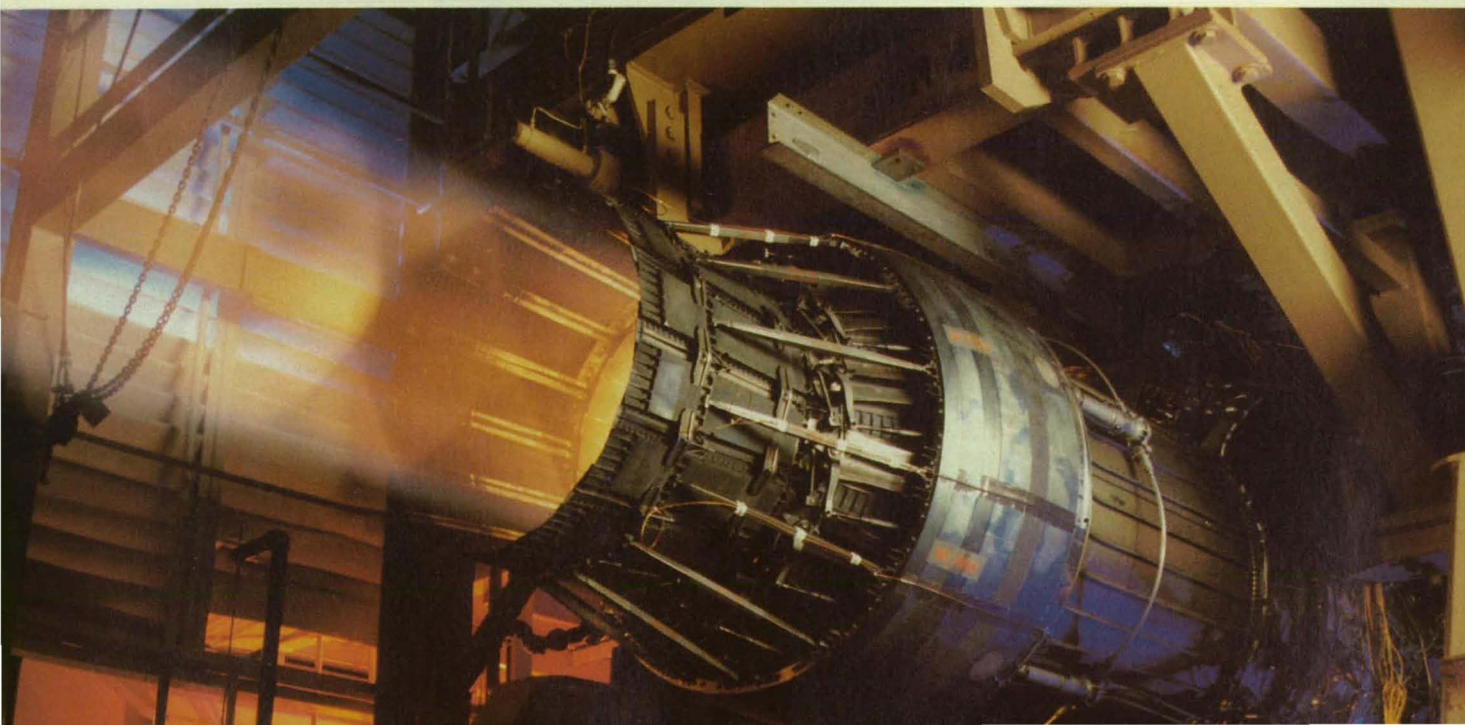
"This work is significantly more complete than previous flow simulations," said Terry Holst, Chief of the Applied Computational Fluids Branch at NASA's Ames Research Center. "Previous computer models have involved major approximations. Some do not calculate unsteady flow, and others rely on simplified geometries."

In contrast, the NASA model's geometry is so complex it can account for minute details such as the narrow gap between the tips of the rotors and the outer casing of the turbine hub.

The model tracks flow in three dimensions over time, allowing engineers to accurately analyze interior changes in pressure, temperature, and velocity of proposed designs.

"Calculating airflow within aircraft engines is difficult because the flow constantly changes due to the relative motion between the stator and rotor airfoils," explained Dr. Man Mohan Rai, the Ames engineer who developed the model. Wind gusts outside an airplane or other changes in the pressure of air entering the engine add to the unsteady flow, inducing stresses on engine parts. These stresses cause thermal and mechanical fatigue that can drastically reduce the lifetime of parts.

Rai's model predicts when changes in pressure will occur, enabling engineers to alter their designs to minimize stress, or to reinforce components under pressure with high-strength alloys.



Rai's model reproduces the intense pressures and heat inside a jet engine.

This simulation of rotor-stator interaction in an aircraft engine is based upon computations by Ames researcher Dr. Man Mohan Rai. Rai's computer model enables engineers to track changes in air pressure, temperature, and velocity within a turbine in greater detail than previously possible.

Compact Power Plants

Airflows interacting around closely positioned parts can also create a complex, unsteady flow field. The closer the parts are, the more severe the fluctuations become. Rai's method provides analyses of these interactions, so that engine designers can understand their effects. "Once they know exactly what's happening and why," Rai said, "they'll be able to place engine parts even closer together. Engines could be made smaller and lighter, saving space and fuel."

The model also is useful for calculating the frictional drag produced by the motion of fluids over the turbine blades, as well as the formation of vortices that block air traveling through engine channels. It can predict the size, strength, and location of these vortices, paving the way for more efficient turbine designs, said Rai. "If every engine presently on U.S. commercial aircraft were replaced with a model just one percent more efficient," he said, "the net savings per year would be about one hundred million dollars."

Quieter Subs

Rai's simulation technique should enable researchers to experiment with new turbine blade designs without having to build and test expensive prototypes, and could be adapted for designing other turbomachinery, such as rocket engines, helicopter rotors, gas turbines in power plants, and submarine pumps. The latter application has attracted interest from the Navy, according to Rai.

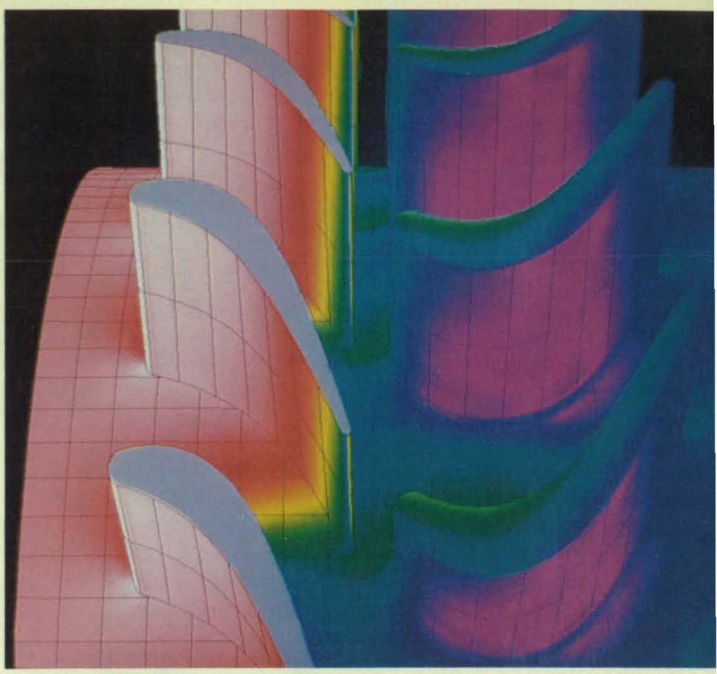
"The pumps on board a submarine generate a lot of noise," he explained. "If you could minimize this noise during the design process, you would greatly decrease the sub's chances of being detected by an opposing force. The model gives as part of its solution the amount of noise being put out, so it should be ideal for solving this type of problem."

The Number Crunch

A single simulation by the NASA model can create two billion data points—enough to fill a library of books. "There's so much information," said Rai, "the problem is where to look."

To help researchers understand the results, Rai and Sterling Software engineer Paul Kelaita structured the data for visual display, a painstaking task requiring nearly a year to complete. Using a Silicon Graphics IRIS workstation, they developed high-speed color graphics that visualize the complex fluid flow.

"The graphics are constantly evolving," Rai said. "Mr. Kelaita is now working on 3D stereo animation. To watch the graphics you wear colored glasses—just like 3D movies."



A simulation of airflow through a three-dimensional rotor-stator combination. Colors indicate different pressure levels.

Grid Interlock

Developing an accurate model for jet engine airflow required a technological leap in grid generation. Explained Rai: "It's standard practice in computational fluid dynamics to put a grid around a body in order to study the surrounding flow. But this gets tricky when you have to account for both stationary and multiple moving bodies, as is the case with the rotor-stator combinations in jet engines. If you tried to wrap a single grid around the rotor and stator you'd have to distort the grid points considerably to accomodate the motion of the rotor, which could result in inaccurate calculations."

Rai's solution was to use several grids that were either patched together or overlaid to simulate the relative motion of the stator and rotor airfoils. He developed a scheme to accurately transfer information between the grids by applying specialized boundary conditions. "The boundary conditions had to be numerically stable, spatially and temporally accurate, and conservative so that flow discontinuities could move from one grid to another without distortion," he said.

In 1984 Rai created a two-dimensional multiple grid program for unsteady flow which is now being used in rotor-fuselage analysis. The new model's three-dimensional geometries eliminate the approximations involved with that earlier program.

Rai's codes have been distributed to General Electric, Pratt & Whitney, and other U.S. engine manufacturers. Now valuable to these companies as an analytical tool, the model must achieve a faster computer run time to be practical for design purposes. Although the simulation now requires 100 hours on a Cray Research CRAY-2 supercomputer, NASA expects within a year to reduce the time to 20 hours, in part by using the new CRAY Y-MP which was recently delivered to Ames' Numerical Aerodynamic Simulation (NAS) supercomputer facility. Presently the world's fastest supercomputer, the Y-MP can handle up to 240 billion bytes of high-speed storage.

Much of the future work on multiple engine stages awaits the development of even faster and larger computers. "In a few years we'll have machines that are five or ten times faster than what's available today," predicted Rai. "At that point the model's run time will be about an hour, making it economical for a broad range of commercial applications."

"We're pushing the state-of-the-art in supercomputing," he added. "We can't give you reality just yet, but we're getting closer every day." □

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Product profile

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Circle Reader Action No. 496

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 18). NASA's patent-licensing program to encourage commercial development is described on page 18.

Self-Protecting Heat Exchanger

A proposed double-wall heat-exchanger tube would protect itself from overloads. When the temperature at any location on the tube increases above a prescribed limit, the thermal resistance through the walls of the tube would increase at that location. When the heat load falls to a normal level, the tube would automatically lower its thermal resistance and resume heat exchange at its rated capacity.
(See page 61).

Circular-Waveguide Power Combiner/Divider

A waveguide coupling device combines power from 16 input ports into 1 output port or distributes power from 1 input to 16 outputs. Operating at frequencies of 55 to 67 GHz, the combiner/divider exhibits an insertion loss of no more than 1 dB and a return loss of at least 12 dB.
(See page 34).

Airplane Takeoff-and-Landing Monitoring System

The Takeoff Performance Monitoring System (TOPMS) is designed to increase safety during takeoffs and landings of aircraft. The system provides valuable takeoff/abort/landing information not currently available in the cockpit and presents it in forms that are simple and easily monitored by the pilots.
(See page 36).

Protective Socket for Integrated Circuits

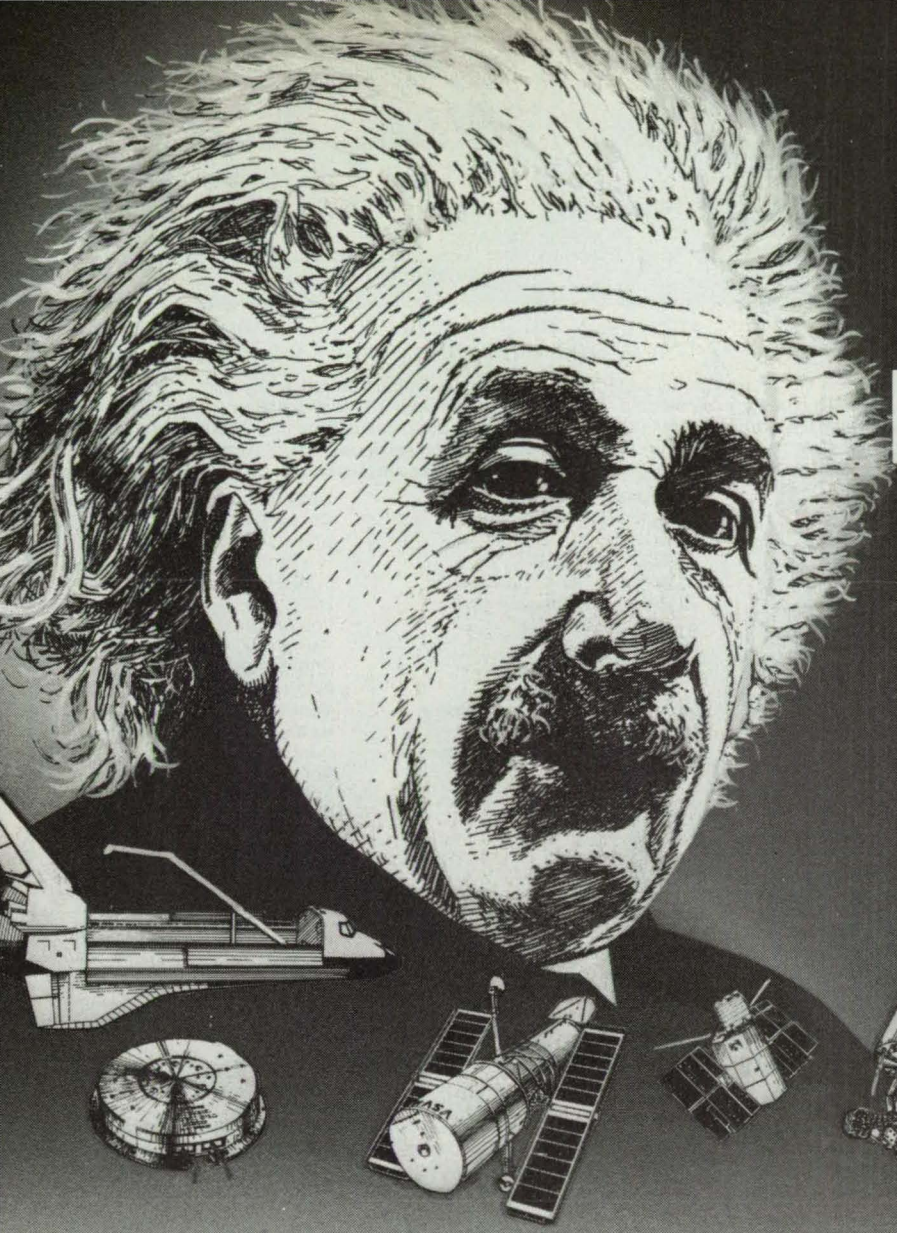
A built-in switch in a proposed socket would protect an IC from excessive voltages and currents. The socket would contain a built-in switch that would open as the IC is removed, thereby disconnecting its leads, and that would close as the IC is inserted, thereby connecting the leads electrically.
(See page 20).

Convertible Gas-Turbine Engines

Convertible engines could be used to power vertical/short-takeoff-and-landing (V/STOL) airplanes and advanced high-speed rotorcraft. Studies of conceptual high-speed rotorcraft have shown that these engines can save as much as 16 percent in fuel and 20 percent in direct operating costs.
(See page 68).

Automated Water-Purification System

An automatic water purifier uses reverse osmosis to purify raw well water from 500 to 600 ppm of dissolved solids to less than 45 ppm. Processing water at 15 gal/min (0.95 L/s), the system is regulated by a programmable controller that minimizes manual maintenance and monitoring. (See page 70).



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

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How You Can Access Technology Transfer Services At NASA Field Centers:
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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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Circle Reader Action No. 339

Electronic Components and Circuits

Hardware Techniques, and Processes

Protective Socket for Integrated Circuits

A built-in switch would protect against transients during removal and insertion.

Goddard Space Flight Center, Greenbelt, Maryland

A proposed socket for integrated circuits (IC's) would protect an IC from excessive voltages and currents or from the application of voltages and currents in the wrong sequence during insertion or removal. The socket would contain a built-in switch (see figure) that would open as the IC is removed, thereby disconnecting its leads from signals and power, and that would close as the IC is inserted, thereby connecting the leads electrically. The socket would also protect other components on the circuit board from transients produced by insertion and removal of the IC.

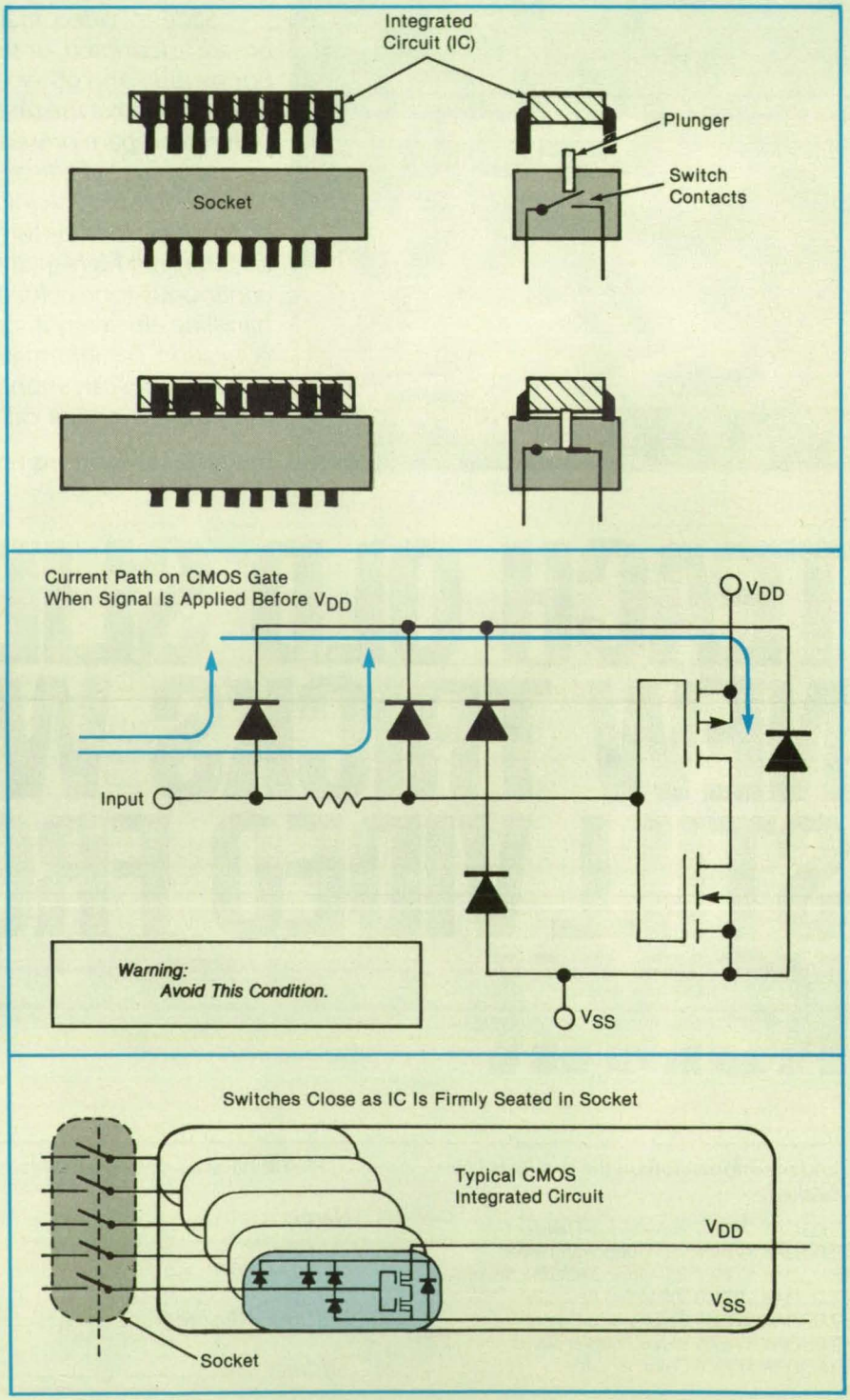
The socket would make it unnecessary to turn off power to the entire circuit board so that other circuits on the board could continue to function. The socket would prevent inadvertent damage in case one forgets to turn off the main power before inserting or removing an IC.

It would also be unnecessary to place protective resistors in series with the IC leads to limit transients. Space on circuit boards would thereby be saved, and the slight deterioration of signal quality that protective resistors introduce would be avoided.

The socket would be designed so that the switch opens before the leads lose firm electrical contact with the socket during extraction. During insertion, the switch would close only after all leads make firm contact.

For complementary metal oxide/semiconductor (CMOS) IC's, it is essential that no signals be applied until the circuits have power. Accordingly, sockets for CMOS IC's would be designed so that during insertion built-in switches turn on power before other switches admit signals.

This work was done by Chris Wilkinson and Greg Henegar of **Goddard Space Flight Center**. *No further documentation is available. GSC-13033*



An **Integrated-Circuit Package** would push a plunger as it is inserted in a socket. The plunger would close the contacts on the switch, thereby applying power and signals to the integrated circuit. Other sockets, such as those for zero-insertion-force and pin-grid-array packages, could be adapted to the built-in-switch concept.

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Circle Reader Action No. 636

Estimating Rates of Single-Event Upsets

Probabilities of errors are calculated from a semiempirical model.

NASA's Jet Propulsion Laboratory, Pasadena, California

A mathematical model yields estimates of the upper and lower bounds on the rates of single-event upsets (SEU's) in logic circuits. SEU's are reversible changes in logic states, caused by single high-energy ions. The model should be useful in the design of such integrated circuits as high-density memories for minimal susceptibility to bit errors.

According to the model, SEU occurs in a memory cell that holds 1 bit when an ion penetrates a critical volume V_c in the cell and deposits there enough energy, E_c, to form at least a critical charge Q_c. The parameters in the model are obtained experimentally by measuring the rates of the SEU's and the energies deposited by ions that come to rest in and that pass through the critical volume of the cell (see figure).

First, the minimum ion energy E_c for SEU is assumed to be the measured energy of high-stopping-power heavy ions (e.g., bromine) that enter the cell along a track perpendicular to the surface and come to rest in the critical volume. The critical charge, Q_c, in picocoulombs, is assumed to be given by $Q_c = E_c/22.5$, E_c being expressed in megaelectronvolts. The ion energy is then increased until the measured SEU cross section, A, per bit (that is, per cell) reaches its maximum value, A_{max}.

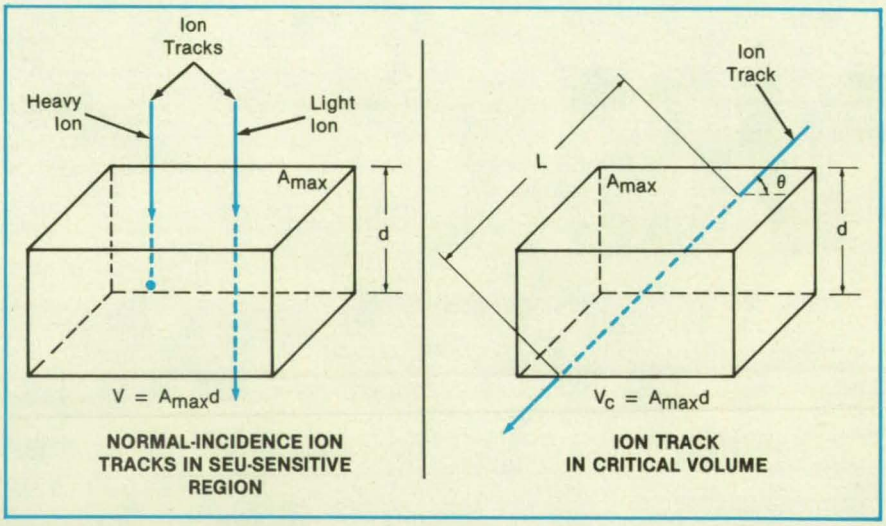
Next, measurements are made with light ions (e.g., carbon) of lower stopping power, which pass through the critical volume of the cell. In this case, the maximum ion energy that causes SEU is determined since the stopping power decreases with increasing energy. The values of the linear energy transfer (LET) and linear charge transfer (LCT) at this energy correspond to the critical values LET_c and LCT_c, respectively, of these two parameters. The charge-collection depth, d, is calculated in micrometers from the following:

$$d = Q_c/LCT_c$$

where Q_c is in picocoulombs, LCT is in picocoulombs per micrometer, and LET (in MeV•cm²/mg)/$LCT \approx 100$ (MeV•cm²•μm)/(mg•pC). The critical volume is then given by $V_c = A_{max}d$.

In applying the model to an ion track that passes through the cell at an arbitrary angle (θ) and has a chord length L through the cell, SEU is assumed to occur if the collected charge $Q = L \cdot LCT$ is at least Q_c. To estimate the rate of SEU contributed by ions entering from all angles, it is necessary to have detailed data on the LET spectrum and its dependence on the orientation of the ion track. However, the minimum error rate can be estimated by assuming that all the ions in a given radiation environment enter at normal incidence (producing the shortest possible ion track in the shallow critical volume), while the maximum error rate can be estimated as that of particles traveling along the body diagonal (the longest possible ion track) through the critical volume.

This work was done by John A. Zoutendyk of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 152 on the TSP Request Card.*
NPO-17270



Energetic Ions are passed through the device in question along tracks perpendicular to the surface, to determine the parameters of the model for SEU. The parameters are then used to estimate the rates of SEU caused by ions of various energies incident at arbitrary angles.

Lens Antenna for Mobile/Satellite Communication

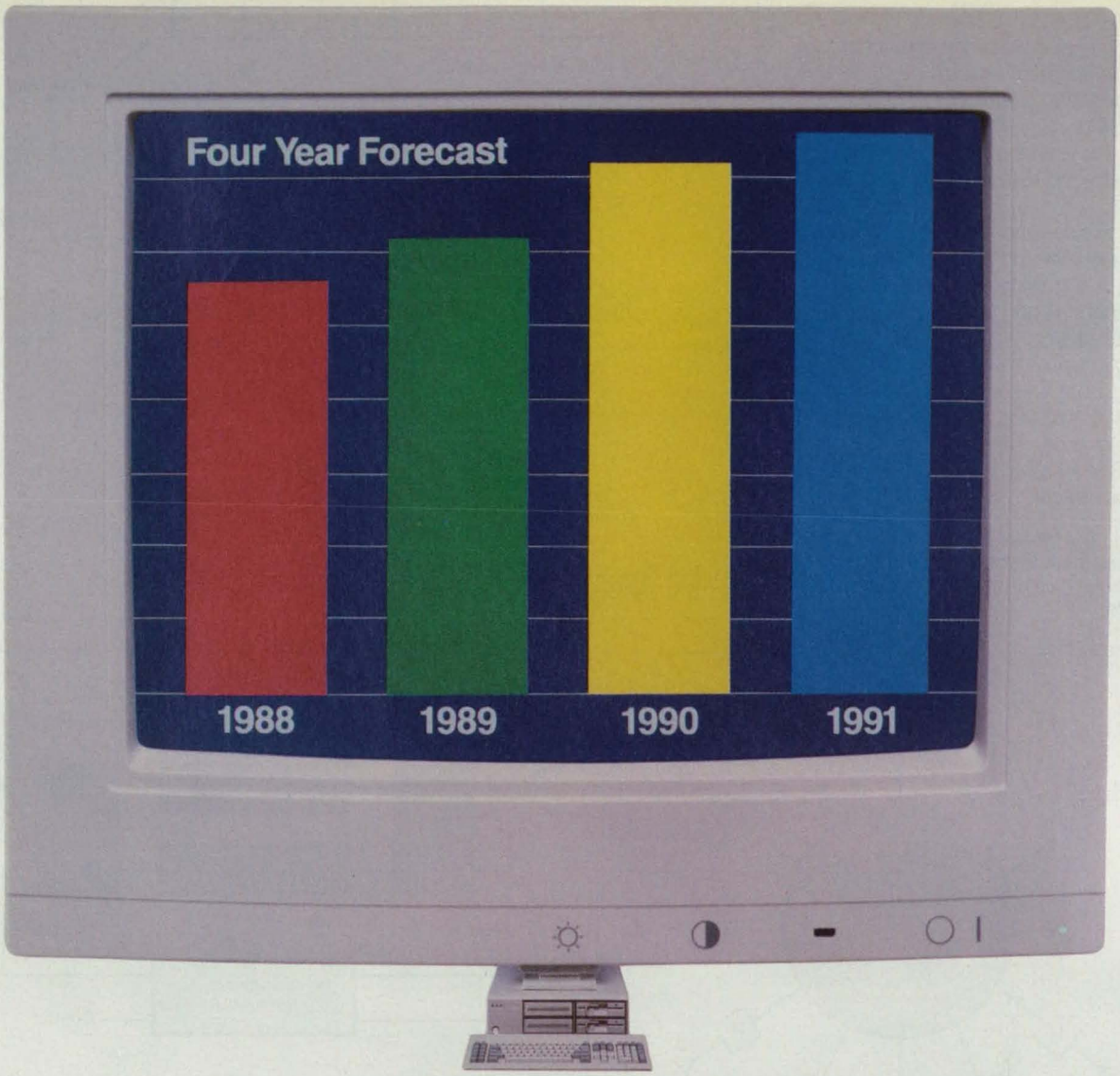
A phased array of elements would lie flat on top of a vehicle.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed flat, compact antenna made of stripline elements would be aimed at a fixed elevation angle but could be steered electronically in azimuth. The antenna is required to transmit and receive circularly polarized radiation in the frequency ranges of 821 to 825 and 860 to 870 MHz, respectively, at elevation angles from 20° to 60° and at all azimuthal angles. Intended for use in the Mobile/Satellite Service, the antenna would be mounted on top of a vehicle on Earth and used to keep the transmitted and received antenna beams aimed approximately toward a communication satellite.

The design is simplified by maintaining a fixed elevation and relying on the width of the beam to cover the desired elevation range. The design is simplified further, and the need for a phase shifter at each radiating element is eliminated by arranging the elements in circles and feeding them through stripline disks called "R-KR lenses" (see Figure 1). Connectors are distributed at equal intervals around the edge of each lens to provide ports to the signal. The elevation angle depends on the radius ratio K and the dielectric constant of the stripline substrate. The relationships among the ports, elements, and lens are such that the far radiation fields of the elements add in phase along the desired beam direction.

A pair of lenses is required per circle of elements for complete azimuth coverage. For complete illumination of the aperture, it is necessary to use two lens pairs: an upper (B_1 and B_2 in Fig. 2) and a lower pair (A_1 and A_2 in Fig. 2). Radiating elements are connected to the lenses and their associated switching networks (see Figure 2) through 90° hybrids. The switching network for each lens includes two 90° hybrids, a 360° phase shifter, and a positive/intrinsic/negative diode for each



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element. Each diode acts as the on/off switch for its port, while the hybrid phase-shifter arrangement enables power to be shared between ports, thereby doubling the number of azimuthal aiming angles and reducing the variation of gain with azimuth angle between selectable beam directions.

Of the two designs subjected to computer simulation, the more successful one involved a 2-ring system with 12 elements on the inner ring and 12 on the outer ring. The worse case gain at any azimuth angle including all losses as well as lobing losses resulting from satellite tracking, is 12.3 dBic at 40°, 10.2 dBic at 60°, and 8.7 dBic at 20° elevation. This configuration produces 48 beams and provides 360° of azimuthal coverage.

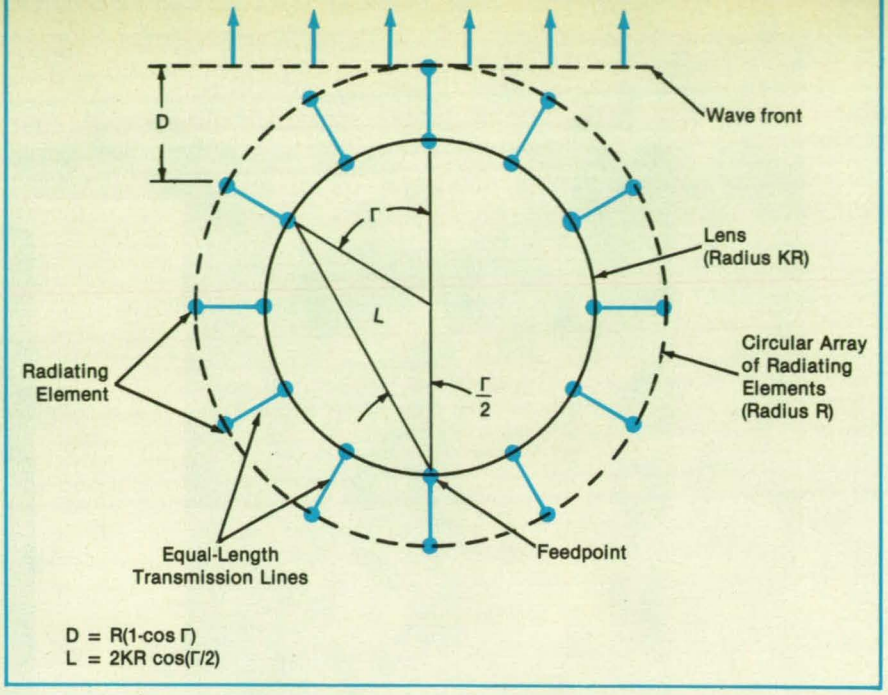

Figure 1. An **"R-KR Lens"** is a circular stripline element that sets the proper phase relationships among radiating antenna elements.

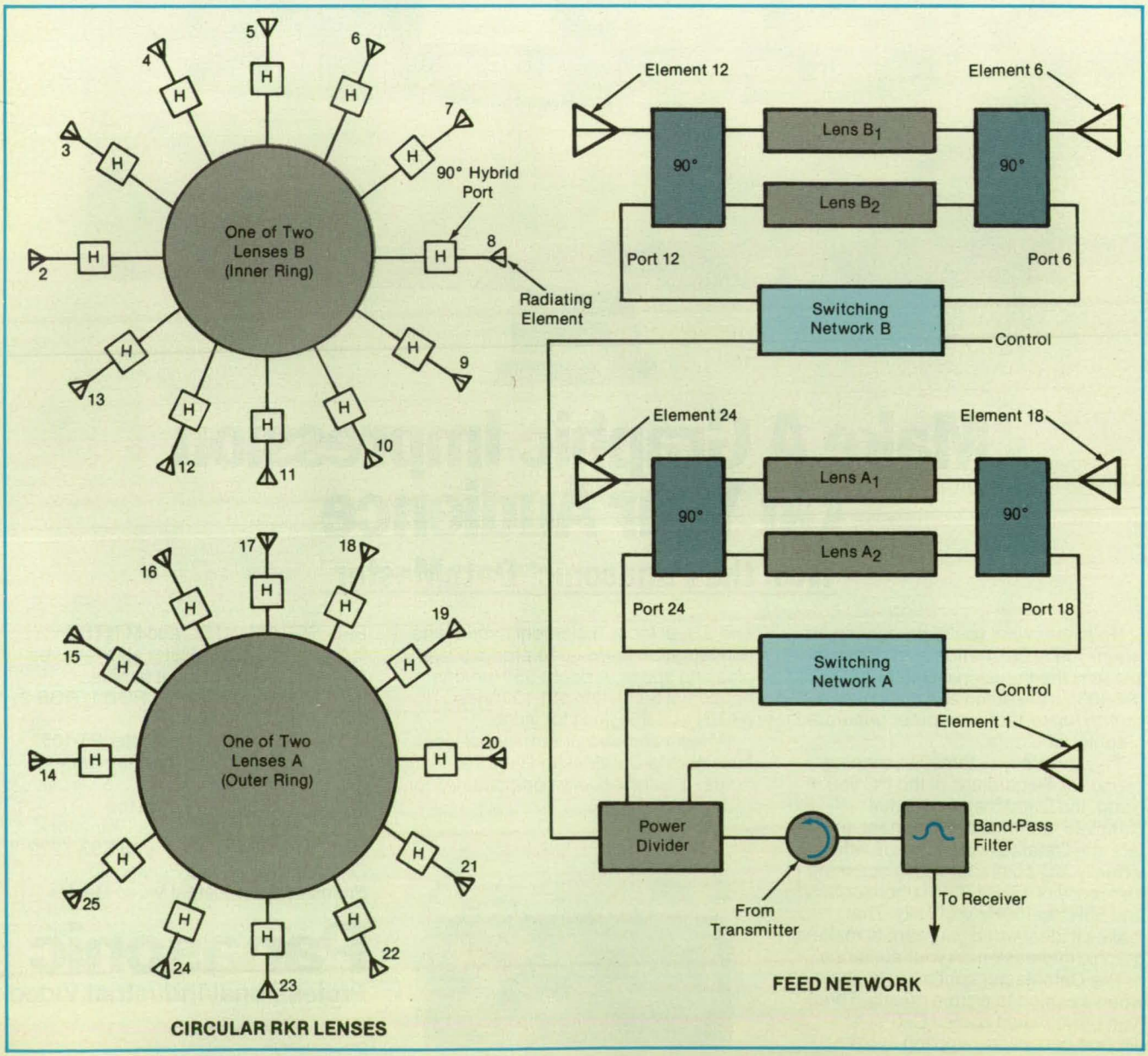

Figure 2. The **Choice of Input or Output Ports** determines the azimuth of the transmitted or received beam in this two-ring, four-lens antenna.

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Circle Reader Action No. 658

This work was done by D. G. Bodnar and B. K. Rainer of Georgia Tech Research Institute for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 127 on the TSP Request Card.*

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

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Refer to NPO-16948, volume and number of this NASA Tech Briefs *issue, and the page number.*

Measuring Critical Charges for Single-Event Upsets

A test circuit would make direct measurements possible for the first time.

NASA's Jet Propulsion Laboratory, Pasadena, California

A concept for determining the susceptibility of integrated circuits to single-event upsets (SEU's) is based on the direct measurement of the critical charge that would cause an upset. Caused by cosmic rays and other ionizing radiation, SEU's are false changes of logic states in memory circuits.

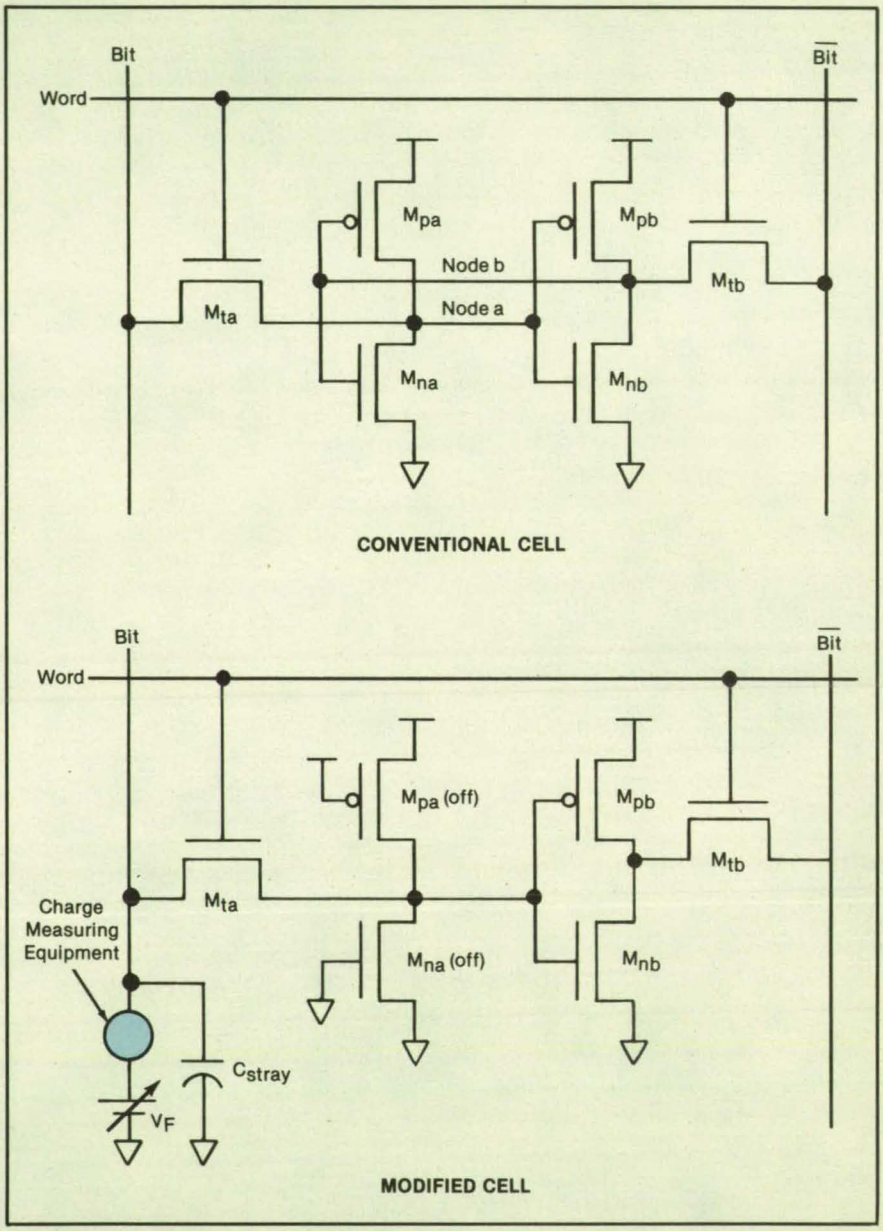
The critical charge of a latch or memory cell has never been measured directly. It has only been inferred in tests involving bombardment by heavy ions and from error-prone numerical simulations. A test circuit embodying the concept would make it possible to evaluate vulnerability to SEU during design and development of digital equipment.

The proposed test circuit is a modified version of a standard complementary metal-oxide/semiconductor static cell (see figure). The cell contains six transistors, connected to form a latch that retains the state of the cell set by input pulses.

The latch proper consists of two p-channel transistors M_{pa} and M_{pb} and two n-channel transistors M_{na} and M_{nb}. Two n-channel transistors M_{ta} and M_{tb}, controlled by the word line of the cell, give the bit lines access to the latch.

In the test cell, the feedback connection at node *b* in the standard cell is omitted, and transistors M_{pa} and M_{na} are turned off by rewiring the cell. In this configuration, the cell can be charged to the critical voltage that causes it to change its output logic state, and the charge at node *a* (the critical charge) can be isolated in preparation for measurement. Before the measurement, an isolation step neutralizes the effect of the large stray capacitance of the bit lines, the test-probe pad, and the instrument wires. Otherwise, the charge stored in the stray capacitance at the critical voltage would swamp the charge-measuring equipment because it is large in comparison with the cell charge that one is trying to measure.

In operation, the cell is first charged by raising V_F to the critical potential (thereby unavoidably also charging the stray capacitance to the critical potential). Then the cell is isolated by opening access transistor M_{ta} so that the critical potential on node *a* is maintained while the charge on the stray capacitance is discharged through the charge-measuring equipment (without taking a measurement) by reducing V_F to zero. At this point, transistor M_{ta} is closed, and the charge on node *a* flows initially into the stray capacitance and finally discharges completely through the charge-measuring equipment, which is activated this time to take a measurement to determine the critical charge. The charge is expected to be quite small — 0.1 to 1 picocoulomb or between 500,000 and 5 million electrons.

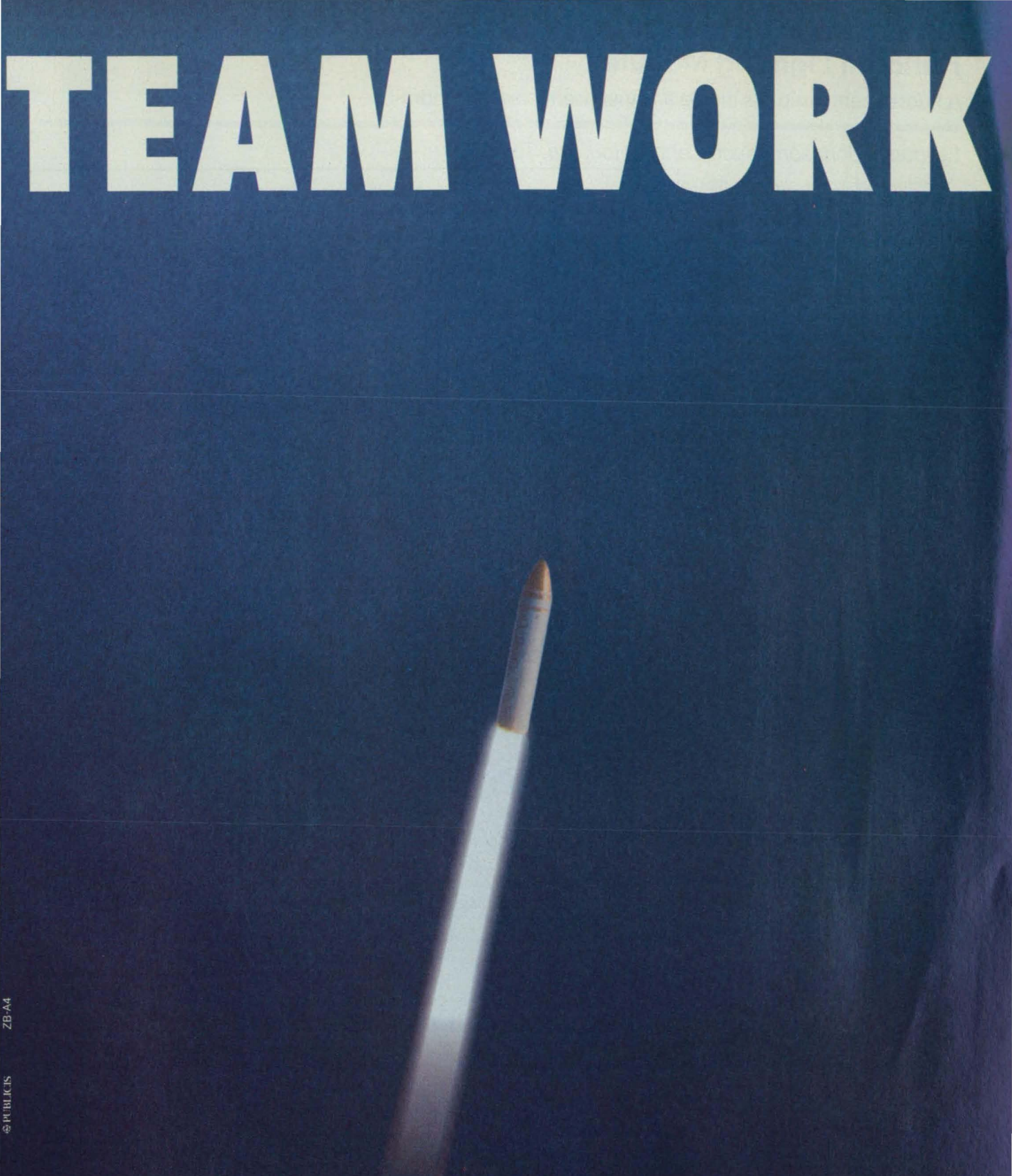


A **Conventional Static RAM Cell Is Modified** by eliminating the feedback connection of node *b* and turning off transistors M_{pa} and M_{na}.

This work was done by Martin G. Buehler and Brent R. Blaes of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 64 on the TSP Request Card.*

NPO-17073

TEAM WORK



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Circle Reader Action No. 659

Handrail Lighting Module

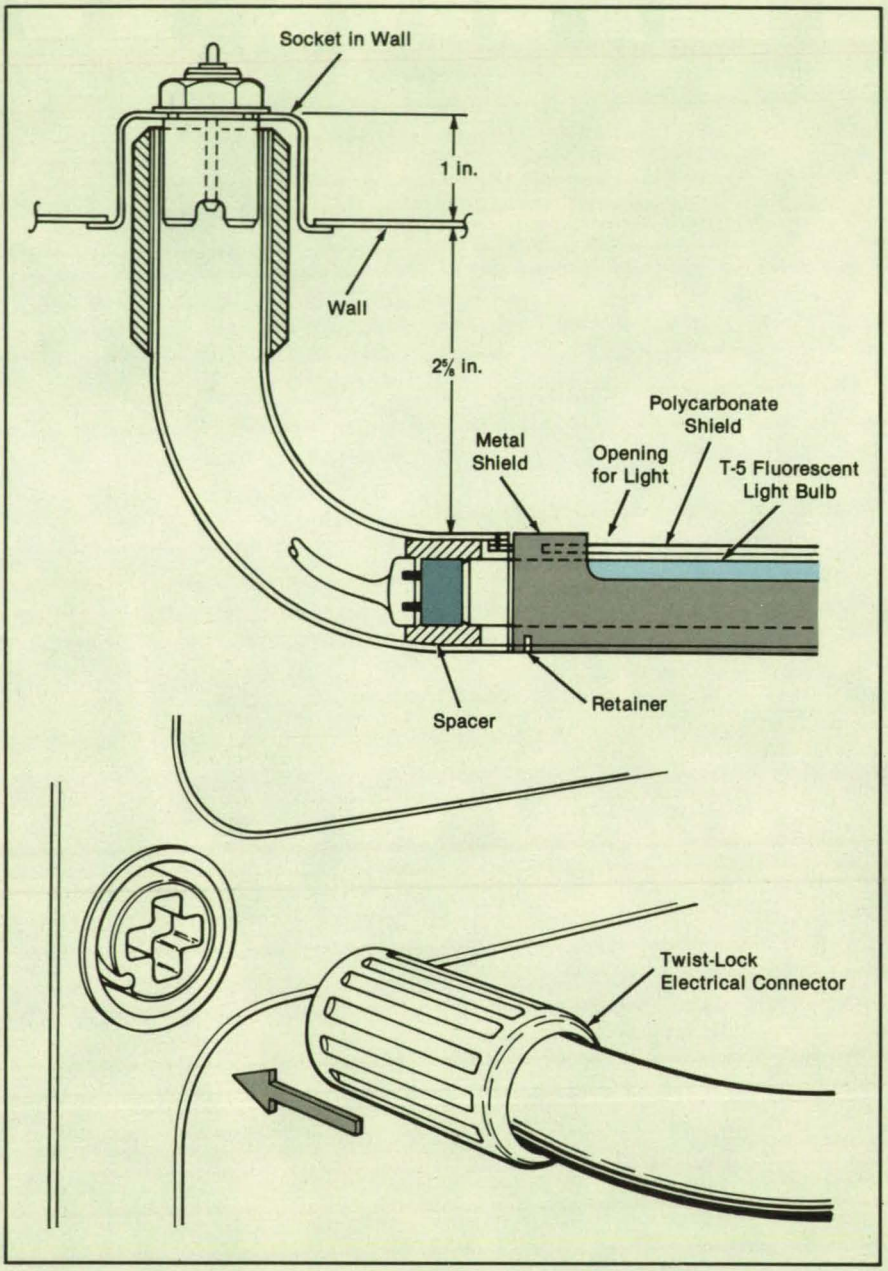
A fluorescent lamp fits inside a transparent plastic handrail.

Lyndon B. Johnson Space Center, Houston, Texas

A lightweight, space-saving, combined handrail-and-fluorescent-light unit can serve decorative or safety functions. The fluorescent lamp is mounted inside a clear tubular plastic housing shaped to form a handrail. Depending on the type of power and mounting connector used at the ends of the unit, such handrails could be designed for either temporary or permanent installation. As part of an emergency lighting system, such handrails could be used to illuminate and call attention to escape ladders, hatches, or exits. Directional arrows or other signs could be placed inside handrails to be illuminated by the lamps.

The handrail light (see figure) was originally proposed as a dual-function, weight-saving way to provide temporary lighting at various locations in the Space Station. A plastic tube of 1-in. (2.54-cm) outer diameter encloses a T-5-size, miniature, pinless, 13-W fluorescent lamp. The curved ends of the assembly provide 2⅝ in. (67 mm) of clearance between the handrail and the mounting surface to provide room to grasp the handrail. The handrail is approximately 39 in. (1 m) long. A rotatable metal shield controls the angular distribution of light around the rail, confining the light to one side. Depending on the application, the starter/ballast necessary for 110-Vac operation could be located either in the handrail or on or behind the mounting surface.

This work was done by John P. Mattei of Rockwell International Corp. for **Johnson Space Center**. *For further information, Circle 17 on the TSP Request Card.*
MSC-21302



A **Combined Handrail and Fluorescent Light** can save space and weight while serving either a decorative or a safety function.

Hazard-Free Pyrotechnic Simulator

A testing circuit checks firing circuits without setting off electroexplosive devices.

Goddard Space Flight Center, Greenbelt, Maryland

A simulator evaluates the performance of firing circuits for electroexplosive devices (EED's) safely and inexpensively. It tests the circuits realistically when the pyrotechnic squibs are not connected to them and thus eliminates the risks of explosions.

Previous methods of testing firing circuits sometimes caused latent damage that later prevented EED's from being fired. For example, flashbulbs or fast-blow fuses were substituted for the EED's during testing. However, the resistances of such devices varied widely, and they therefore did not present a uniform load representative of a real EED to the firing circuit. Moreover, they often damaged the protective resistors, which were intended to reduce power when the EED's failed as short circuits. Damaged resistors left the firing circuits open and incapable of activating the EED's. Sometimes real EED's were used and replaced after testing, but they were costly and showered the test area

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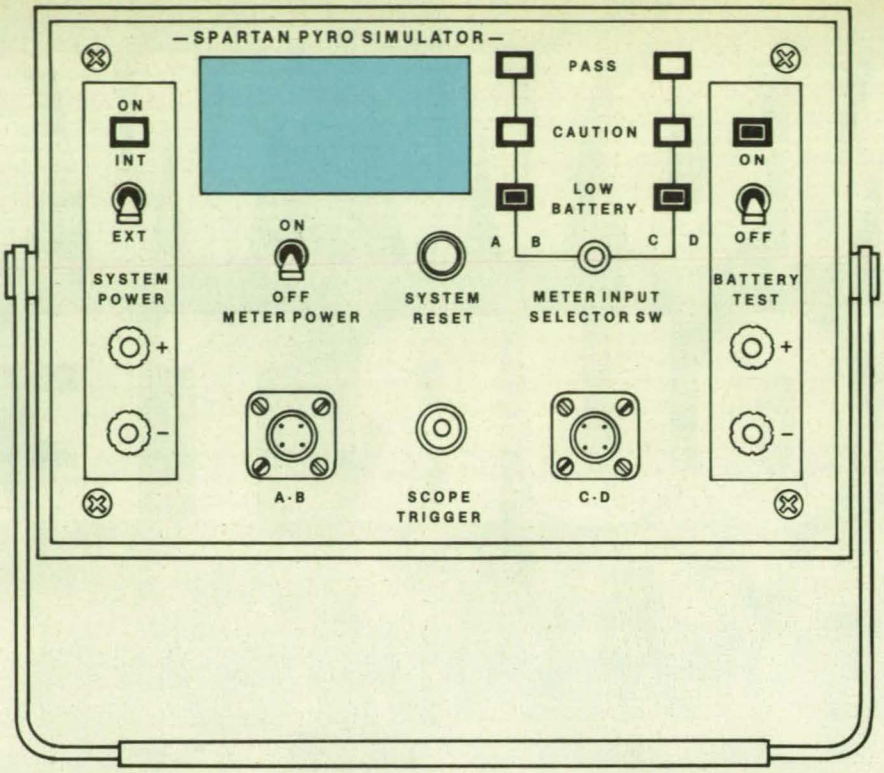
with hot pyrotechnic debris.

The new instrument avoids the problems by presenting a controlled, simulated load to the firing circuit. Developed to test the firing circuits of pyrotechnic separation devices on spacecraft, the simulator can also be used to test safely such devices as batteries where the test conditions might otherwise degrade them.

The simulator (see figure) applies a nominal pulsed load of 1 Ω, representing the EED, to the circuit under test. It measures the firing current that the EED firing circuit supplies to the load, displays the value on a digital panel meter, and gives a visual go/no-go indication of the condition of the firing circuit. The load pulse lasts only 150 ms — too short a time to harm the firing circuit, its protective resistor, or the EED battery.

The simulator is easy to use. The operator connects it to the prime and backup firing circuits and switches the simulator power on. The operator closes the ground-safety barometric switch on the firing circuits, and the prime and backup timers start to run. The simulator applies the proper load to the firing circuit and indicates the test results. There is no need to interrupt tests of other systems.

This work was done by William B. McAlister, Jr., of **Goddard Space Flight Center**. *For further information, Circle 29 on the TSP Request Card.*
GSC-13111



This **Compact Instrument Displays the Measured Value** of firing current as well as an indication of the condition of the firing circuit: "Pass" indicates a firing current greater than 5.5 A. "Caution" indicates a firing current of 2.75 to 5.5 A. "Low Battery" indicates a current between 0.5 and 2.75 A. At firing currents below 0.5 A, the simulator does not respond.

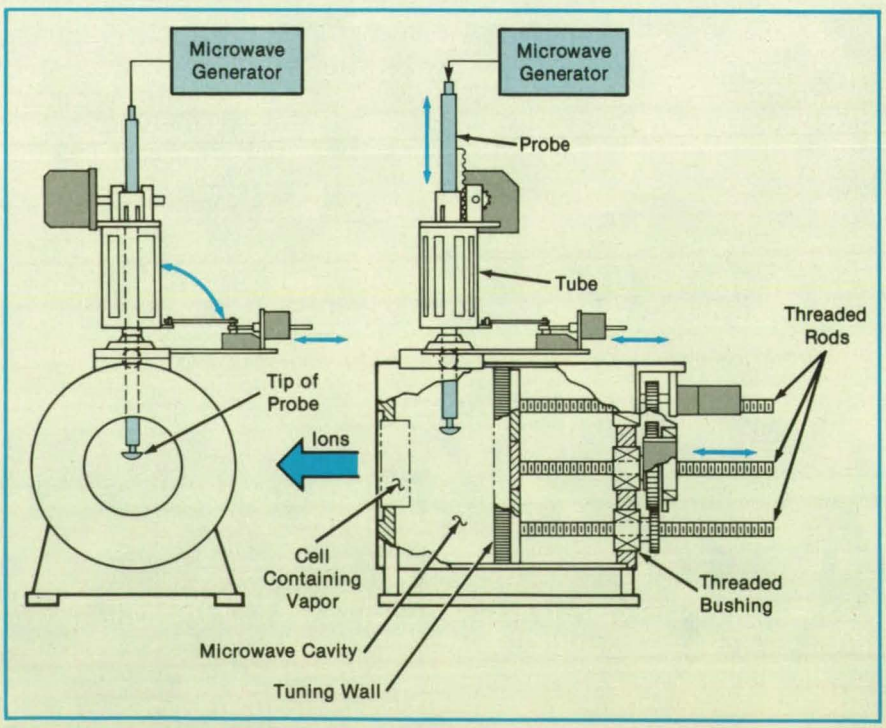
Tunable Microwave Cavity for Ion Source

Positions of components are adjusted for resonance.

Lewis Research Center, Cleveland, Ohio

A tunable microwave cavity can be used to ionize a gas or a metal vapor to provide a source of ions. Such methods as direct-current (dc) cathode discharges, radio-frequency (RF) induction, and microwave resonance in cavities have been used to generate gaseous plasma discharges, from which ions have been extracted to produce ion beams. All of these approaches have certain disadvantages. In the dc method, cathodes that are heated to emit electrons are subject to sputter erosion and chemical deterioration. Over time, the RF-induction method produces changes in operating characteristics due to the deposition of sputtered films of conductive material on components used in the process.

In the microwave-resonance/tunable-cavity method, RF energy is injected into a cavity and produces a plasma in a cell that contains vapor at one end of the cavity. This is an electroless discharge without the disadvantages of the dc-cathode-dis-



A **Movable Probe and a Tuning Wall** are adjusted to obtain resonance at the microwave frequency used to generate a plasma in a cell at one end of a microwave cavity.

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charge and RF-induction methods. However, it is extremely difficult to tune the microwave cavity to resonance because it is necessary to position an RF coupling tip precisely within the cavity. The required position depends on such factors as the dimensions of the cavity and the type and amount of vapor to be used.

To achieve precise positioning, a coaxial probe extends into the microwave cavity through a tube (see figure). One end of the tube is retained in a spherical joint in the cavity wall so that the probe can be pivoted. The probe can be slid in the tube to extend or retract it as needed. Mechanisms are provided for moving the tube in both a side-to-side and back-and-forth motion.

A tuning wall in the cavity is moved by threaded rods extending through threaded bushings, which are geared together. Thus, the rotation of one of the bushings causes the other bushings to rotate simultaneously, thereby positioning the tuning wall precisely.

This work was done by Shigeo Nakanishi, Frank S. Calco, and August R. Scarpelli of **Lewis Research Center**. *No further documentation is available.*

This invention has been patented by NASA (U.S. Patent No. 4,642,523). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Lewis Research Center [see page 18]. Refer to LEW-13935.

Circular-Waveguide Power Combiner/Divider

A large number of inputs or outputs can be accommodated.

Goddard Space Flight Center, Greenbelt, Maryland

Because solid-state sources have limited power output at millimeter wavelengths, it is often necessary to combine the power from many devices to achieve the required transmitter power. Several advantages accrue if the power output is in the TE_{01} mode of circular waveguide rather than of the more-conventional rectangular waveguide. This circular mode has lower loss than that of the rectangular guide and is ideal for the construction of the rotary joints that are often required between the transmitter and antenna. Therefore, a power combiner/divider has been devised in which the output from several solid-state modules can be combined directly into the TE_{01} mode of the circular waveguide.

The principle of operation is most easily explained for the combining mode. An arbitrary number, N (in this case, $N = 16$, but more or fewer could be used), of radio-frequency sources radiate power through N rectangular waveguides, which converge radially and symmetrically until they terminate on the circumference of a circular waveguide (see Figure 1). The electromagnetic fields of the rectangular waveguides are coupled through irises to the electromagnetic field of the circular waveguide.

The rectangular waveguides are oriented with their broad-wall dimensions parallel to the axis of the circular waveguide, so that if the N sources are in phase, they excite the TE_{01} electromagnetic mode in the circular waveguide.

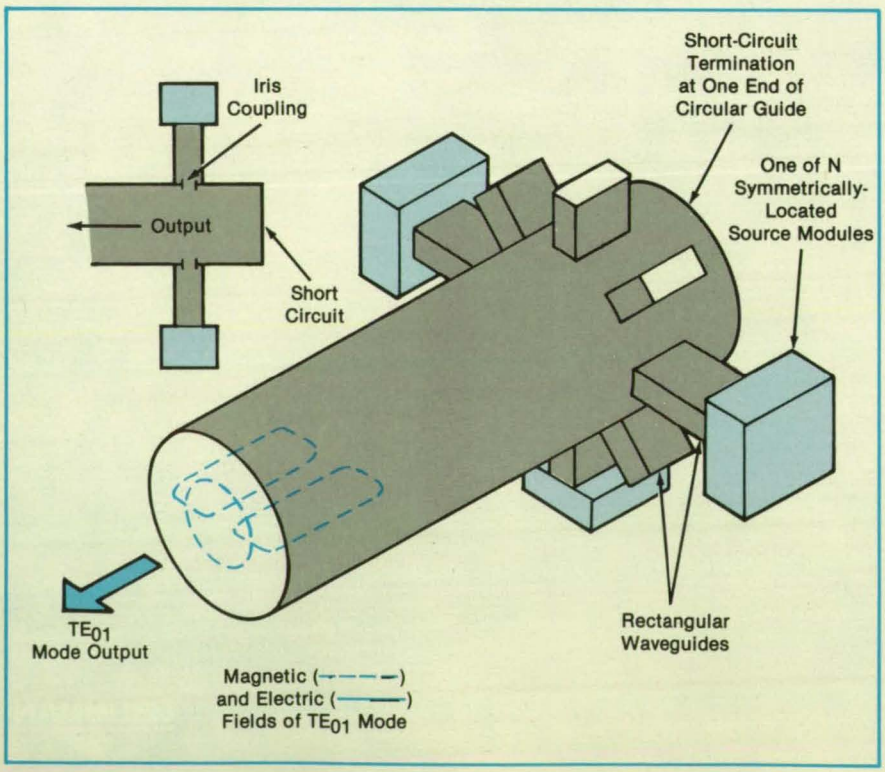

Figure 1. **Electromagnetic Fields** are coupled from N radio-frequency sources to the TE_{01} mode of a circular waveguide.

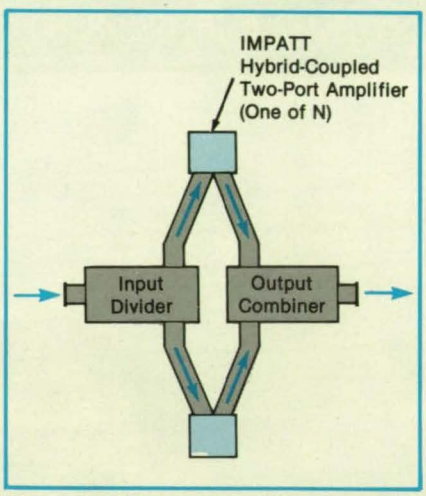

Figure 2. A **Microwave Amplifier Assembly** includes a divider that distributes the input signal to N impact-avalanche-and-transit-time (IMPATT) diode amplifiers and a combiner, which, as the name implies, combines the outputs of the N amplifiers into one output.

Care must be taken to match the impedances at the various junctions. The impedances of the circular waveguide and the converging rectangular waveguides are matched by uniform dielectric chips placed symmetrically near their junctions.

Other combiner/dividers have been inherently narrow-band devices or wide-band devices limited in the number of input ports or have exhibited high losses. In addition to providing the output in the desirable TE_{01} mode, the new combiner/divider concept results in a low-loss, wide band device: Because of the axisymmetry of the TE_{01} mode, there is no essential limit on N. The latter feature is an advantage in the design of wide band, high-power, solid-state amplifiers operating at millimeter wavelengths (see Figure 2).

This work was done by Vernon Dunn of Ford Aerospace and Communications Corp. for **Goddard Space Flight Center**. *No further documentation is available.*
GSC-12996

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Airplane Takeoff-and-Landing Performance Monitoring System

An algorithm and display system are designed to increase the safety of flight.

Langley Research Center, Hampton, Virginia

The Airplane Takeoff-and-Landing Performance Monitoring System (TOPMS) is designed to increase safety during takeoffs and landings of aircraft. Pilots currently rely heavily on flight manuals for planning takeoffs and on judgment during takeoff or abort. The TOPMS provides pilots with graphic information crucial to their decision to continue or reject a takeoff. If a takeoff is rejected or a landing is in progress, the TOPMS also provides crucial information relative to where the airplane can be brought to a stop.

The TOPMS provides information not currently available in the cockpit and presents it in forms that are simple and easily monitored by the pilots. The information is generated in a two-part algorithm and could be displayed to the pilots by electronic screens on their instrument panels or projected as a head-up display. The algorithm calculates a pretakeoff prediction of nominal acceleration and determines where the airplane will reach takeoff speed, based on such factors as the gross weight of the airplane, the slope and the condition of the surface of the runway, the ambient temperature, the atmospheric pressure, the wind conditions, and the flap setting.

The pretakeoff part of the algorithm also determines the remaining-groundroll-plus-air distance needed for the airplane to clear a 35-ft (11-m) obstacle at the departure end of the runway after an engine failure at the decision speed and also the distance required to brake to a stop after the same engine failure. The initial groundroll distance to the point where engine failure occurs plus the greater of the two distances above constitute an important metric called the balanced field length, or the minimum runway length required for the particular airplane and the existing conditions. This value is displayed on the TOPMS for reference before the pilot enters the actual length of the runway about to be used.

After the takeoff is underway, a real-time part of the algorithm continuously updates the prediction of the distance required to reach takeoff speed, based on sensed acceleration. In addition, the real-time part continuously calculates the distance required to stop the airplane, based on specified delays for the initiation of abort and deceleration resulting from maximum wheel braking and deployment of the speed brakes. The algorithm also calculates a stopping point based on the actual deceleration of the airplane. The pilot can see on the display where the airplane will be brought to a stop if a reduced level of braking is used or if reverse thrust is added. These same calculations can be applied to a landing situation.

The TOPMS display and logic were modified into a refined form following a real-time simulator evaluation by over 40 experienced NASA, Federal Aviation Administration, Air Force, airline, and industry pilots. It summarizes critical/priority information into a "go/no-go" situation-advisory flag. Additionally, it indicates the points on the runway where such important events as the decision speed, rotation speed, and expected stopping point will occur. Off-nominal acceleration performance and engine failures are also detected and flagged.

This work was done by David B. Middleton and Lee H. Person, Jr., of **Langley Research Center** *and Raghavachari Srivatsan of the University of Kansas. Further information may be found in NASA TM-89001 [N87-31591/NSP] and NASA CR-178255 [N87-20264/NSP], both titled "Development of a Takeoff Performance Monitoring System," and AIAA Paper 87-2256, "Evaluation of a Takeoff Performance Monitoring System."*

Copies of N87-31591 and N87-20264 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.

Copies of AIAA Paper 87-2256 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.

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 18]. Refer to LAR-13734.

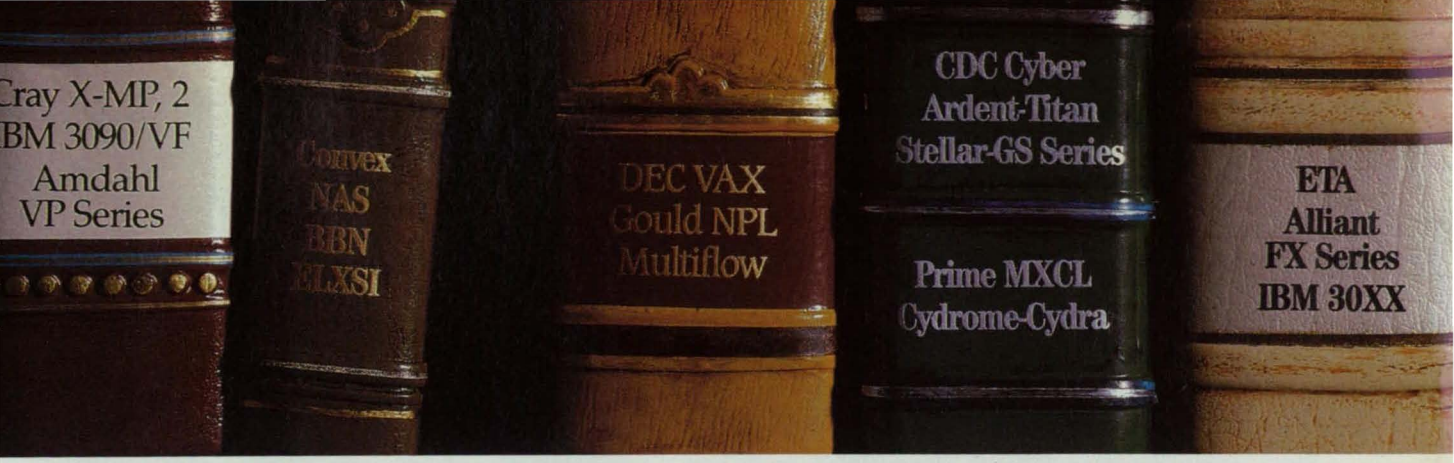
Analyzing Pulse-Code Modulation on a Small Computer

Relatively inexpensive equipment can assist in the diagnosis of faulty encoders.

Goddard Space Flight Center, Greenbelt, Maryland

A system for the analysis of pulse-code modulation (PCM) comprises a personal computer, a computer program, and a peripheral interface adapter on a circuit board that plugs into the expansion bus of the computer (see figure). While the system is no match for an expensive real-time telemetry-data-processing computer, it fills the need for relatively inexpensive means to test PCM encoders. Furthermore, the system enables faster testing and involves less equipment than do older testing systems.

The system functions essentially as a "snapshot" PCM decommutator, which accepts and stores thousands of frames of PCM data, then sifts through them repeatedly to process them according to routines specified by the operator. By displaying the data and/or results of processing, the system assists in the diagnosis of such encoder-



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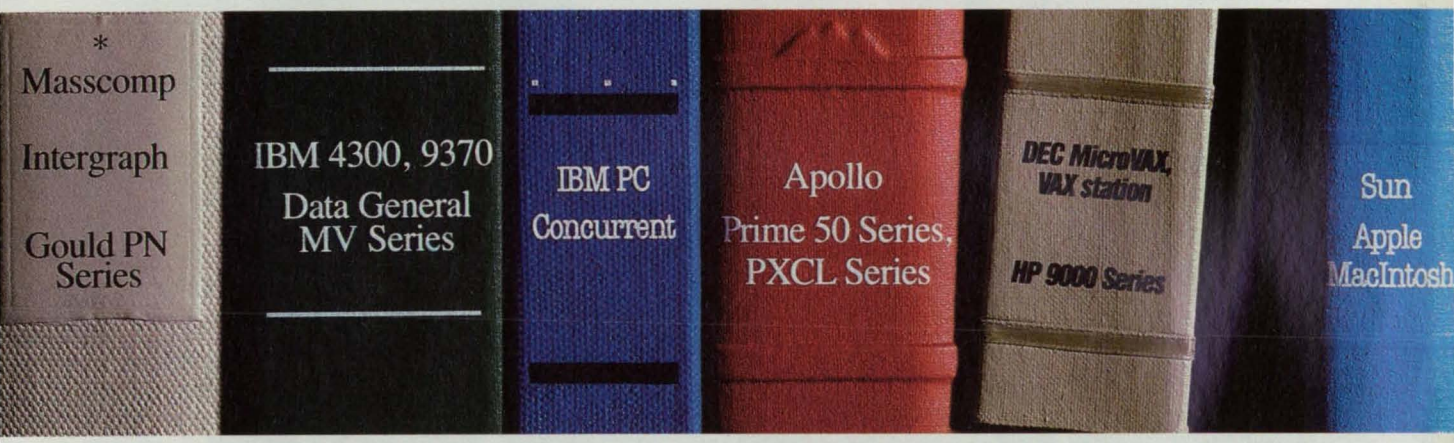

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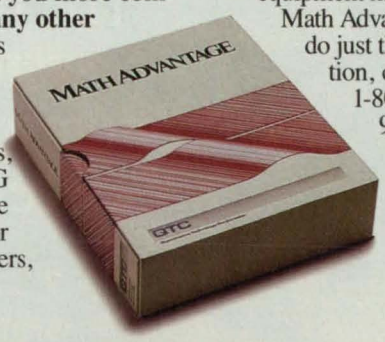

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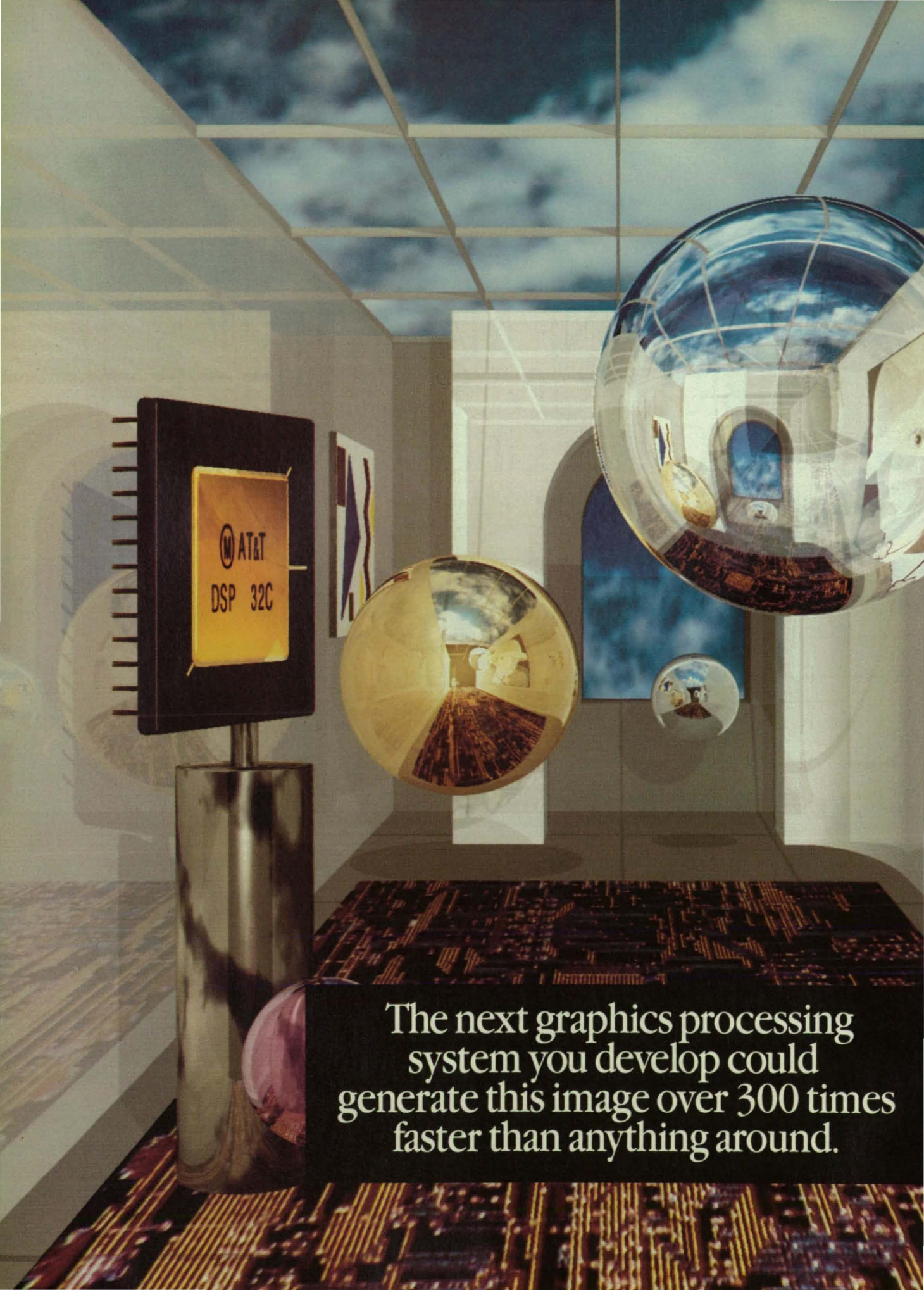

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Image created at R/Greenberg Associates on Pixel Machines' PXM 900 Series graphics workstation, using AT&T's first generation floating point DSPs.

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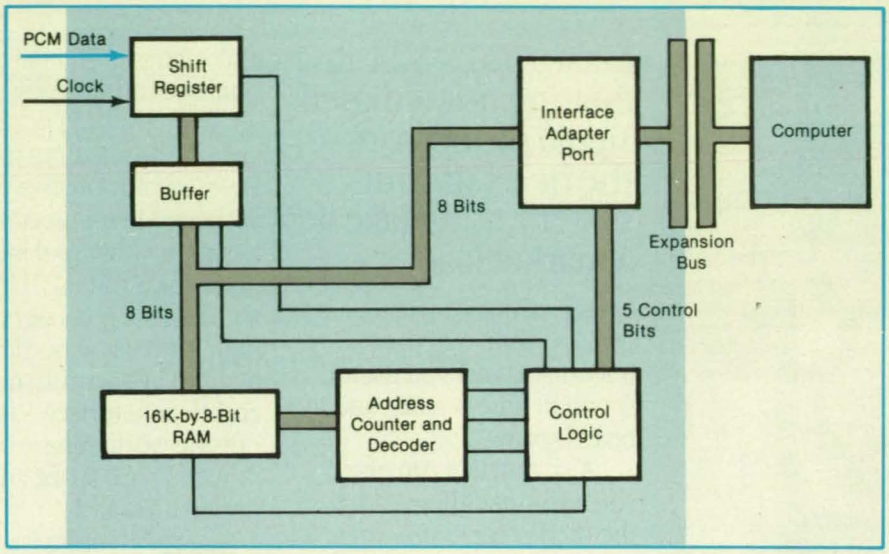
circuit malfunctions as crosstalk between input channels, lack of synchronization, incorrect timing of data within data time frames, and bit errors.

The circuit on the peripheral board contains 16K of 8-bit bytes (131,072 bits) of random-access memory (RAM), an address counter/decoder, a byte counter, control logic, a shift register, and an interface-adapter port. Regardless of the size of data words in the PCM format, the incoming PCM data are converted in the shift register to 8-bit-wide data, then stored in the RAM. The circuit acts as a "windowing" device; i.e., the latest PCM data are always being stored in the RAM. When the circuit receives a "stop" trigger, either manually or automatically, the last 131,072 bits that were transmitted are frozen. After the data are stored, the microcomputer starts to load bits from the storage-device RAM into the main computer RAM and begins to process these bits.

The computer program operates in three main modes: "frame display/scan," "graph plot," and "word compare." The "frame display/scan" mode displays a frame of data grouped into words and numbered on the television screen of the computer. These data can be examined further by selecting a particular word and scanning all other frames for this word. This mode also enables the selection and examination of frames of data in sequence and at random.

The "graph plot" mode enables the selection of a particular word in a PCM frame and plots this word in every stored frame on a graph. This is effectively a graphical digital-to-analog converter.



The **Peripheral Interface Board** plugs into the expansion bus of a small computer and enables the computer to analyze PCM signals.

The "word compare" mode enables the comparison of a word or words in all stored frames. These comparisons can be made to search for errors or changes in data values or to perform other statistical functions.

The present storage capacity of 131,072 bits is insufficient for the analysis of PCM systems that put out data at rates approaching 1 Mb/s. The design of the next version of the circuit calls for 2 to 8 Mb of memory in 252K dynamic-RAM chips. The new design will increase the complexity of the hardware slightly. The only changes in the program are to increase pointer addresses to enable the reading of all of the storage RAM. The circuit would be able to store 10 seconds of data at 800 kb/s, or about 50,000 frames of average size.

This work was done by David E. Massey of **Goddard Space Flight Center**. *Further information may be found in NASA TP-2629 [N87-12718/NSP], "Pulse Code Modulation (PCM) Data Storage and Analysis Using a Microcomputer."*

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. GSC-13170

Self-Testing Computer Memory

A proposed system would have increased tolerance to temporary and permanent faults.

NASA's Jet Propulsion Laboratory, Pasadena, California

A conceptual memory system for a computer would repeatedly test itself during brief, regular interruptions of the normal processing of data. The system would detect and correct such transient faults as single-event upsets (changes in bits due to ionizing radiation) within milliseconds after they occur. Such permanent faults as stuck at one, stuck at zero, short circuits that inadvertently couple neighboring memory cells, and some pattern-sensitive faults could be detected within tens of milliseconds after they occur. These features would enhance the dependability of a fault-tolerant computer by increasing the probability of recovery of the memory from a detected fault before it causes other faults. The cost of the improvement would be a modest increase in the complexity of the circuitry and in the operating time.

Conventional self-checking is based on Hamming-code correction; that is, the inclusion of redundant bits in codes for the correction of single-bit errors or the detection of double-bit errors in data words as they are read out of memory. The new self-testing concept surpasses the conventional one by actively flushing latent defects out of memory and attempting to correct them before they accumulate beyond the capacity for self-correction or detection. Circuits would be designed to check the entire memory during periods interleaved with the memory operations of normal programs.

The memory would contain N words, with each bit of each word stored in a separate memory chip so that the failure of any single chip would damage no more than 1 bit in any word. Each word would consist of M information bits plus P parity bits to implement the Hamming code. An additional memory-interface building-block (MIBB) circuit would provide control and Hamming encoding, decoding, and correction

(see figure). If a single error were found in a word being read out, the MIBB would insert the corrected value into the memory.

Two parity bits would be added to each row of memory cells, and two parity checkers would be included on each chip. One parity bit would be used to check all odd-numbered bits, and the other parity bit would be used to check all even-numbered bits in each row.

Each chip could be commanded to perform a check cycle (typically taking less than a microsecond), during which a specified row of the memory array would be read out, the parity would be checked, and the data bits would be stored back into the row either unchanged or with one of the three following permutations:

- Store row with bits in odd positions inverted;
- Store row with bits in even positions inverted; or
- Store row with all bits inverted.

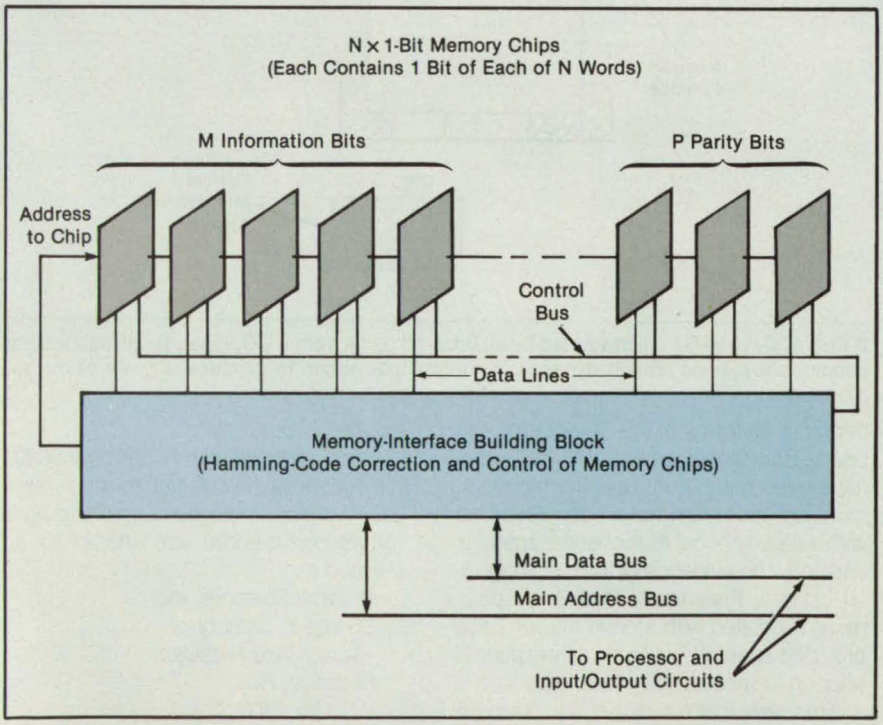
If a parity error were detected, an internal fault signal would be sent to the MIBB. During a check cycle, the memory could be commanded to regenerate parity. In this case, both parity bits would be recomputed over the selected row. The MIBB would then continue its sweep through the memory by initiating check cycles for other rows. Repeated information-recovery cycles (fault indications) initiated by the same chip would indicate a permanent fault, and the central processing unit could command that the affected memory chip be replaced by a spare.

If a cell is stuck at the value (zero or one) of the data stored in it, there will not be an error until an attempt is made to store the other value (one or zero) that it is incapable of storing. To detect this type of fault, the system would perform two sweeps that would invert all bits in the memory. During the first sweep, data would be checked in the true form while being written back in complementary form. In the second sweep, complemented data would be read out and checked while being stored back in memory in true form. Thus, each cell would be required to take on both one and zero values, and the on-chip parity check would be used to verify that this took place.

Coupling between neighboring cells would be tested according to a similar principle — via the responses to permutations of the bit in each cell with the bit in each of the neighboring cells. This test could be performed on every cell in the memory in no more than 16 sweeps.

During normal memory readouts initiated by the data processor in input/output circuits, the memory chip would perform in the conventional manner, without internal parity checks. During normal writing to memory, the corresponding row would be read out, the selected bit modified, and the row re-stored back into the memory array. If the bit being stored were different from the bit originally contained in the memory, the associated (odd or even) parity bit would be inverted.

This work was done by Savio N. Chau and David A. Rennels of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 70 on the TSP Request Card.*
NPO-16850



The **Correction and Detection of Errors** would be built into the memory system of the computer and would require no special programs. The memory-interface building block would check the entire memory, one row of memory cells (multiple words) at a time, during brief periods interleaved with the memory operations of normal computer programs.

Physical Sciences

Pulsed Source of Energetic Oxygen Atoms

Oxygen molecules are dissociated by an infrared laser beam.

NASA's Jet Propulsion Laboratory, Pasadena, California

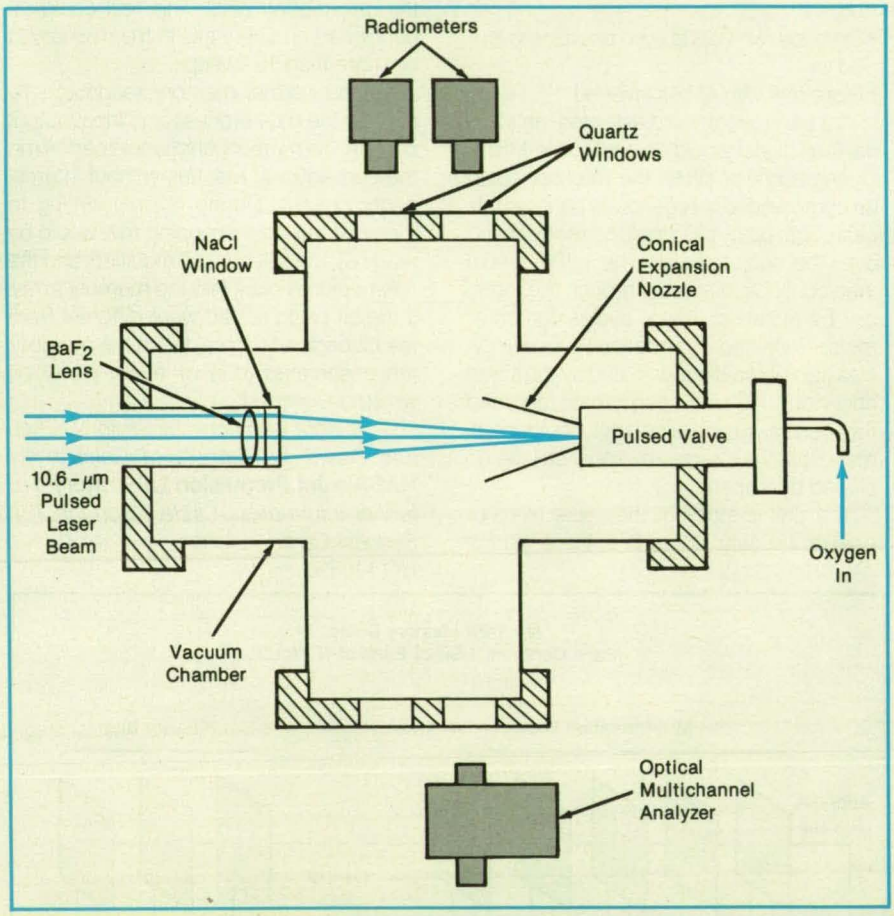
An apparatus has been developed that generates high-flux pulses of oxygen atoms to bombard specimens in experiments on the aging and degradation of materials in a low Earth-orbit environment. The intense atomic oxygen pulses may also be useful in studies of microfabrication techniques.

Within the vacuum chamber of the apparatus (see figure), oxygen gas at a pressure of several atmospheres is introduced into the throat of a conical expansion nozzle through a pulsed valve. After the nozzle is partially filled with gas, the output of a 10-J pulsed CO_2 TEA laser is focused through a BaF_2 lens into the nozzle throat to increase the enthalpy of the flow.

Approximately one-third of the laser energy is delivered in a 200-ns gain-switched spike and induces a breakdown in the high-pressure oxygen near the throat. The resulting plasma continues to absorb the remaining energy in the tail of the 2-μs laser pulse. The rapidly expanding plasma generates a blast wave that propagates through the remaining gas within the nozzle and converts the stagnation energy of the plasma into directed kinetic energy in the exhaust gas.

The nozzle is designed to allow an expansion that favors electron/ion recombination but not the recombination of oxygen atoms into molecules. As the gas expands, the temperature (random kinetic energy) and density decrease as the directed kinetic energy increases. Thus, a cold (low spread in random velocity), high energy beam of oxygen atoms flows out of the nozzle. Under typical operating conditions, the absorption of 5 J of lasser energy into approximately 10^{-4}g of molecular oxygen produces a pulse of approximately 4×10^{18} oxygen atoms with a directed kinetic energy of 5 eV. Operation at pulse repetition rates to 10 Hz has been obtained.

Two kinds of optical measurements have been made to characterize the oxygen-atom pulses. Time histories of the 777.3-nm spectral line of atomic oxygen have been measured by identical radiometers at two different positions along the beam to determine the velocity of the beam. Thus far, velocities from 5 to 13 km/s have been measured. Spectral measurements of the beam have been recorded with a gated optical multichannel analyzer and show no evidence of ionic or molecular oxygen. Preliminary studies of specimens irradiated with atomic oxygen have provided spectral evidence of erosion, in addition to measurable mass loss.



A Puff of Oxygen Gas is irradiated by an infrared pulse from a CO_2 laser. The irradiated gas becomes a plasma, which expands in the conical nozzle to produce a pulse of oxygen atoms.

This work was done by George Caledonia, Robert Krech, David Green, and Anthony Pirri of Physical Sciences, Inc., for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 128 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

Physical Sciences, Inc.
George E. Caledonia,
Senior Vice President
Research Park
P.O. Box 3100
Andover, MA 01810

Refer to NPO-30000, volume and number of this NASA Tech Briefs *issue, and the page number.*

High-Performance Ambient-Temperature Heat Pipe

Passages for liquid and vapor are separated by a porous wick.

Marshall Space Flight Center, Alabama

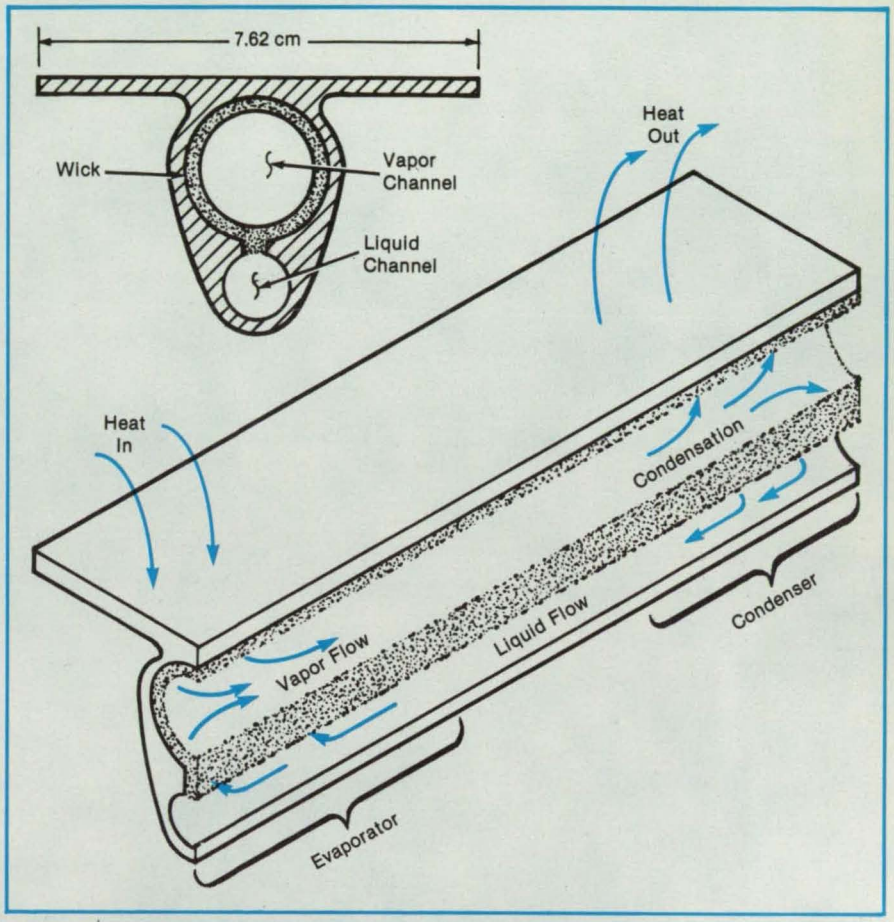
An experimental heat pipe with two channels is designed for the regulation of temperature in enclosed spaces. When fully developed and when operating in zero gravity, the heat pipe is expected to transport heat at a rate of 5 kW along a distance of 50 ft (15 m), with a heat flux of 10 W/cm^2 at the evaporator end. (The performance in normal gravity would be somewhat lower because gravitational effects are significant with respect to the capillary effects upon which the operation of the heat pipe depends.)

The pipe (see figure) is made of aluminum, and the heat-transfer material is ammonia. The pipe contains two channels: one for the vapor phase and one for the liquid phase of the ammonia. A porous wick of sintered aluminum powder lines the vapor channel and fills the slot between the two channels.

This design confers several advantages: The small pores in the wick give rise to high capillary pressure, which in turn enables mass and heat to flow at high rates. The losses of pressure in the liquid and vapor channels can be minimized by appropriate choices of the dimensions of the channels and wick. The heat pipe can accept a large heat flux at the evaporator end, partly because the high thermal conductivity of the wick helps to suppress temperature gradients, thereby preventing the liquid from boiling in the wick.

The heat is added at the evaporator end, causing the liquid that saturates the wick to vaporize. The evaporation creates a locally high vapor pressure. Because the liquid remaining in the wick has surface tension, the vapor is prevented from entering the wick and must therefore flow along the vapor channel toward the condenser end.

At the condenser end, the heat is removed from the vapor, causing it to condense into the wick. Because the vapor pressure remains slightly higher than the liquid pressure, the condensate is pushed through the wick and fills up the liquid channel. Because the liquid pressure in the evaporator is less than the liquid pressure in the condenser, the liquid flows in the liquid channel toward the evaporator, where it wets the wick, completing the cycle.



The **Two-Channel/Porous-Wick Design** of this heat pipe enables it to transport heat at 2 to 3 times the rate of comparable heat pipes of older designs.

This work was done by Michael D. Keddy, Nelson J. Gernert, and James W. Owen of Thermacore, Inc., for **Marshall Space Flight Center**. *For further information, Circle 162 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 18]. Refer to MFS-26062.

Transferring Heat in Conjugating Binary Liquids

Less pumping would be required.

Marshall Space Flight Center, Alabama

Conjugating binary liquids have been proposed for use as phase-change heat-transfer fluids. Because such a fluid would transport thermal energy largely in the form of the latent heat of the change of phase, the fluid would exhibit a specific heat much higher than that of a single-component fluid or a fluid without a phase change. Consequently, less of the binary fluid would have to be pumped to transfer a given amount of heat. This could be an important engineering consideration where the weight or power of the pump has to be minimized. Also, because all phases remain liquid throughout the heat-transfer cycle, there is no need to cope with the difficulties posed by gas/liquid and solid/liquid phase separations.

In a conjugating binary system, two liquids mix with or separate from each other to a degree that depends on the temperature. While many types of behavior are possible, depending on which liquids are chosen, a particularly useful combination would have a phase diagram like that shown in the lower right portion of the figure. In this combination, the liquids remain completely mixed above the critical

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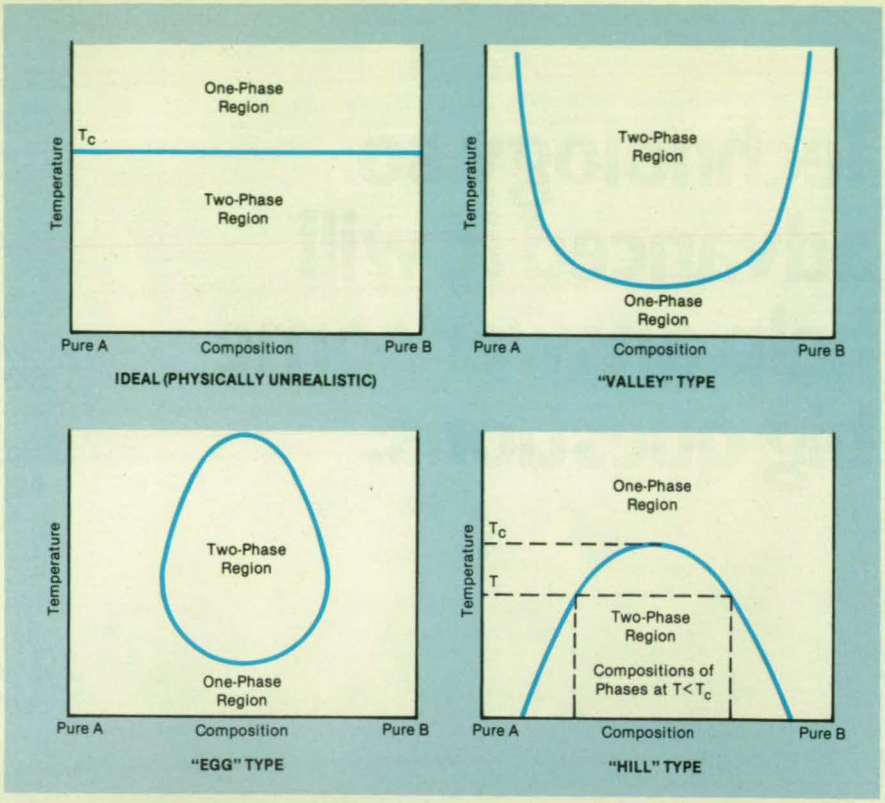
solution temperature, T_c. As the temperature decreases below T_c, the liquids separate increasingly, giving off latent heat of mixing. Thus, to realize the maximum benefit from the binary system, the source of heat in the heat-transfer loop should be hotter than T_c, while the sink should be colder than T_c.

One of the more promising of the pairs of liquids tested thus far is 38 weight percent triethylamine with 62 weight percent water. This pair exhibits the desired mixing/separating characteristics, with a T_c of 18 °C and a latent heat of mixing of 60 joules per gram of solution. Using the measured specific heat of the pair as a function of temperature, the calculated heat-transfer capacity of a system operating between a heat source at 70 °F (21 °C) and a heat sink at 48 °F (9 °C) would be 45 Btu/lb (105 J/g). In contrast, a typical chlorofluoromethane heat-transfer fluid flowing between the same temperature limits could transport only about 4:4 Btu/lb (10 J/g).

This work was done by P. G. Grodzka and J. W. Owen of Lockheed Missiles & Space Co. for **Marshall Space Flight Center**. *For further information, Circle 146 on the TSP Request Card.*
MFS-28249



These **Phase Diagrams** illustrate the more common types of mixing and separation of conjugating binary liquids A and B.

Mounting Thin Samples for Electrical Measurements

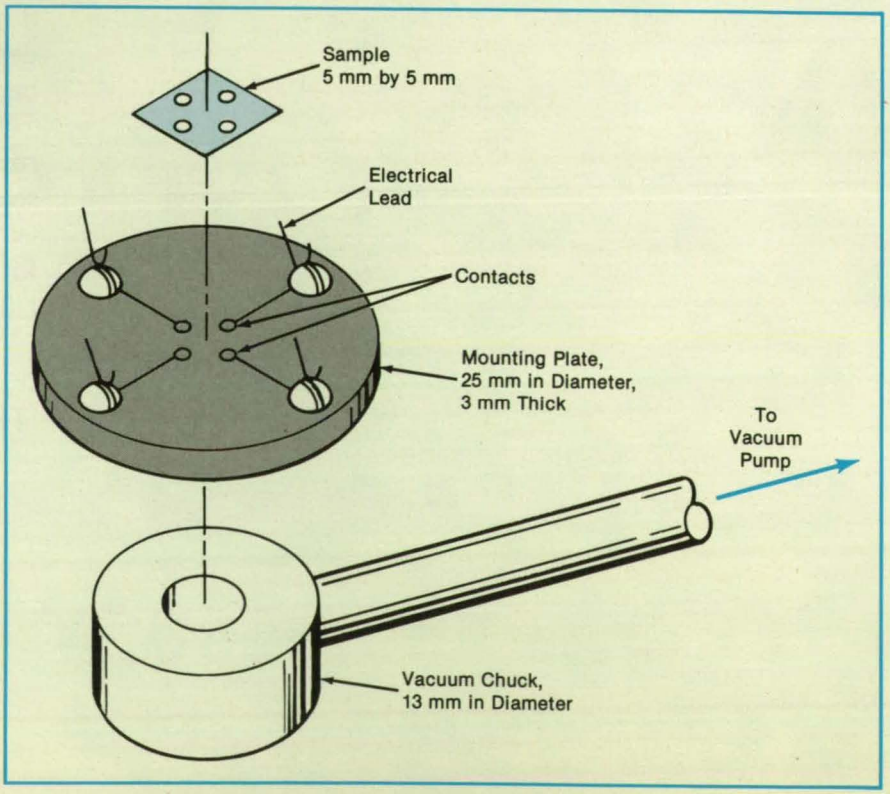
A vacuum chuck holds samples gently but securely.

Lewis Research Center, Cleveland, Ohio

A new method for mounting a thin sample for electrical measurements involves the use of a vacuum chuck to hold a ceramic mounting plate, which, in turn, holds the sample. Contacts on the mounting plate establish the electrical connection to the sample (see figure). The method has been used to make electrical measurements over the temperature range from 77 to 1,000 K and does not introduce distortions into the magnetic field during Hall measurements.

The mounting plate is made of a machinable, glass/ceramic insulating material. Both surfaces of the plate and the surface of the vacuum chuck are polished to enhance the vacuum seals between the various elements. Holes through the mounting plate communicate the vacuum, which is provided by a commercial Venturi pump, to the interface between the plate and the sample. Atmospheric pressure on the sample provides the mechanical force to hold the sample in place and to establish electrical contact.

The contacts on both the sample and the mounting plate are deposited by sputtering. The vacuum holes through the mounting plate are concentric with the



This **Exploded View** shows the scheme for mounting and making electrical contact to the sample.

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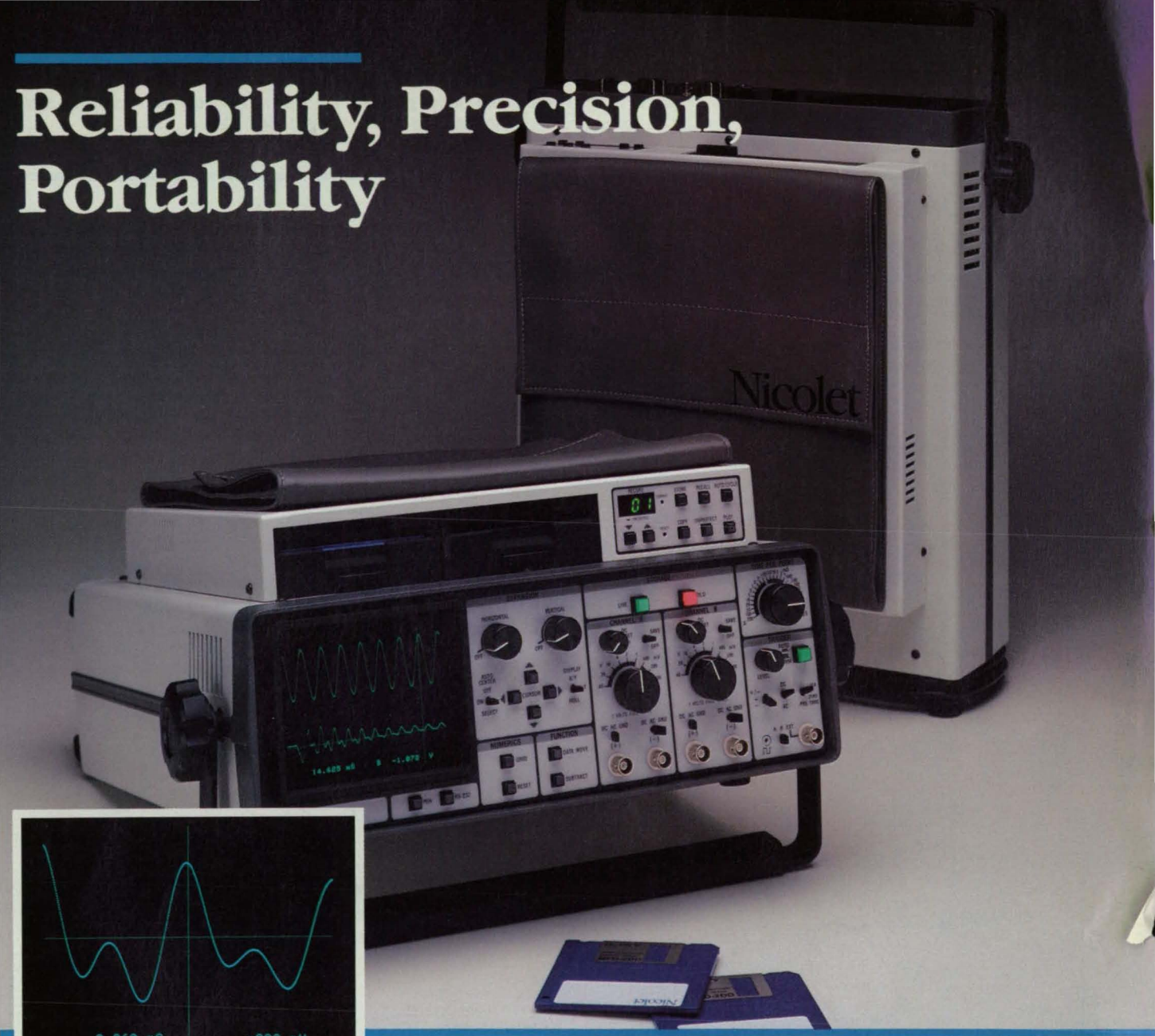

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contacts on the plate, which are in the form of conducting annuli. Each sample has a pattern of solid contacts identical to that of the mounting plate, and the contacts are positioned on the plate so that they are aligned over the conducting annuli. The contact pattern deposited on the mounting plate includes conductors extending from the conducting annuli to a second set of contacts near the periphery of the plate. The peripheral contacts are used to connect lead wires that, in turn, are connected to the appropriate measuring devices.

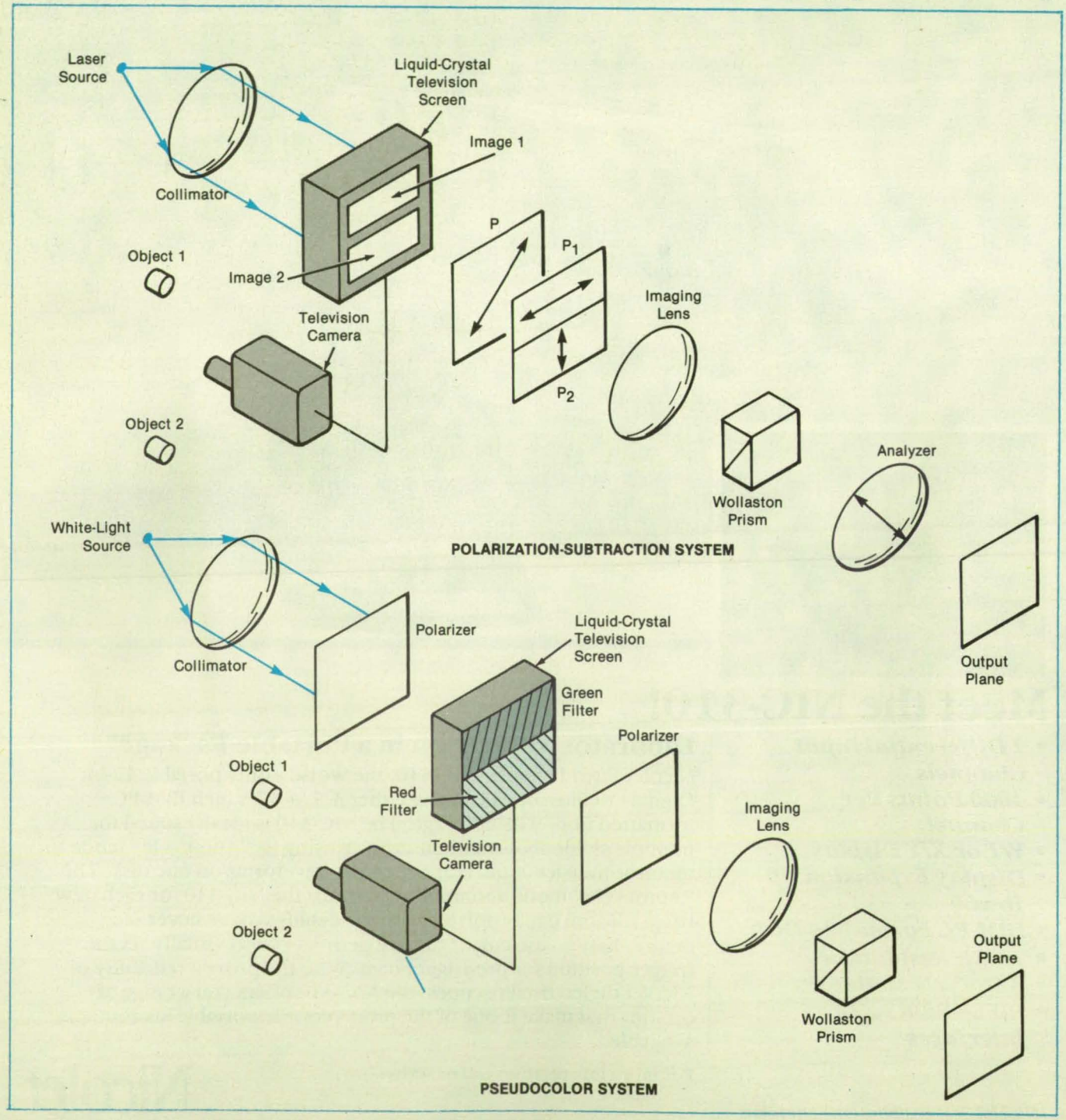
This work was done by L. G. Matus and R. L. Summers of **Lewis Research Center**. *No further documentation is available. LEW-14646*

Liquid-Crystal-Television Image Subtracters

Image data are processed quickly by optical components.

NASA's Jet Propulsion Laboratory, Pasadena, California

Either of two similar optoelectronic systems can be used to form an output image that shows the differences between two input images. All parts of the two images are processed simultaneously by optical components only; digital electronic processing



These **Image-Subtraction Systems** form output images that show the differences between the input images of the two objects. In the upper system, the differences appear as bright regions in an otherwise dark output image. In the lower system, the differences and similarities are shown by colors.

of data is not required. Thus, the system concept offers the potential for rapid, inexpensive comparison of images in such applications as automatic inspection, medical diagnosis, and robotic vision.

The first system exploits differences in polarization. As shown in the upper part of the figure, a television camera views the two objects to be compared. The images of the two objects are projected on a liquid-crystal television screen, which is positioned to act as a spatial light modulator. Light from a laser is collimated and passed through the liquid-crystal screen, becoming spatially modulated by the two images as it does so.

The modulated light beam is passed through polarizer P, then through side-by-side polarizers P_1 and P_2. The combination of polarizers is positioned and oriented to make the polarization in one image perpendicular to the polarization in the other. After passing through an imaging lens, the polarized, image-bearing light beam enters a Wollaston prism at a focal plane of the lens. The prism deflects the light according to its polarization; in this case, the prism is oriented to produce equal but opposite deflections of the light from the two images, causing the two images to be superimposed at the output plane of the imaging lens.

On the way to the output plane, the light is passed through analyzer P_3 (that is, another polarizer), which acts in concert with P, P_1, and P_2 to impart opposite polarizations to the light in the two superimposed images. Thus, the identical portions of the two images cancel each other, and only the differences are displayed.

The second system is similar to the first system, except that it is based on pseudocolor encoding. As shown in the lower part of the figure, the liquid-crystal television screen is illuminated through a polarizer with collimated white light. The light modulated with one image is passed through a green filter, and the light containing the other image is passed through a red filter. The light is then processed in a manner similar to that of the first system, except that an analyzer is not used. On the output plane, the superposition of identical red and green portions yields a yellow image. The portions of one image that lie outside the other are shown in red or green.

This work was done by Tien-Hsin Chao and Hua-Kuang Liu of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 47 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 18]. Refer to NPO-17144.

Materials

Hardware, Techniques, and Processes

Books and Reports

Biphase Metal Electrodes for AMTEC

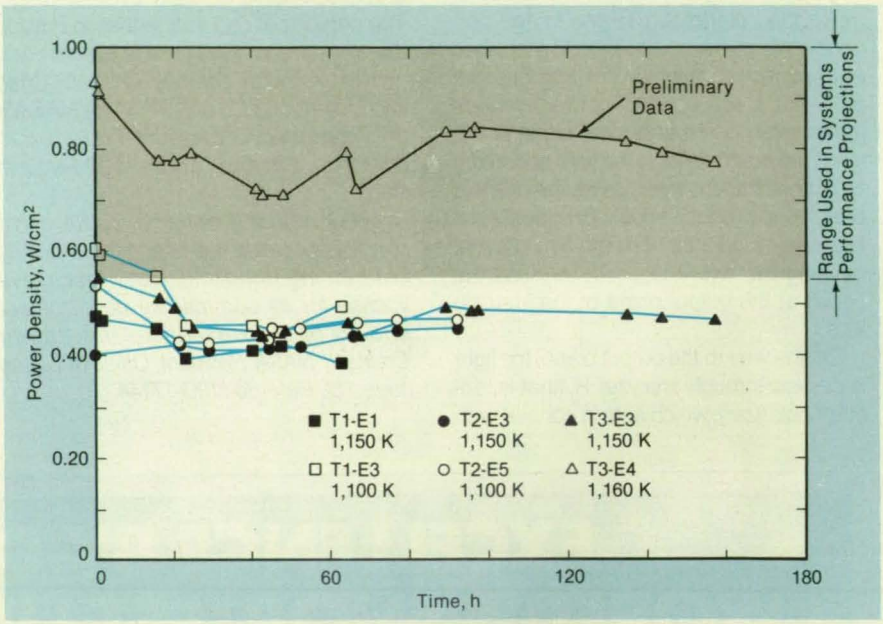
High Power Densities are Achieved.

NASA's Jet Propulsion Laboratory, Pasadena, California

New biphase metal electrodes for the alkali metal thermoelectric converter (AMTEC) exhibit low electrical resistance, fast alkali metal transport, and good power densities and lifetime at operating temperatures from 1,100 to 1,160K. When fully developed, AMTEC electrodes are expected to last as long as 10,000 h in service without significant degradation.

A biphase electrode is made up of two refractory metals, one of which forms strong bonds with sodium, the other being inert to sodium. The first metal binds sodium in the operating electrode, while the second metal maintains the stability of the electrode structure. Suitable inert metals include Mo, W, Ta and others in groups 4b, 5b, and 6b of the periodic table of elements. The refractory metals that strongly bind sodium include Pt and Rh.

The AMTEC is a thermally-regenerative electrochemical cell that depends on the sodium-ion conducting properties of beta alumina solid electrolyte and a very high sodium activity gradient between the high-temperature sodium reservoir and an external electrode from which sodium evaporates to a low-temperature condenser. The cell has demonstrated a direct thermal-to-electric conversion efficiency of 19 percent, which is much higher than state-of-the-art conversion efficiencies of other direct thermoelectric devices.



Maximum Power Density Versus Time for six graded composition Pt/W AMTEC electrodes shows stable performance for the length of the test. One electrode, which exhibited superior adhesion to the solid electrolyte, also performed exceptionally well at ~0.8 W/cm².

The goal of AMTEC research has been to create electrodes that show stable performance with low impedance for long periods of operation. The new electrodes operate with very low impedance to sodium transport from the electrode/solid-electrolyte interface to the exterior surface. It appears that there is strong surface binding of sodium to the metallic walls of pores within the electrode and rapid sodium transport by surface diffusion. Sodium gas is released at the electrode surface from which it flows to the condenser.

Details of the transport process are still being investigated, but it is clear that a highly-efficient sodium transport mode operates in these electrodes. Unoptimized Pt/W electrodes have been operated consistently at ~0.5 W/cm², but one electrode showed exceptional performance, delivering ~0.8 W/cm² for 160 h before exhaustion of the sodium charge. This long-term performance is four times that observed only a few years ago in mature performance of molybdenum electrodes, which were the best electrodes at that time. Reliable performance at ~0.55 W/cm² is considered necessary for high efficiency, practical thermoelectric conversion by AMTEC's.

This work was done by R. Williams, C. Bankston, T. Cole, S. Khanna, B. Jeffries-Nakamura and B. Wheeler of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 6 on the TSP Request Card.*

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

Edward Ansell,
Director of Patents and Licensing
Mail Stop 301-6
California Institute of Technology
1207 East California Boulevard
Pasadena, CA 91125

Refer to NPO-16787, volume and number of this NASA Tech Briefs *issue, and the page number.*

Improved Aluminized Multilayer Insulation

The number of reflective surfaces is increased while reducing or only slightly increasing bulk.

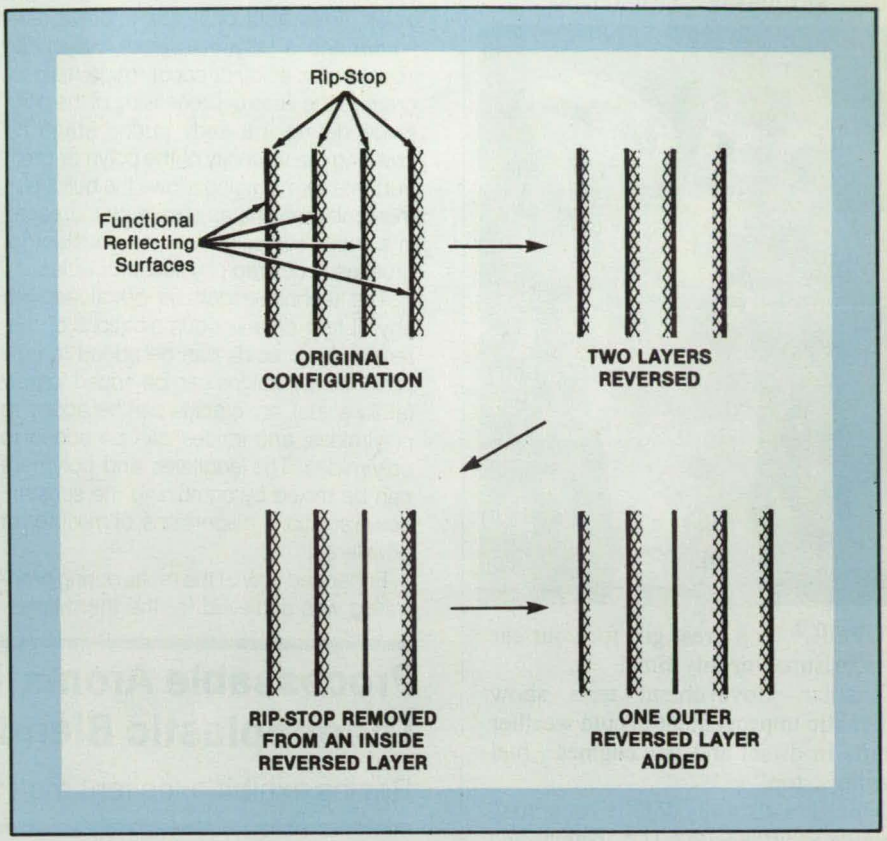
Lyndon B. Johnson Space Center, Houston, Texas

It is possible to improve the insulating quality of multilayer reflective thermal insulation by modifying the configuration of the layers. In a blanket of such insulating material, layers of aluminized Mylar (or equivalent) polyethylene terephthalate separated by spacers cause multiple reflections of thermal radiation and thereby impede the passage of the radiation through the blanket. The insulating quality of the blanket is proportional to the number of functional aluminized radiation-shield surfaces in the assembly.

In the original version of the insulation (see figure), which was designed for use on a spacesuit, a spacer layer of rip-stop material is glued to one side of each reflective layer. Four such layers are stacked, with the spacer sides all facing the same way. While this design provides an easily handled, durable assembly, the glue on one face of each layer counteracts the low radiation emissivity of that face, thus reducing the number of effective radiation shields per layer from two to one.

Provided that the insulation is not used in direct contact with another surface, the performance of the insulation would be unchanged if two of the layers were reversed, because there would still be four functional radiation-shield surfaces. In this configuration, two spacer layers are adjacent to each other, making one of them redundant. The removal of the redundant layer would increase the number of functional radiation-shield surfaces to five, thus improving the quality of insulation. This change would also decrease the bulk of the insulation and increase its flexibility. The long-term resistance to wear will be slightly reduced due to the relative weakness of the plain layer with no rip-stop spacer.

Alternatively, instead of removing one of the adjacent spacer layers, another layer can be inserted between them to form an insulating system with six functional radiation-shield surfaces. This blanket would have half again as many functional surfaces as the original insulation, yet would be only slightly thicker and less flexible. While the durability of the added layer must be considered, the overall performance is expected never to deteriorate to the level of the original configuration.



Multilayer Reflective Insulation is made of layers of aluminized polyester with rip-stop backing. The structure at the top has only four functional low-emissivity surfaces. If two of the layers are reversed, the performance is essentially unchanged. The two variants shown at the bottom have five and six functional surfaces, respectively, and would provide better insulation.

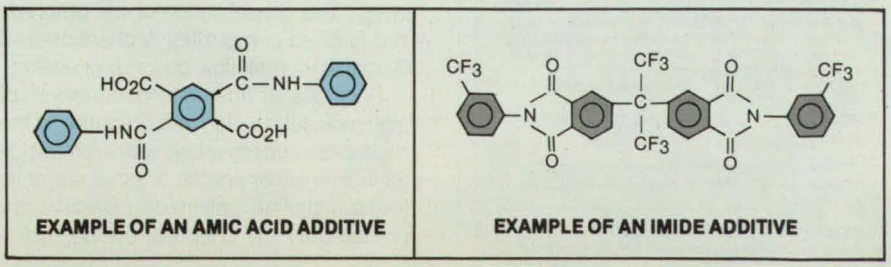
This work was done by Edward H. Tepper of United Technologies Corp. for **Johnson Space Center**. *No further documentation is available.*
MSC-21259

Additives Improve Processing of Polyimides

Low-molecular-weight, thermally stable additives enhance flow properties.

Langley Research Center, Hampton, Virginia

Aromatic polyimides are usually considered to be high-temperature, high-performance plastics that require processing via poly(amic acid) precursors. This is because polyimides are usually insoluble in most organic solvents and are either infusible or have very high melting or softening temperatures near those at which decomposition begins. Therefore, a need exists for polyimides as matrix resins and



Amic Acid or Imide Additives are used to decrease the viscosities of certain polymer melts.

adhesives that exhibit enhanced flow during processing. Recently, melt-processable polyimides that maintain desirable polymer properties were prepared by adding small amounts of certain low-molecular-weight, thermally stable additives.

The thermal treatment of a mixture of approximately 0.05 to 15 percent by weight of an amic acid or imide additive (see figure) and a poly(amic acid), polyimide, copoly(amic acid), or copolyimide resin increases the ease of processing of the polyimide during the early curing stage by lowering the viscosity of the polymer melt. Further thermal aging allows the buildup of molecular weight, as shown by increases in solution viscosity, with concomitant increases in desired physical properties.

The technique can be practiced with any of four different combinations of materials. Amic acids can be added to poly (amic acids), imides can be added to poly (amic acids), amic acids can be added to polyimides, and imides can be added to polyimides. The additives and polymers can be mixed by combining the substances in solutions, dispersions, or mixtures of powders.

Enhanced flow of the melts during processing was achieved for the thermoplastics produced by the above combinations. This technique will be useful in the preparation of void-free polyimide composites from higher flow resins that wet out fibers at lower processing temperatures. Likewise, this technique can be applied to the preparation of high-temperature polyimide adhesives that allow enhanced wetting of the adherends and, ultimately, better adhesion. By control of the amount of additive, the flow of the polyimide can be optimized. The technique is an improvement to the processing of polyimides and has potential application for the production of films, coatings, adhesives, and composites.

This work was done by Terry L. St. Clair, Harold D. Burks, and Diane M. Stoakley of **Langley Research Center** *and J. Richard Pratt of PRC Kentron, Inc. For further information, Circle 120 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 18]. Refer to LAR-13669

Processable Aromatic Polyimide Thermoplastic Blends

Resins exhibit excellent melt flow during processing.

Langley Research Center, Hampton, Virginia

Polyimides are attractive to the aerospace industry because of their toughness, thermal and thermo-oxidative stability, resistance to solvents, and excellent mechanical and electrical properties over a wide range of temperatures. However, the production of structurally-sound, void-free laminates from prepregs (layers of fabric preimpregnated with resin) has been difficult due to the poor melt-flow characteristics exhibited during processing. A method has been developed for preparing readily-processable thermoplastic polyimides by blending linear, high-molecular-weight, polyamic acid solutions in ether solvents with ultrafine, semicrystalline, thermoplastic polyimide powders. The slurries thus formed are used to make prepregs. The consolidation of the prepregs into finished composites is characterized by excellent melt flow during processing.

Solutions of linear polyamic acids of high molecular weight are prepared by the reactions of dianhydrides with aromatic diamines in either aprotic or ether solvents. Semicrystalline polyimide powders are prepared by the chemical cyclodehydration of the polyamic acids in aprotic solvents. The semicrystalline powders must have low melt viscosities, usually obtained by controlling molecular weight; yet on heating, these powders must increase in molecular weight by slow chain-growth polymerization of the amine and anhydride end groups to form tough linear thermoplastic material.

To make the prepregging slurry, the semicrystalline polyimide powder is added to a 10- to 40-percent solution of the high-molecular-weight polyamic acid. Ether solvents are preferred. The powder must remain insoluble. Depending upon the desired amount of improvement in the melt flow, the weight ratio of polyimide powder to polyamic acid can vary from 1:10 to 10:1. The total content of solids can vary from 20 to 50 weight percent. The resultant slurry must be stable and not separate into its components if it is to be employed in prepregging fiber or fabric in continuous processes.

The slurry can be applied to film, fiber, fabric, metal, polymer, or composite surfaces. After a "B-stage" heat treatment to remove solvent and water of imidization,

the polymer coating thus obtained includes the semicrystalline powder homogeneously dispersed on the substrate in the polyimide derived from the polyamic acid. Thermal treatment above the melting temperature of the semicrystalline powder with or without the application of pressure causes enhanced melt flow of the blend of the two polyimides. The viscosity of the melt increases as the molecular weight of the polyimide derived from the semicrystalline powder increases.

This technique was used to make various stable slurries from which prepregs were prepared. The composites fabricated from the prepregs exhibited high glass-transition temperatures, excellent consolidation, and had no voids, as indicated by good ultrasonic C-scans by equipment capable of detecting microvoids. High short-beam shear and flexure properties of these composites were also obtained at both room and high temperatures.

This work was done by Robert M. Baucom, Norman J. Johnston, Terry L. St. Clair, James B. Nelson, John R. Gleason, and K. Mason Proctor of **Langley Research Center**. *For further information, Circle 140 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 18]. Refer to LAR-13695.

Sizing Increases Fiber/Matrix Adhesion

Graphite fibers are precoated in a dilute solution of the matrix.

NASA's Jet Propulsion Laboratory, Pasadena, California

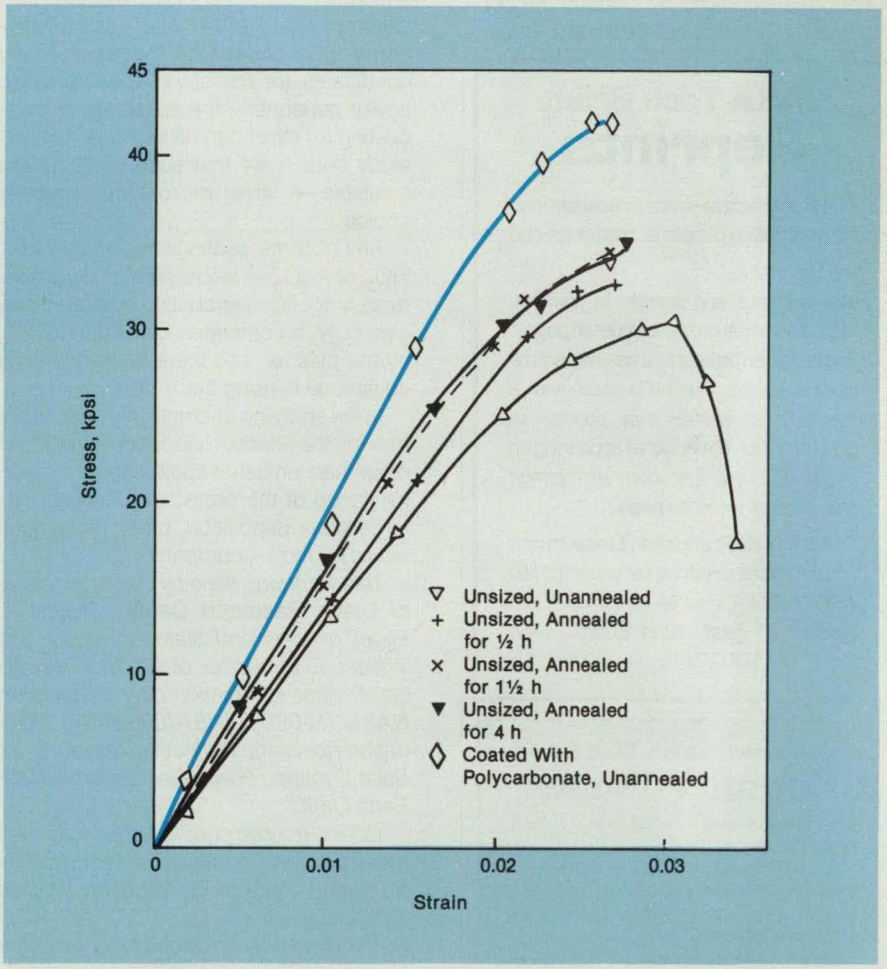
Experiments have shown that the strengths of graphite fiber/polycarbonate matrix composites are increased by precoating ("sizing") the fibers with a thin layer of polycarbonate. It is widely recognized in the industry that sizing can promote the wetting of fibers by matrix polymers, thereby enhancing fiber/matrix adhesion; however, until now the proprietary nature of commercially sized fibers has made it difficult to investigate the factors that determine the effectiveness of sizing.

The graphite fibers to be sized were immersed in a solution of 0.1 weight percent of polycarbonate in methylene chloride for ½ h, then drained and dried at 65 °C in an air-circulating oven for about 1 h. From the length [0.25 in. (6.35 mm)], diameter (8 μm), and weight gain of the fibers (0.65 percent), the thickness of the polycarbonate coating on the fibers was estimated to be 125 Å.

Composite mats were formed by pressing mixtures of sized or unsized graphite fibers and polycarbonate flakes at a temperature of 275 °C and a pressure of 5,000 psi (34 MPa) for 15 min, then allowed to cool slowly to room temperature while remaining under pressure. Some of the samples were annealed in the press by maintaining them at 245 °C for various intervals from ½ to 4 h before allowing them to cool to room temperature.

Specimens were cut from the composite mats and subjected to three-point bending tests to fracture, to determine their flexural strengths and moduli. As shown in the figure, the flexural strength of the specimens made from unsized fibers was increased by annealing. However, the unannealed specimens made from sized fibers showed the greatest strength of all.

The question of the molecular structure of the fiber/matrix interface in the sized specimens has not yet been addressed. However, x-ray diffraction analysis of the unsized specimens showed that annealing causes the matrix polymer to crystallize partially on and around the graphite fibers.



The **Flexural Strengths** of composite samples were measured to determine the effects of different fabrication conditions.

Such crystallinity was previously known to be caused by exposure to solvents or by annealing above the glass-transition temperature and may be responsible for the enhancement of the fiber/matrix bonding.

This work was done by Muzaffer Cizmecioglu of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 143 on the TSP Request Card.*

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

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Refer to NPO-16975, volume and number of this NASA Tech Briefs *issue, and the page number.*

Books and Reports

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

Oxidation-Resistant Surfaces for Solar Reflectors

Thin films on silver provide highly-reflective, corrosion-resistant mirrors.

A study has evaluated a variety of oxidation-resistant reflective materials for use in a solar dynamic power system, one that generates electricity by focusing the Sunlight onto the receiver of a heat engine. Such a system offers the advantage of high efficiency — higher than that of a photovoltaic system, for example.

Thin films of platinum and rhodium were deposited by ion-beam sputtering on various substrate materials. Solar reflectances were measured as a function of time of exposure to a radio-frequency-generated air plasma. Similarly, several protective coating materials — magnesium fluoride, silicon dioxide, aluminum oxide, and silicon nitride — were deposited on silver-coated substrates and exposed to the plasma. The films were analyzed before and after exposure by electron spectroscopy for chemical analysis and by Auger spectroscopy.

Although platinum and rhodium survived the exposure to atomic oxygen in the plasma, their reflectances are so low compared to that of silver that they are not likely candidates for mirrors in solar dynamic power generators. If a suitable protective coating for silver can be found — and the study data show that such coatings are available — silver mirrors are a better choice.

Any of three coatings tested — MgF_2, SiO_2, or Al_2O_3 — would protect silver adequately against degradation by atomic oxygen. Si_3N_4 is completely converted to SiO_2 by the plasma, and there is therefore no advantage in using the nitride.

In the study, no attempt was made to determine the effect of deposition techniques other than ion-beam sputtering on the performance of the protective coatings. For large-scale deposition, other techniques would be more appropriate.

This work was done by Daniel A. Gulino of **Lewis Research Center**, *Robert A. Egger of Cleveland State University, and William F. Banholzer of General Electric Co. Further information may be found in NASA TM-88865 [N87-10960/NSP], "Oxidation-Resistant Reflective Surfaces for Solar Dynamic Power Generation in Near Earth Orbit."*

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-14636

Hydrogen Embrittlement and Stacking-Fault Energies

Embrittlement in Ni/Cu alloys appears to be related to stacking-fault probabilities.

A report describes an attempt to show a correlation between the stacking-fault energy of different Ni/Cu alloys and their susceptibility to hydrogen embrittlement. Such a correlation could lead to a more fundamental understanding and to a method of predicting the susceptibility of a given Ni/Cu alloy from its stacking-fault energies calculated from X-ray diffraction measurements. Currently, this susceptibility is measured by a costly, time-consuming procedure involving the physical testing of notched tensile specimens in 34.5 MPa of hydrogen and in a mixture of air and helium: The ratio of ultimate tensile strength in hydrogen to that in air is a measure of the relative susceptibility of an alloy to hydrogen embrittlement, a smaller ratio indicating a greater sensitivity.

Stacking-fault energies have been used to explain hydrogen embrittlement of alloys in terms of hydrogen transport. According to this theory, a low stacking-fault energy entails very difficult cross-slip for dislocations; consequently, moving dislocations on the slip plane transport hydrogen to a small region of the grain boundary as the dislocations pile up. The resulting concentration of hydrogen causes the loss of integrity in the grain boundary. On the other hand, dislocations in an alloy with a high stacking-fault energy (narrow fault width) easily undergo cross-slip. Therefore, hydrogen in a dislocation is scattered throughout the grain, with less damage to the grain-boundary integrity.

Copper and nickel react oppositely to hydrogen and have high and low stacking-fault energies, respectively. It was hoped that the stacking-fault energies in copper/nickel alloys could be correlated with hydrogen embrittlement over the compositional range above 50 weight percent nickel, in which these alloys begin to show marked hydrogen embrittlement.

Experiments were performed with six copper/nickel alloys having the percentage of nickel from 47.7 (notched tensile ratio hydrogen/air = 0.96) to 73.5 (notched tensile ratio hydrogen/air = 0.52). Stacking-fault energies and probabilities were calculated from X-ray diffraction measurements on cold-worked and annealed powders. Hydrogen embrittlement was found to increase with decreasing stacking-fault probabilities, but the correlations among stacking-fault energies, stacking-fault probabilities, and embrittlement appear to be indirect. Even with an increase in the precision of X-ray diffraction measurements, it may not be possible to produce a direct correlation.

This work was done by R. A. Parr, M. H. Johnson, J. H. Davis, and T. K. Oh of **Marshall Space Flight Center**. *For further information, Circle 60 on the TSP Request Card.*
MFS-27114

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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.

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

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

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Computer Programs

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

Mathematics and Information Sciences

File-Format Program for Transferable Output ASCII Data

TOAD utilities are machine-independent and require minimal central memory.

The Transferable Output ASCII Data (TOAD) file-format computer program facilitates the transfer of data files from one computer installation to another. TOAD files are of the preferred type and record length to make them easy to edit, read, and write on magnetic tape or to transfer across communications networks. Applications programs can write TOAD files directly yet still conform to all ANSI FORTRAN 77 standards.

The TOAD utilities are written in ANSI FORTRAN 77 and have been implemented on CDC NOS, CDC NOS/VE, VAX VMS, VPS-32 VSOS, and Gould UNIX systems, requiring a minimum of central memory. This technique and these utilities are machine-independent. The TOAD format and associated utilities were developed in 1985.

This program was written by Bradford Bingle of Computer Sciences Corp. for **Langley Research Center**. *For further information, Circle 103 on the TSP Request Card.*
LAR-13755

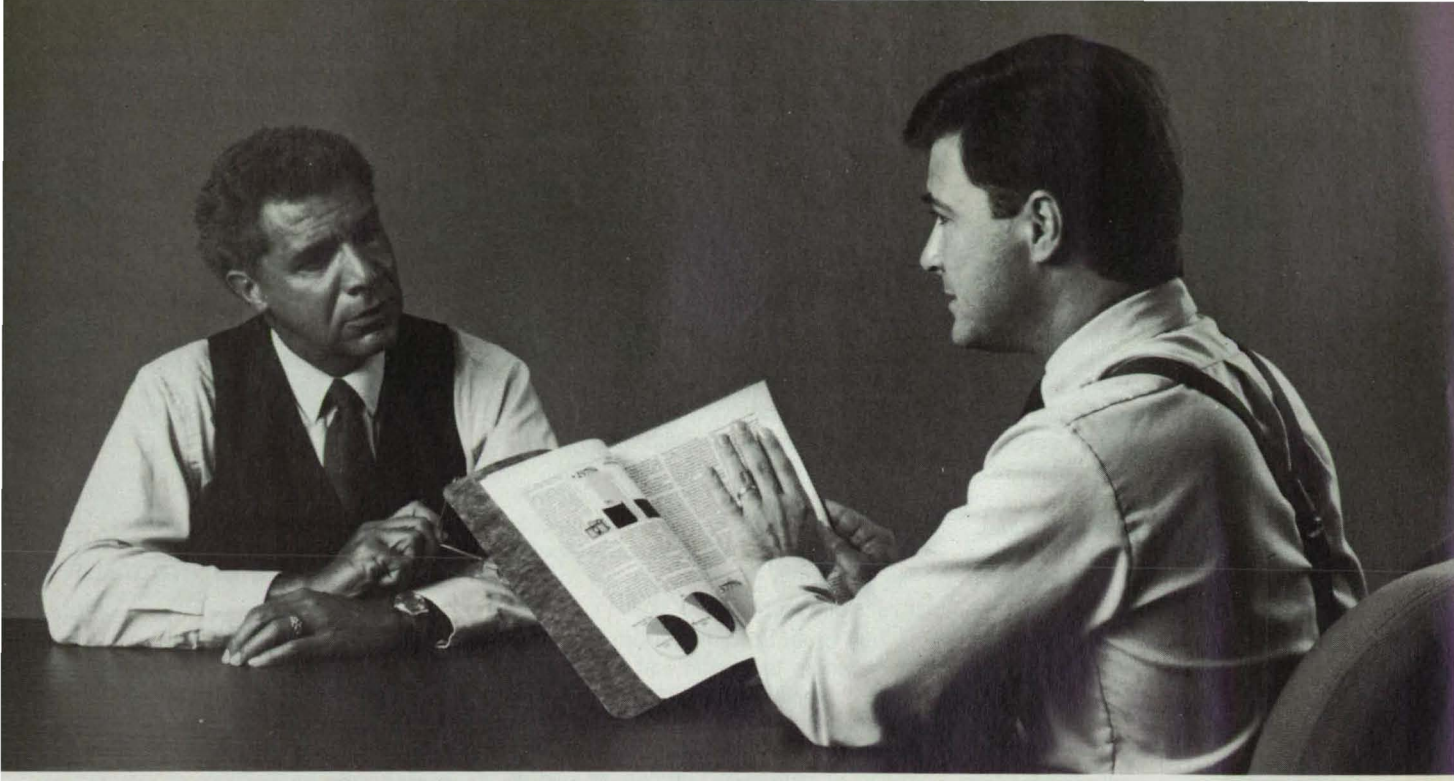
Definition of Touch-Sensitive Zones for Graphical Displays

Touch zones are defined simply by touching, while editing is done automatically.

The development of a touch-screen interactive computing system can be a tedious task. The Interactive Editor for Definition of Touch-Sensitive Zones computer program greatly increases the efficiency of human/machine communications by enabling the user to define each zone interactively, thus minimizing redundancy in programming and eliminating the need for manual computation of the boundaries of touch areas. The information produced during the editing process is written to a data file, to which access can be gained easily when needed by an application program.

The touch-editing program is linked as a subroutine to the display-generating software. After answering questions concerning the format of the desired data file, the user defines each area individually by touch. The user touches the screen in one corner of the desired zone and then moves to the opposite corner of the zone without breaking contact with the screen. As this is done, a rectangle is drawn on the monitor showing the user the touch zone as it is being defined. The rectangular area expands dynamically with the motion of the user's finger, as though the periphery were being stretched like a rubberband. When the area is defined to the user's satisfaction, the coordinate data are written to the file.

Additionally, diagnostic routines in the editing program alert the user when touch areas overlap and allow for correction of the error. The application program can then provide the appropriate response to a



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Circle Reader Action No. 661

touch input by using the data file to determine easily which, if any, area has been pressed.

This program has been implemented in VAX-11 FORTRAN on a DEC VAX 11/780 computer operating under VMS 4.4. Graphics routines are written in the Real-Time Animation Package (RAP), a high-level graphics language used to control the Adage, Inc., Adage-3000 programmable display generator. Any VAX that controls a graphic display by communicating with a RAP procedure can use the editing program in its present implementation. The program has a memory requirement of under 10,000 8-bit bytes and was released in 1988.

This program was written by Burt L. Monroe III and Denise R. Jones of **Langley Research Center**. *For further information, Circle 147 on the TSP Request Card.*
LAR-13822

Rational-Spline Subroutines

Smooth curves can be drawn among plotted data more easily.

Scientific data often include random errors that make plotting and curve fitting difficult. The Rational-Spline Approximation with Automatic Tension Adjustment algorithm leads to a flexible, smooth representation of experimental data. As used here, "tension" denotes a mathematical analog of mechanical tension in a spline or other mechanical curve-fitting tool, and "spline" as used here denotes a mathematical generalization of such a tool.

The user sets the conditions for each consecutive pair of knots, which are user-defined divisions in the set of data. These conditions are set to apply no tension, to apply fixed tension, or to determine tension with a tension-adjusting subalgorithm. The user also selects the number of knots, the abscissas of the knots, and the allowed maximum deviations from line segments. The selection of these quantities depends on the actual data and on the requirements of a particular application.

This program differs from the usual spline under tension in that it allows the user to specify different values of tension between adjacent pairs of knots rather than a constant tension over the entire range of data. The subroutines use an automatic adjustment scheme that varies the tension parameter for each interval until the maximum deviation of the spline from the line joining the knots is less than or equal to an amount specified by the user. This procedure frees the user from the drudgery of adjusting individual tension parameters while still giving control over the local behavior of the spline.

The Rational Spline program is written completely in FORTRAN for implementation on a CYBER 850 operating under NOS. It has a central-memory requirement of approximately 1,500 words. The program was released in 1988.

This program was written by James R. Schiess and Patricia A. Kerr of **Langley Research Center** *and Olivia C. Smith of Computer Sciences Corp. For further information, Circle 100 on the TSP Request Card.*
LAR-13694

Permanent-File-Validation Utility Computer Program

Errors in files can be detected and corrected during operation.

The Permanent File Validation (PFVAL) utility computer program provides CDC CYBER NOS sites with a mechanism to verify the integrity of the permanent file base. PFVAL locates and identifies permanent file errors in the Mass Storage Table (MST) and Track Reservation Table (TRT), in the permanent file catalog entries (PFC's), in the permit sectors, and in the disk sector linkage. All detected errors are written to a listing file and to the system and job day files.

A site can use PFVAL either to verify that the permanent file base is intact or to isolate errors for correction via the Display Disk File (DDF) utility computer program, a CDC NOS standard product. The program can also be used to clear an error idle condition on a disk (entry point CLREI) and to perform online validation of the track linkage in the MST/TRT for a specified mass storage device (MSVAL).

The program operates by reading system tables (the MST and TRT), the catalog track (PFC's), the permit sectors, and the disk linkage bytes to validate expected and actual file linkages. This program has been used extensively to identify and locate errors in permanent files and enable online correction, thus reducing computer-system downtime.

PFVAL is written entirely in COMPASS (CPU & PPU) and includes common decks and has been implemented on a CDC CYBER 170 and 180 series running NOS version 2. Approximately 22,000 words (octal) are initially required for execution, but field length will increase as internal tables are built. The program was developed in 1983.

This program was written by Stephen D. Derry of Unisys Corp. for **Langley Research Center**. *For further information, Circle 148 on the TSP Request Card.*
LAR-13946

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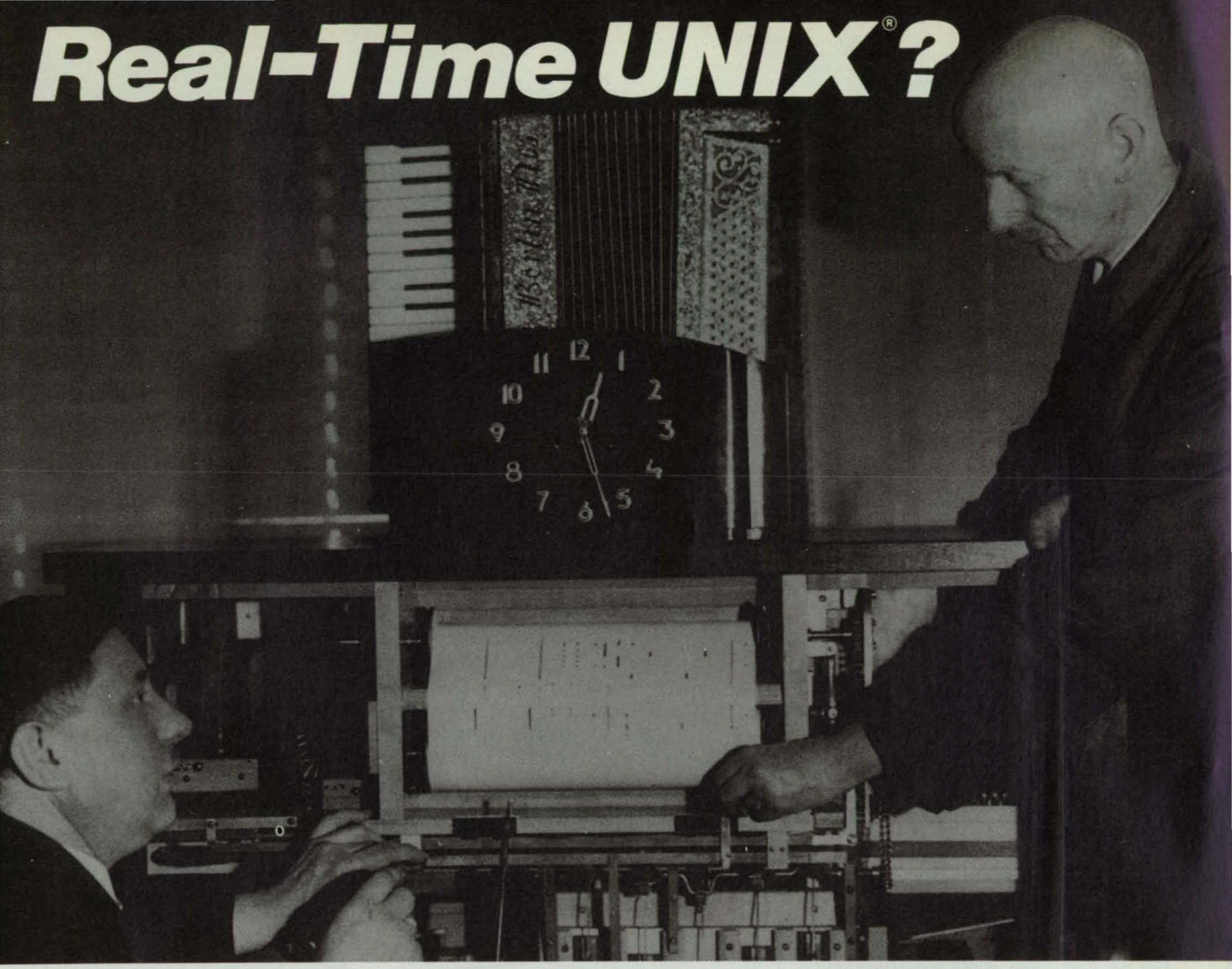

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Mechanics

Hardware Techniques, and Processes

Positioning Rotors in Turbine Flowmeters

Lengths of wakes are roughly proportional to thicknesses of vanes.

Marshall Space Flight Center, Alabama

A mathematical model simplifies the analysis of the effects of flow-straightening vanes in a turbine flowmeter. The model yields a numerical solution of the differential equations of flow for a quick examination of the effects of the thicknesses of the vanes and the rate of flow on the extent of the wake behind the vanes. From this examination, the minimum distance at which the flowmeter rotor should be placed behind the vanes can be determined.

The purpose of the flow straightener is to make the velocity uniform across the flowmeter pipe. Ideally, the rotor spins with a rotational velocity proportional to the rate of flow through the pipe. However, if the rotor is positioned too closely to the flow straightener, the wake of the straightener vanes imposes substantial nonuniformity on the flow that impinges on the rotor. In that case, the rotational velocity of the rotor is no longer proportional to the rate of flow, and the indications of the flowmeter are inaccurate.

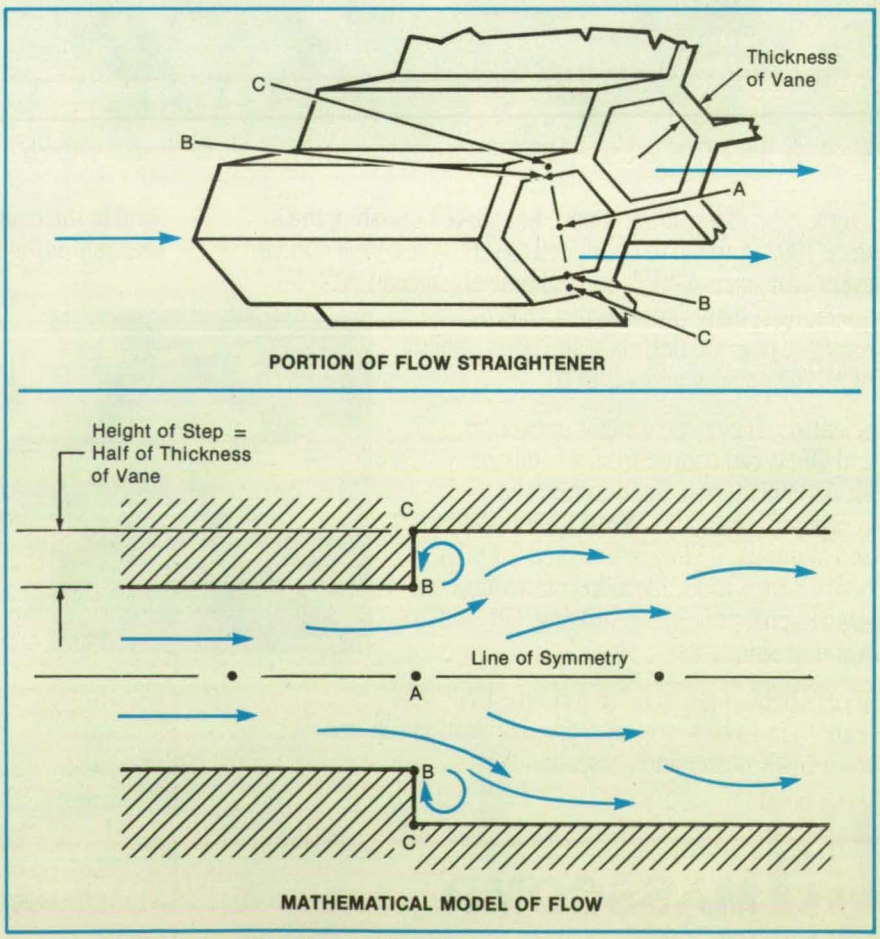
The mathematical model represents a portion of a hexagonal array of flow-straightening vanes as a two-dimensional backward-facing step that is half of a symmetric pair. The height of the step is equal to half the thickness of a vane (see figure).

The analysis is performed with the help of a computer code that has been modified to calculate the flow past a straightener vane and to estimate both the length of the recirculation region behind the vane and the deviation of the velocity field behind the vane from uniformity. The code, which uses a two-dimensional, steady-state formulation, solves the Navier-Stokes equations of fluid flow by an iterative underrelaxation procedure combined with integral control-volume analysis, hybrid finite differencing, and a staggered grid system. Another model, called the k-ε model, is applied to solve for the turbulent Reynolds stresses.

The analytical technique was first used to solve a long-standing problem in a liquid-hydrogen flowmeter: When the rotor was moved from 1.5 in. (3.8 cm) to 0.75 in. (1.9 cm) behind the straightener, the ratio of the rotational speed of the flowmeter to the rate of flow varied with the rate of flow. From experience, the intensity of the turbulence was known to have only a weak effect on the flow field. Therefore, the extent of the wake was calculated as only the two remaining parameters — the thickness of the vanes and the rate of flow — were varied.

The calculation showed that the rate of flow was large enough so that it had only a minor effect on the extent of the wake. On the other hand, the thicknesses of the vanes had a substantial effect. The length of the wake was found to be linearly related to the height of the step and, therefore, to the vane thickness. This suggests that if the rotor is moved closer to the flow straightener and/or the straightener vanes are made thicker, the flow at the rotor becomes nonuniform, and the performance of the flowmeter is impaired. Thus, to maintain adequate performance when placing the rotor closer to the straightener, it is necessary to decrease the thickness of the vanes.

This work was done by Edward D. Lynch, Daniel C. Chan, and Munir M. Sindir of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information, Circle 163 on the TSP Request Card.*
MFS-29331



The **Wake Behind a Flow-Straightening Vane** in a hexagonal array of such vanes is modeled as the two-dimensional flow past a backward-facing step.

Self-Protecting Heat Exchanger

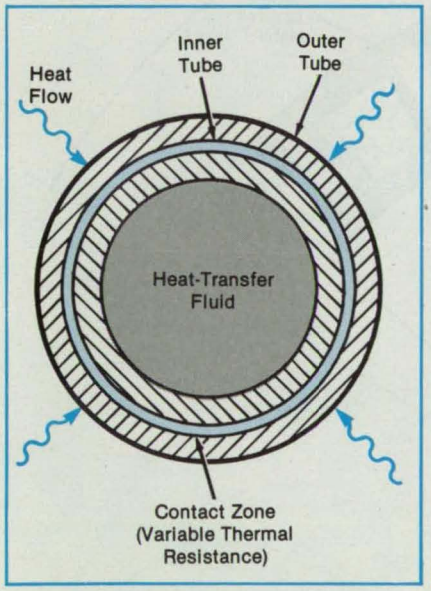
A double wall with a variable gap would have variable conductance.

Marshall Space Flight Center, Alabama

A proposed double-wall heat-exchanger tube would protect itself from overloads by changing its thermal resistance automatically. When the temperature at any location on the tube increases above a prescribed limit, the thermal resistance through the walls of the tube would increase at that location. It would thus prevent the local excess heat load from overheating the tube or boosting the internal pressure and thereby weakening the tube, shortening its life expectancy, or destroying it. When the heat load falls to a normal level, the tube would automatically lower its thermal resistance and resume heat exchange at its rated capacity.

The double-wall tube would consist of an outer tube fitted around an inner tube in such a way that the local thermal conductivity across the gap between the tubes would vary with the local contact pressure (see figure). Fluid flowing through the inner tube would carry off the heat absorbed through the outer tube from the hot gas or other medium surrounding it. Ordinarily, the outer tube would fit tightly around the inner tube, and the close contact would enable the rapid and efficient flow of heat from the outside medium to the fluid in the inner tube. When the temperature of the outside medium rises above a preset level, the jacket would expand, creating or increasing the gap between the inner and outer tubes at that point. The local thermal resistivity would therefore rise at the point, and heat flow from the outside would decrease, preventing thermal overload of the inner tube and the fluid within it. When the outside temperature falls to a safe value, contact between the jacket and core would be restored.

The double-wall tube was conceived for the tank-pressurization heat exchanger of the Space Shuttle main engine, where it would have to operate at a pressure of 3,500 psi (24 MPa) and a temperature of 778 K (505 °C). The double-wall design would increase the safety of present single-wall tubes, which must be thin for high heat flux, long life, and low thermal stress. The most likely terrestrial applications are heat exchangers in airplanes.



A **Heat-Conductive Outer Tube** would surround a heat-conductive inner tube. Expansion of the outer tube under an excessive external temperature would increase the thermal resistance of the tube-to-tube contact and thereby diminish the flow of heat to the inner tube.

This work was done by William R. Wagner 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 18]. Refer to MFS-29286.

Condensing, Two-Phase, Contact Heat Exchanger

A unit separates liquid from vapor as it condenses.

Lyndon B. Johnson Space Center, Houston, Texas

A two-phase heat exchanger continuously separates the liquid and vapor phases of the working fluid and positions the liquid phase for efficient heat transfer. The exchanger consists of alternating channels for liquid and vapor in a cylindrical wall (see figure).

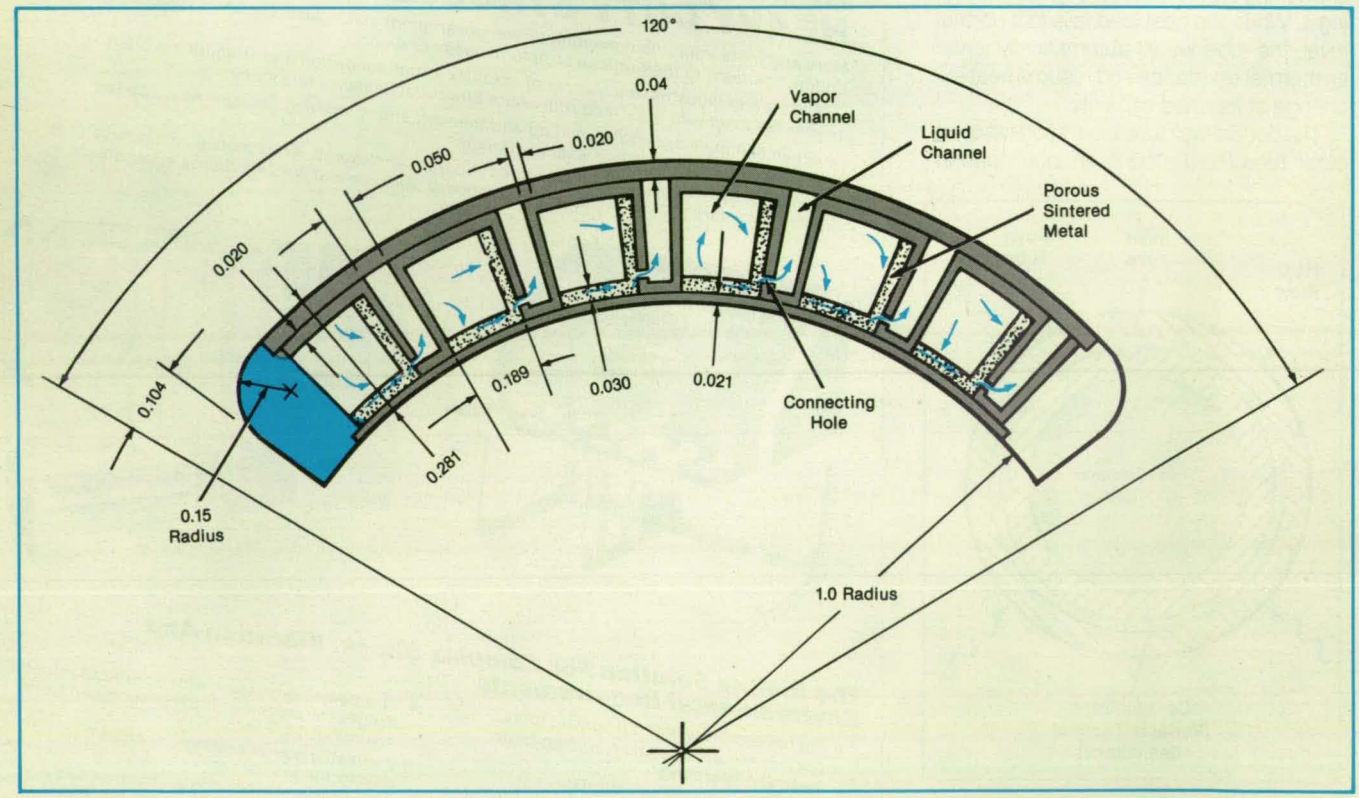
Saturated vapor flows in the vapor channels. As the vapor condenses, capillaries in a porous sintered-metal layer on the channel walls wick the liquid away. Holes in the wall, behind the sintered layer, carry the condensed liquid into the adjacent liquid channel. The higher pressure in the vapor channel aids in driving the condensate into the liquid channel, which is continuously drained by a suction pump.

Each liquid channel communicates with only one vapor channel through its holes. The liquid channels join a suction manifold at one end. The opposite ends of the liquid channels are sealed.

If only vapor enters the vapor channels through the vapor manifold, they too could be sealed at one end. However, if the vapor enters with a noncondensing carrier gas, the vapor channels would have to be exhausted through a second manifold so that the carrier gas can be recycled.

The heat exchanger is designed for zero gravity. The principle can be adapted to other phase-separation applications; for example, in thermodynamic cycles for solar-energy conversion.

This work was done by R. L. Cox, J. A. Oren, and L. W. Sauer of LTV Aerospace and Defense Co. for **Johnson Space Center**. *No further documentation is available. MSC-21179*



The **Cylindrical Heat Exchanger** consists of three 120° segments like the one shown here in cross section. Dimensions, in inches, are for an ammonia-condensing unit that can transfer 2.3 W/cm^2 at the inner surface of the cylinder at a maximum operating temperature of 100°F (38°C).

Thread-Mounted Thermocouple

A simple device measures the average temperature of the surrounding material.

Langley Research Center, Hampton, Virginia

A thread-mounted thermocouple has been developed to accurately measure the temperature of the surrounding material. The thermocouple (see figure) comprises a threaded rod or bolt drilled along its length, a dual-hole ceramic insulator rod, a thermocouple wire, optional ceramic filler, and epoxy resin. The device is totally in contact with, and takes an average temperature of, the surrounding material.

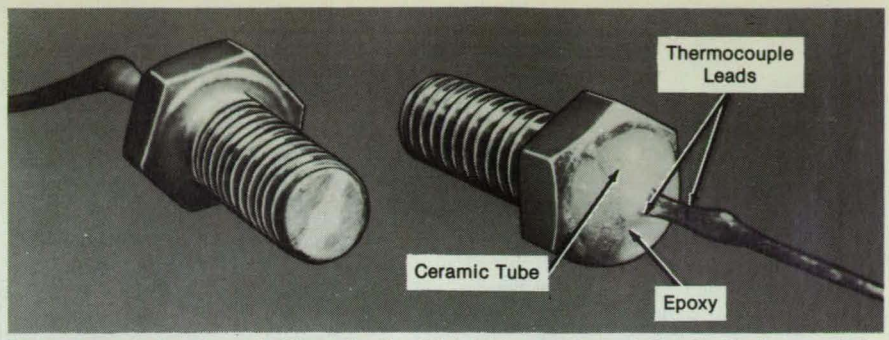
Three different versions of the thermocouple have been installed for use with two different wind-tunnel models at Langley Research Center's 8-Foot High Temperature Tunnel (8 ft HTT). The ceramic filler

used makes the thermocouple suitable for dynamic use: the 8 ft HTT reaches air speeds of mach 7. The thermocouple can replace an ordinary heat-flux gauge and can screw into any similarly sized threaded hole. The thread/jam nut design enables a solid, precise adjustment.

The thermocouple can be fabricated easily in the size and metal to suit the particular application. Because of its simplicity and ability to measure the average temperature, widespread use of this design is foreseen in a variety of applications.

This work was done by Stanley W. Ward of **Langley Research Center**. *No further documentation is available.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 18]. Refer to LAR-13475.



Thermocouple Leads are fed from the tip of the device out through the dual-hole ceramic insulator.

Support for Fragile Borescopes

A fixture guides and protects small-diameter optical-inspection instruments.

Marshall Space Flight Center, Alabama

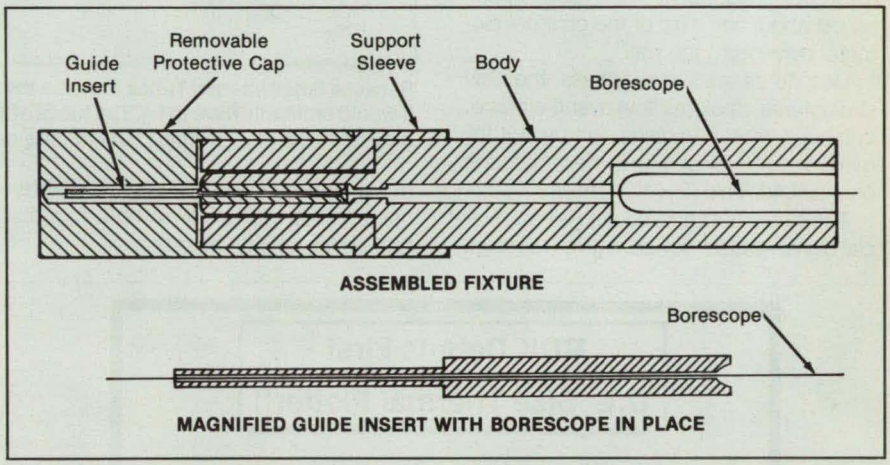
A fixture supports thin borescopes during inspections through 0.0405-in. (1.03-mm) orifices. The borescopes, which have a diameter of only 0.037 in. (0.94 mm), are extremely fragile and often fracture during inspections, contaminating the inspected cavities with debris. Fractures can also cause production delays because the borescopes cannot be repaired and have to be replaced with new handmade units.

The fixture reduces the risk of breakage, enabling the use of the borescopes in inspections in the field as well as under laboratory conditions. It supports both rigid and flexible borescopes, protecting them from damage caused by crimping as they are fed through orifices. With modifications of its dimensions, the fixture concept could be adapted to other borescopes of various sizes and degrees of flexibility.

The fixture consists of a body, a support sleeve, and a guide insert, all with axial holes to accommodate the borescope (see figure). A protective cap covers the guide insert and protruding tip of the borescope (if present) when the fixture is not in use.

The fixture is inserted in a hole slightly larger than itself, immediately outside the inspection orifice, so that the support sleeve rests on a surface of the part to be inspected, stabilizing the assembly. The borescope is fed through the fixture and into the orifice, then rotated for a complete inspection. The guide insert prevents the borescope tip from striking the edge of the orifice as it enters, keeping it squarely in the center of the orifice. It is therefore unlikely to damage itself or the part. The fixture has rounded contours so that it does no damage when it is inserted in the large hole immediately outside the inspection orifice.

The fixture dampens vibrations of borescopes. It thus helps to prevent the damage caused by vibrations and eliminates the constantly moving view that afflicts unsupported small-diameter borescopes.



The **Nylon Guide Tip and Acrylic Support Sleeve and Body** protect and guide a fragile borescope. The support sleeve is press-fitted on the body and can be removed when there is little clearance around the orifice to be inspected. Otherwise, it helps to stabilize the fixture.

This work was done by William S. Brown and David E. Janke of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information, Circle 145 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 18]. Refer to MFS-29230.

Portable Airflow Meter

A matrix of tubes reduces turbulence in a relatively short length.

Lyndon B. Johnson Space Center, Houston, Texas

A compact hand-held instrument (see figure) measures airflow. The instrument consists of a hot-wire anemometer probe in a flow-straightening tube that reduces swirling. It weighs less than 8 lb (3.6 kg) and can be readily stored on the Space Shuttle, for which it was developed to measure airflow in the waste-collection system during flight. The instrument could

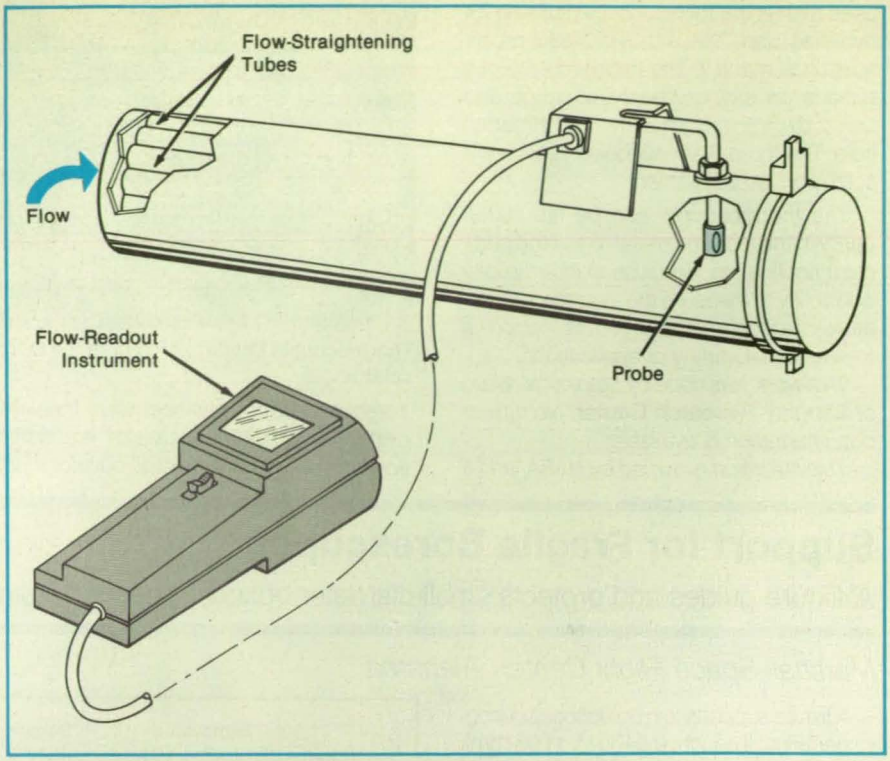
also be used on Earth to measure airflow in ventilation systems, vacuum cleaners, and the like.

The configuration of the flow straightener was developed empirically to reduce the length of the instrument to a practical dimension for use and storage in a confined space. Standards for conventional flow straighteners recommend a minimum length upstream of the probe of 10 times the tube diameter and a minimum downstream length of 6 diameters. However, adherence to these criteria would have required a straightener 64 in. (1.6 m) long. The two versions of the new straightener are only 17 and 18 in. (43.2 and 45.7 cm, respectively) long.

The inlet of the new straightener contains a matrix of internal tubes to reduce swirl and turbulence. The internal tubes are 4 in. (10.2 cm) long and ½ in. (1.3 cm) in diameter. The screen is made of wire 0.032 in. (0.81 mm) in diameter woven in a 14 by 14 mesh per square in. (5.5 by 5.5 mesh per square cm). The probe is positioned about one-third of the channel diameter away from the wall.

Despite its relative shortness, the new straightener stabilizes flow over the probe. Without it, meter readings vary by ± 4 ft^3/min (2×10^{-3} m^3/s); with it, the variation is only ± 0.4 ft^3/min (2×10^{-4} m^3/s).

The instrument is used with a commercial digital readout device. It gives readings of the air temperature in degrees Fahrenheit and airspeed in ft/min on a four-digit light-emitting diode display.



Because **Small Internal Tubes Stabilize the Airflow**, the flowmeter can be made shorter than it would ordinarily have to be. The tubes offer minimal resistance to the airflow: the pressure drop at a flow of 30 ft^3/min (0.014 m^3/s) is only 0.1 in. of water (about 22 Pa).

This work was done by Frank A. Burgett of **Johnson Space Center** *and Donald R. Hardwick and Johnny L. Porter of Northrop Services, Inc. For further information, Circle 71 on the TSP Request Card.*
MSC-21200

Simplified Analysis of Vehicle/Payload Vibrations

An approximate method yields a conservative criterion for stability.

Lyndon B. Johnson Space Center, Houston, Texas

A simplified mathematical model of the coupled vibrations of a vehicle and its payloads can be used in a stability analysis for control purposes. Developed to avoid the complexity and cost of full vibrations/stability calculations for each different combination of Space Shuttle payloads, the simplified analysis technique may also be useful in assessing stability in loaded airplanes, ships, trucks, cranes, and conveyor systems.

The multiple-payload stability criterion is an extension of a single-payload criterion that is based on measurements and on detailed calculations of the fundamental vibrational modes of the vehicle and pay-

load. The vehicle and single payload are represented in simplified form by coupled masses and springs vibrating in one dimension, each spring having the stiffness that would give rise to the previously determined fundamental vibrational frequency of the associated mass in the absence of coupling with the other mass (see Figure 1).

The dynamics of the coupled vehicle and payload are expressed in standard characteristic-equation form. The equations are solved for the frequency of the fundamental vehicle-bending mode in the presence of coupling. If this frequency is set to a value that is known to enable control stability to be achieved and if the constrained-payload vibrational frequency lies at or above the frequency on a previously determined stability curve (see Figure 2), then the system satisfies the single-payload stability criterion.

For a vehicle with n payloads, there are $n + 1$ coupled dynamical equations. These can also be placed in standard characteristic-equation form and solved for the $n + 1$ fundamental vibrational frequencies, one of which represents the fundamental vehicle-bending mode in the presence of coupling. The body-bending frequency ω^* can also be represented as that of a system having a single payload of mass equal to the sum of all the payload masses, and having an equivalent spring that yields the body-bending frequency ω^*. This frequency is set to a value that enables control stability to be achieved as in the case of a single payload.

If the sum of payload masses vibrating on the equivalent spring has a frequency $\omega_{e\omega}$ that satisfies the single-payload stability criterion, and if each payload considered in isolation also passes the stability test, then the entire payload/vehicle system passes the test. This criterion is conservative in that it assumes that all payload masses respond together in phase, thereby exerting the maximum impact on the vehicle. In practice, payloads vibrate in different phases, thereby partially cancelling the effects of each other. Furthermore, the full mass of each payload does not participate in the fundamental constrained-payload vibrational mode: thus, the impact of each payload is less than assumed, making the system more stable than assumed.

This work was done by Reginald R. J. Yu of McDonnell Douglas Corp. for **Johnson Space Center**. *For further information, Circle 86 on the TSP Request Card.*
MSC-21231

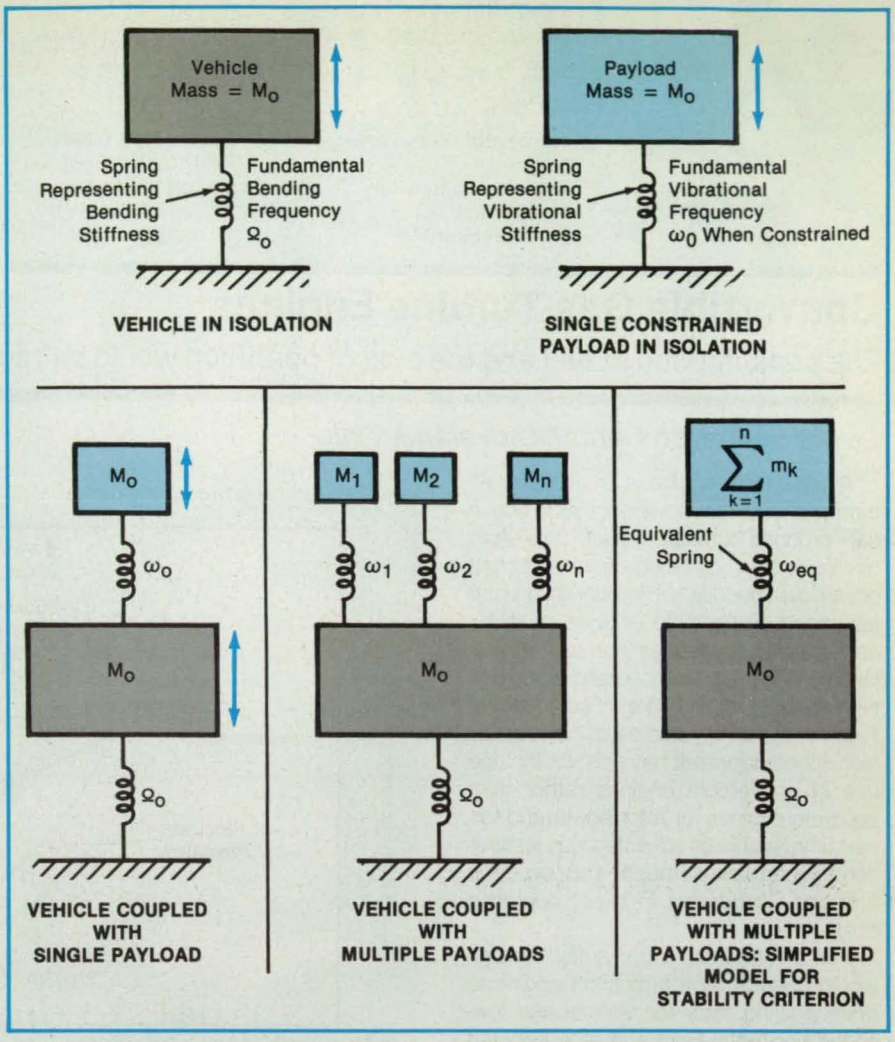


Figure 1. **Lumped Masses and Springs** that have vibrational frequencies equal to those of the vehicle and payloads in isolation are coupled together in a simplified one-dimensional analysis to determine the fundamental vibrational frequencies of the system.

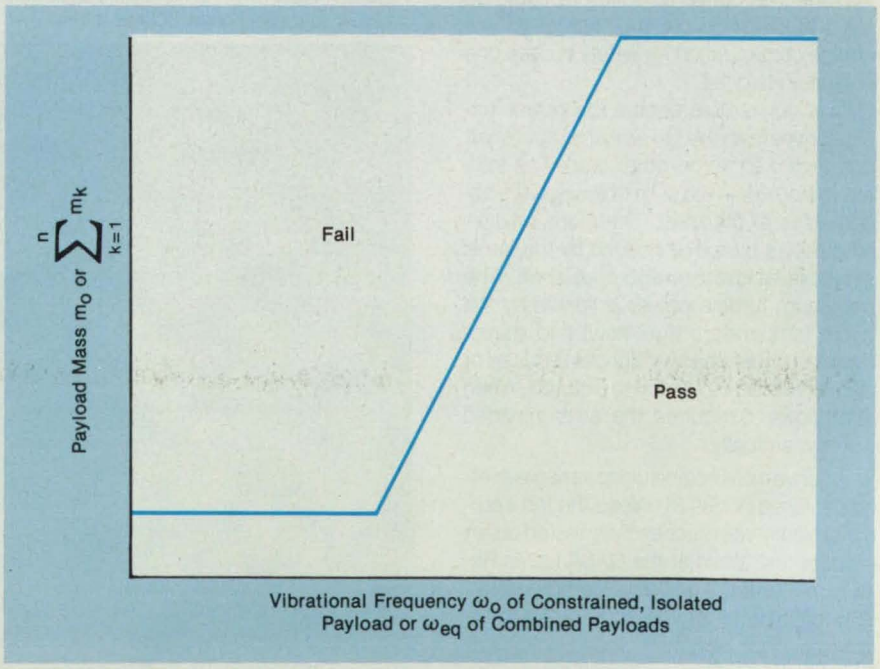


Figure 2. The **Payload/Vehicle System Is Stable** if the mass of the payload and the frequency at which it vibrates when constrained against an infinitely massive object lie on, or to the right of, the stability curve. The curve is obtained from an extensive theoretical and experimental analysis of the interactions between the vibrations and the control systems of the vehicle.

Machinery

Hardware Techniques, and Processes

Convertible Gas-Turbine Engines

The consumption of fuel and the cost of operation would be reduced.

Lewis Research Center, Cleveland, Ohio

A convertible engine is an aircraft gas-turbine engine that is two engines in one. It can produce turbofan thrust, turboshaft power, or any combined thrust and shaft power continuously while operating up to full speed. Convertible engines could be used to power vertical/short-takeoff-and-landing (V/STOL) airplanes and advanced high-speed rotorcraft like those shown in Figures 1 and 2. Studies of conceptual high-speed rotorcraft have shown that the use of convertible engines rather than separate engines for rotor power and forward thrust affords advantages in installation and can save as much as 16 percent in fuel and 20 percent in direct operating costs.

For a rotorcraft, a convertible engine would operate as a turboshaft engine to drive a lifting rotor for vertical and low-speed horizontal flight and as a turbofan engine to produce thrust for high-speed horizontal flight. For a jet-powered V/STOL airplane, the convertible feature could be used to cross-couple the fans in a two-engine configuration for safety in case one engine should fail.

In a convertible engine the power turbine drives both the fan and an output shaft connected to some other load. The total turbine power is the sum of the powers absorbed by all the loads. Therefore, any turbine power over that needed by the fan is available at the power-output shaft. The maximum turbine power is limited by the cycle temperature (fuel flow) and speed. For high thrust, the shaft load is reduced or decoupled, as by releasing a clutch. When shaft power is required, the fan is unloaded aerodynamically.

A convertible engine using variable inlet-guide vanes (VIGV) to unload the fan aerodynamically was successfully tested on an outdoor test stand at the NASA Lewis Research Center. The tests demonstrated that this type of engine could be used for propulsion of new high-speed rotorcraft that need both thrust and shaft power. The engine might also be used to cross-couple the fans of a two-engine V/STOL aircraft, but the controls and dynamics for that application were not tested.

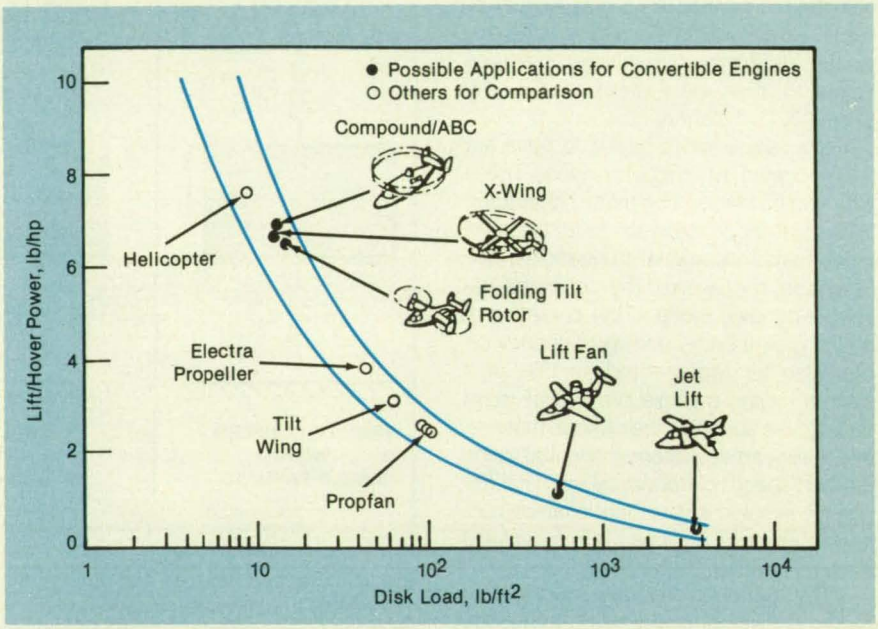


Figure 1. **Hovering Performance and Disk Loads** are plotted for various aircraft, some of which could use convertible engines.

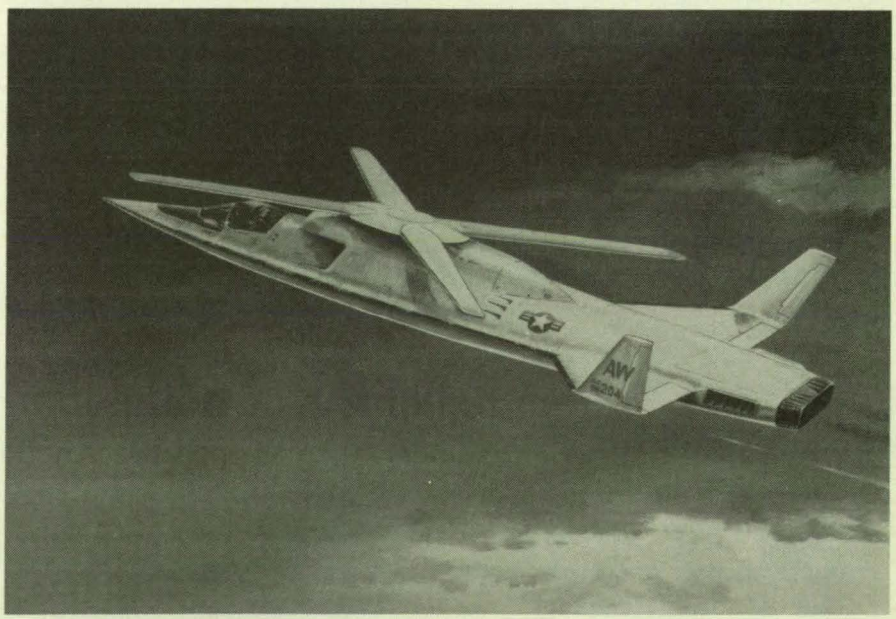


Figure 2. This **Conceptual Drawing** shows the X-wing rotorcraft with convertible engines.

In the steady-state tests, the engine was operated in the turboshaft, turbofan, and dual (combined fan and shaft) power modes. The engine ran smoothly except for a small region at high VIGV closure and high fan speed, where aeromechanical in-

stability of the fan tips was found. Otherwise, it was stable as the speed, shaft power, and any of the variable hardware settings were changed. This instability is not considered to be a big problem for a new engine and could be avoided by changes in the design of the blades.

For the propulsion of a rotorcraft, the engine would be used in the turboshaft or in the dual-power mode to drive a rotor for takeoff and low-speed flight. If thrust during takeoff is low, the VIGV would be closed, and the consumption of fuel by the engine would be about 25 percent more than that of a turbofan engine running at the same core power level. The additional fuel is needed because power is wasted in churning and heating the tip airflow with the VIGV closed. The wasted power is not detrimental to rotorcraft having engines sized for high-speed cruise, such as the X-wing, because the installed power would be great enough to permit hover at sea level while one engine is inoperative.

In high-speed cruising flight, the engine would be operated in the turbofan mode with the VIGV open (or nearly open) to produce thrust or in the dual-power mode if shaft power is also needed for such auxiliary equipment as a compressor for X-wing blowing. The fuel consumption of the engine would be comparable to that of a conventional turbofan engine because the only change in the use of fuel comes from the loss of inlet pressure across the VIGV. The loss is small when the VIGV are nearly open.

This work was done by K. L. Abdalla and J. G. McArdle of **Lewis Research Center** *and H. Lindsay of General Electric Co. Further information may be found in NASA TM-88939 [N87-16825/NSP], "Outdoor Test Stand Performance of a Convertible Engine with Variable Inlet Guide Vanes for Advanced Rotorcraft Propusion."*

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-14597

Angular-Momentum-Compensating Servomechanism

This nonlinear servomechanism prevents reaction torques from disturbing the supporting structure.

NASA's Jet Propulsion Laboratory, Pasadena, California

A servomechanism for rotating an instrumentation platform isolates the supporting vehicle or stationary platform from reaction torques produced by the rotations. The servo thus prevents the aiming of an instrument from disturbing the vehicle or other instrument platforms.

The servo includes a reaction wheel that provides a compensating torque to oppose the reaction torque. It uses a stepping motor instead of a continuously running motor to avoid the tendency to stick, which plagues linear motors at low speeds. In addition, it uses a set of reduction gears to connect the motor to the load instead of connecting it directly and thus provides both ample torque margin and more precise aiming.

The shaft of the motor, the reaction wheel, and gear 1 of the gear train rotate counter to the platform (see figure). If the angular momentum stored in these rotating elements precisely matches that stored in gear 2, the output shaft, the platform, and the load, the system forms a closed, reactionless unit that transmits no torque disturbances to the structure on which it is mounted.

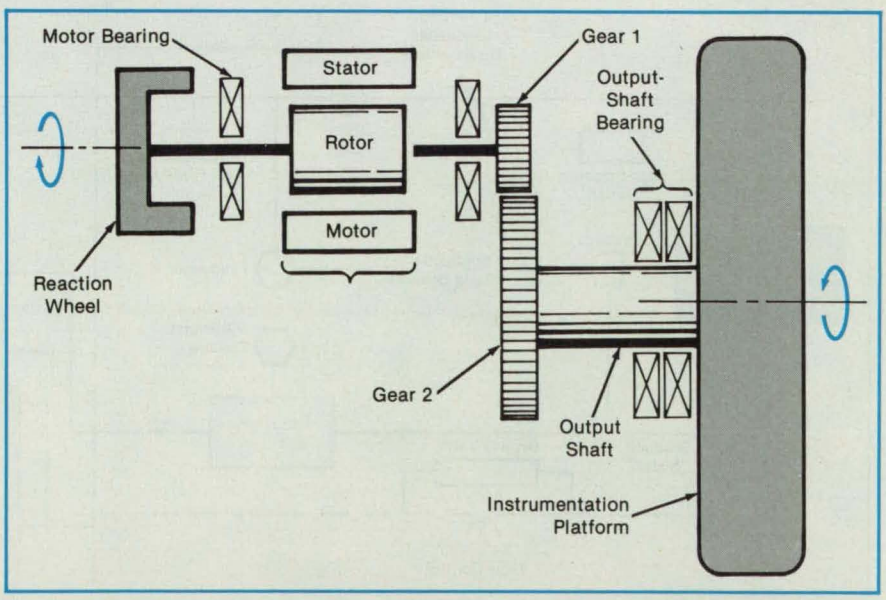
The desired perfect balance can be upset during angular acceleration if there is backlash between gears 1 and 2. Therefore, a high-quality gear train must be used — one having little or no backlash. Moreover, motor cogging — variations in torque and speed resulting from variations in magnetic flux as rotor poles move past stator poles — can act in concert with backlash to inhibit or prevent the precise matching of angular momentum and to cause overshoots. The accelerations from cogging are not transmitted exactly to the platform but are taken up partly by the shaft and gear-tooth compliance. The stepping motor, with its short, precise movements and high damping, reduces the effects of cogging.

The natural 1.8° step of the stepping motor is divided into microsteps. Using a sine/cosine microstepping procedure, logic circuitry divides the motor current into 64 discrete levels that are applied as pulses to both windings of the two-phase motor. With each pulse, the rotor takes a step of 0.028°.

The stepping motor drives a 100:1 gear train, producing a rotation of 1.0125 seconds of arc with every pulse. Because the system operates in discrete steps, it reaches the final position without overshooting or undershooting, within the resolution of 1 microstep. Thus, unlike a linear servo, this nonlinear system attains high angular resolution without sacrificing slowing speed.

Instead of conventional spur gears, the gear train includes a circular spline, a wave generator, and a flexible spline. This system reduces backlash and tooth-mesh error and carries higher loads than does a spur-gear train. The circular and flexible splines engage on the pitch circle at two diametrically opposed points. If the errors of both tooth meshes are equal and of opposite sign, they cancel. Only if they are equal and of the same sign do they equal the mesh error of a spur-gear train. In practice, 10 or more spline teeth are engaged at each mesh point, and this exerts an additional averaging effect on the errors in the placement and shapes of the spline teeth.

This work was done by Carl A. Marchetto of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 132 on the TSP Request Card. NPO-17173*



Rotating Oppositely to the instrument platform, the reaction wheel, motor, and gear 1 have angular momentum equal and opposite to that of gear 2, the output shaft, and the platform. The external torque reaction to the rotation of the platform is thus canceled. Although spur gears appear in this schematic diagram, the gear train is made of spline gears.

Automated Water-Purification System

A reverse-osmosis system operates and maintains itself with minimal human attention, using a programmable controller.

NASA's Jet Propulsion Laboratory, Pasadena, California

An automatic water purifier uses reverse osmosis to produce 15 gal/min (0.95 L/s) of water that typically contains less than 45 parts per million of dissolved solids. The raw water, which comes from wells, contains 500 to 600 ppm of dissolved solids.

Osmosis is the passage of a liquid from a dilute to a more concentrated solution through a semipermeable membrane — one that allows passage of the liquid but not the dissolved solids. Reverse osmosis is the forced reversal of this natural phenomenon by the application of enough pressure to the concentrated solution to overcome the osmotic pressure of the less concentrated solution.

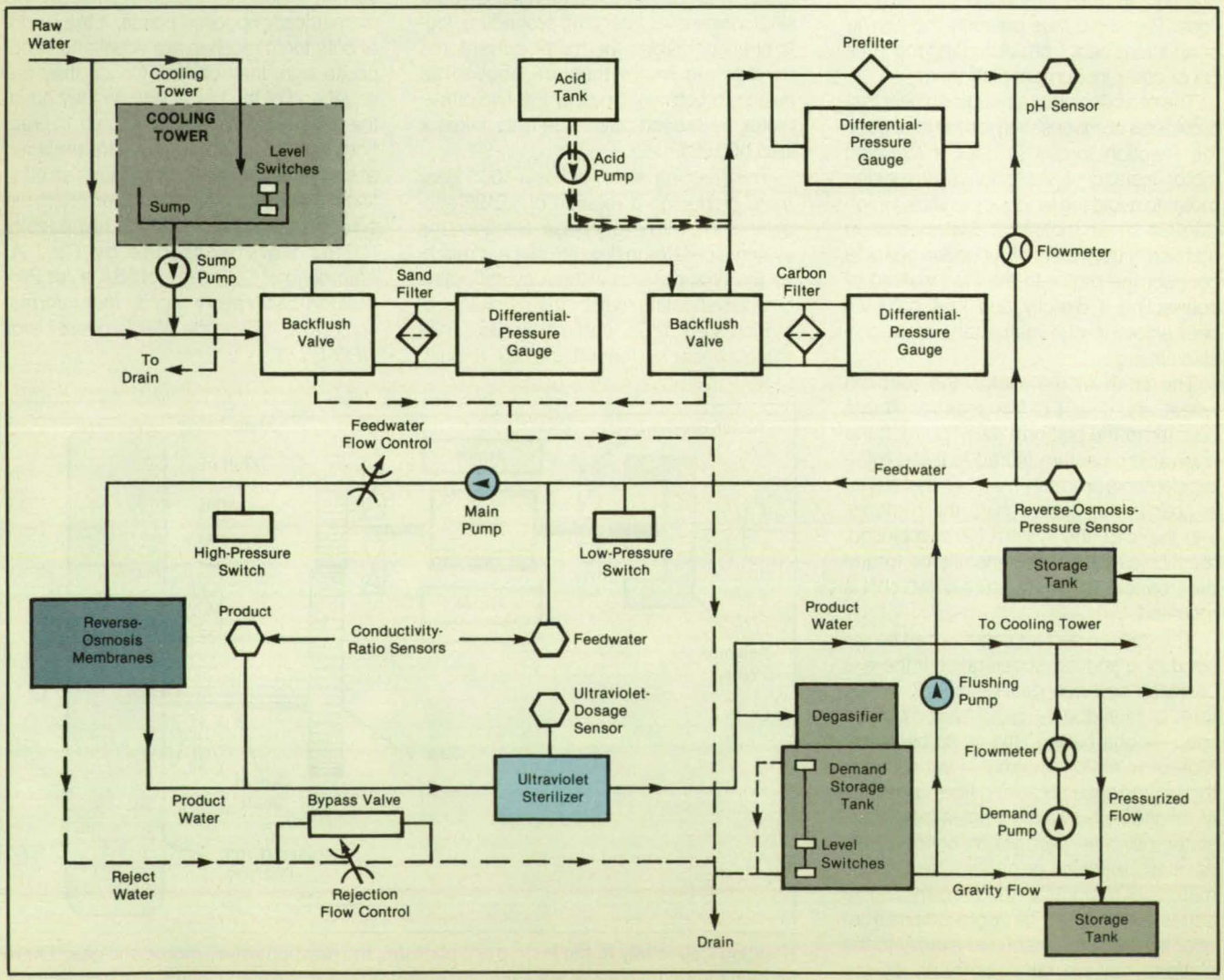
In the purifier, membranes surround hollow cores through which the clean product water flows out of the reverse-osmosis unit. No chemical reactions or phase changes are involved. The reject water, in which the dissolved solids have been concentrated, emerges from the outer membrane material on the same side on which the raw water entered. The flow controls maintain a ratio of 50 percent product water and 50 percent reject water. The membranes can be expected to last from 3 to 5 years.

A programmable controller monitors 32 input signals and produces 64 output control signals. In addition to controlling the reverse-osmosis process, the controller manages the levels of water in an associated cooling tower and storage tanks. It can readily be reprogrammed to change or respond to changed process conditions.

In the pretreatment stage of the process (see figure), raw water is passed through a sand filter to remove large dirt particles and then passed through a carbon filter to remove chlorine, which would otherwise oxidize the membrane. Because excess alkalinity can foul membranes, acid is added to the raw water to reduce its pH to about 6 from its original range of 8.5 to 11.5. A 10-micron prefilter removes most of the remaining nondissolved solids.

In the reverse-osmosis stage, pressure switches, flow controls, conductivity-ratio sensors, flowmeters, pressure gauges, and the main pump enable the programmable controller to monitor and regulate the process. Pressure switches, for example, ensure that the pump inlet pressure is above 10 lb/in.^{2} (69 kPa) to prevent cavitation and that the pressure across the membranes is below 400 lb/in.^{2} (2.8 MPa) to avoid rupture of the membranes.

In the post-treatment stage, the product water flows through an ultraviolet sterilizer, then either to storage tanks by way of a



A **Variety of Sensors, Switches, and Gauges** enables a programmable controller to monitor and regulate reverse osmosis and its associated processes. Recycled water from the cooling tower, as well as raw water from the wells, is used as the feedwater.

degasifier or to a cooling tower. From the storage tanks, it flows on demand to consuming units.

This work was done by Harlow G. Ahlstrom, Peter S. Hames, and Fredrick J. Menninger of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 72 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 18]. Refer to NPO-17049.

Computerized Analysis of Helicopter-Rotor Aeroelasticity

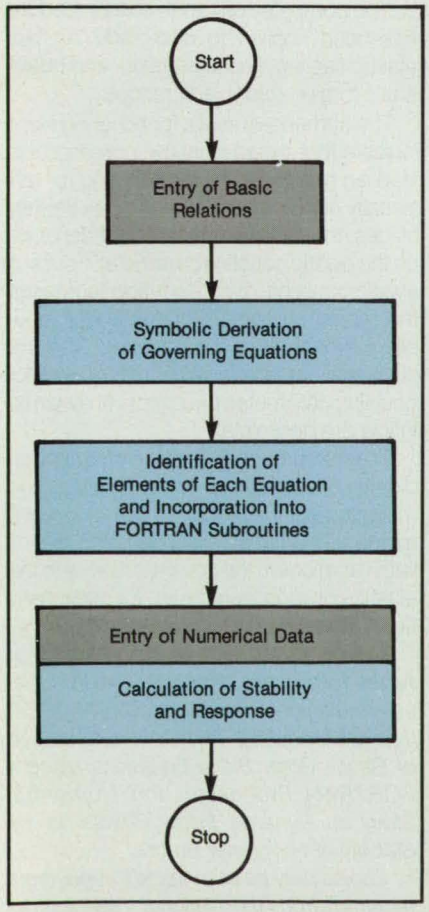
A computer program generates and solves the equations of aeroelasticity.

Ames Research Center, Moffett Field, California

The analysis of the aeroelastic stability of a helicopter rotor has been automated to a degree. The symbolic-manipulation program, HESL, written in FORTRAN, is used to aid in the derivation of the governing equations of motion for the elastic-bladed rotor. The symbolic program can operate both on expressions and matrices. By transferring some of the burden of algebraic manipulations from the human analyst to the computer, the program reduces both the tedium of the analysis and the consequent opportunity for errors.

In the mathematical model of the helicopter rotor, the blades undergo coupled bending and torsional deformations. The interactions between the blades and the airflow are treated by two-dimensional quasi-steady aerodynamics below stall. Although reversed-flow effects are neglected, unsteady effects, modeled as dynamic inflow, are included.

Using a Lagrangian formulation, the governing equations are derived in generalized coordinates with the help of the symbolic program. The symbolic program generates the steady-state and perturbation equations and writes them into FORTRAN subroutines. These subroutines are called



The **Analysis of Aeroelasticity** of the helicopter rotor is a semiautomatic process in which the computer helps to derive the equations, then solves them numerically.

by numerical routines, and the equations are solved numerically. The computer implementation of this procedure consists of three stages (see figure): (1) the symbolic derivation of equations, (2) the coding of the equations into subroutines, and (3) the numerical study after identifying mass, damping, and stiffness coefficients for each equation.

For the case of hovering flight, the equations of motion of the blades and the equations of fluid dynamics that describe the inflow are converted to equations in a multiblade coordinate system by rearranging the coefficients of the equations. For the case of forward flight, the multiblade equations are obtained through the symbolic program. However, the study of forward flight indicates that, for a large number of degrees of freedom and for nonlinear models, the amount of input data required by the symbolic program increases exponentially, making it inconvenient to consider explicitly the harmonic and multiblade equations. Yet, a combination of symbolic and numerical programs at the proper stage in the derivation process makes it effective and beneficial to obtain the numerical results of an analysis of stability by use of this approach. The final multiblade equations are capable of accommodating any number of elastic-blade vibrational modes.

The computerized analytical procedure has been applied to rigid-blade lag-flap, elastic flap-lag, flap-lag-torsion, and quasi-static-torsion rotor-blade models.

The numerical results for hovering flight indicate that dynamic inflow increases the lead-lag regressing-mode damping for torsionally rigid blades. For torsionally flexible blades, the dynamic inflow effect depends on the elastic coupling parameter. For zero elastic coupling, dynamic inflow increases the modal damping. For full elastic coupling, it decreases the damping. This implies that, at some value of the elastic-coupling parameter, the effects of dynamic inflow are negligible.

The numerical study for forward flight indicates that dynamic inflow changes the magnitude of the predicted damping, yet it exerts little influence on damping trends with variations in the advance ratio or in the elastic-coupling parameter for torsionally flexible blades.

This work was done by T. S. R. Reddy of **Ames Research Center**. *Further information may be found in NASA TM-86750 [N87-24455/NSP], "Symbolic Generation of Elastic Rotor Blade Equations Using a FORTRAN Processor and Numerical Study on Dynamic Inflow Effects on the Stability of Helicopter Rotors."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. ARC-11809

Sine-Bar Attachment for Machine Tools

Cutting angles can be set more easily.

Marshall Space Flight Center, Alabama

A sine-bar attachment for collets, spindles, and chucks helps machinists set up quickly for precise angular cuts that require greater precision than provided by the graduations on the machine tools. The machinist uses the attachment to index the head or carriage of a milling machine or lathe relative to the table or turning axis of the tool. The attachment is accurate to 1 minute of arc, more or less, depending on the length of the sine bar and the precision of the gauge blocks in the setup.

A reference bar is attached by screws to one of three sides of a collet adapter (see Figure 1), depending on the job and the angle. The sine bar is loosely positioned on the collet adapter by a locking nut and bolt extending through one of four slots in the adapter and a hole in the middle of the sine bar. Gauge blocks are inserted at one end of the sine bar to provide the required height for the angle according to the formula: length of sine bar × sine of desired angle = height of gauge blocks. The locking nut is tightened so that the sine bar rests securely on the reference bar and gauge blocks.

Next, the assembly is securely chucked in the collet (or chuck or spindle) of the machine. The diameter "A" of the collet adapter is checked for concentricity by a dial indicator. The collet, with its sine-bar attachment, is indexed so that it is either perpendicular or parallel to the direction of travel of the table. A dial indicator is then used to adjust the machine head or the table to the desired angle (see Figure 2); when the adjustment is correct, the indicator will read zero change as it traverses the sine bar. The assembly is then removed, and the machine is used to cut a part to the desired angle.

The attachment can be installed quickly and easily on almost any type of lathe or mill. It requires no special clamps or fixtures, and it eliminates many trial-and-error measurements. It is more stable than improvised setups and cannot be jarred out of position readily.

The usefulness of the attachment can be increased further by adding a fourth

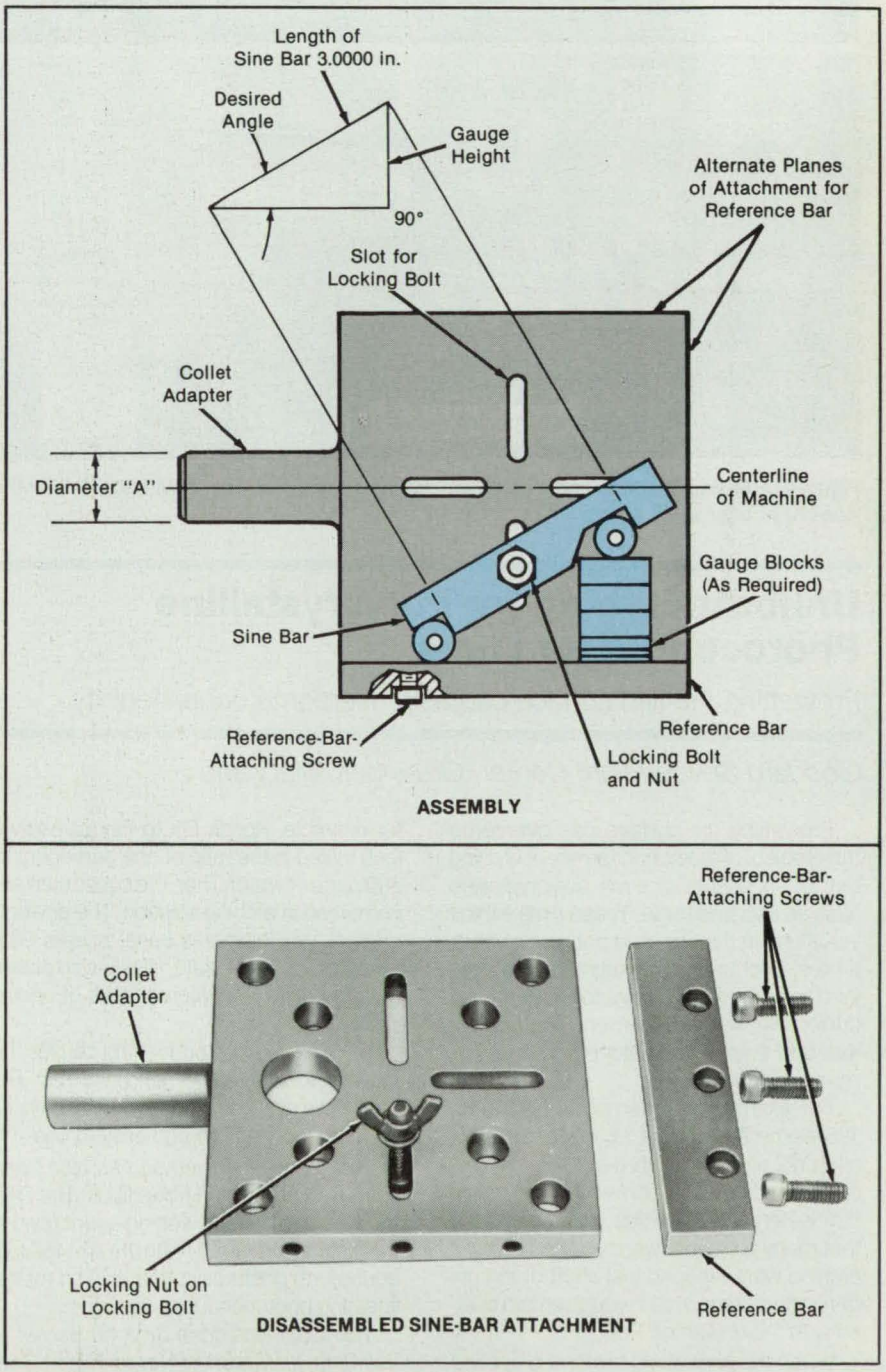
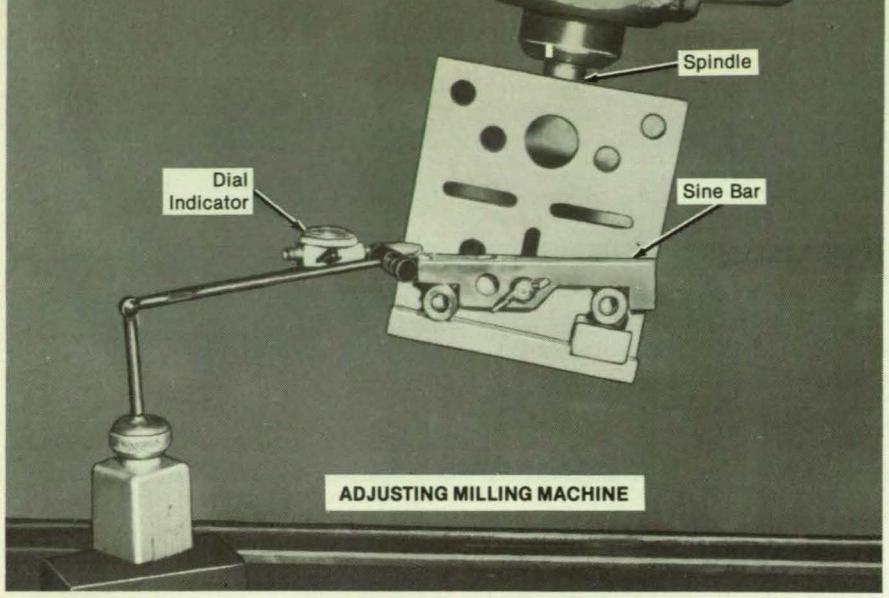


Figure 1. The **Sine-Bar Attachment** can hold a sine bar at a desired angle with respect to any of three reference planes.



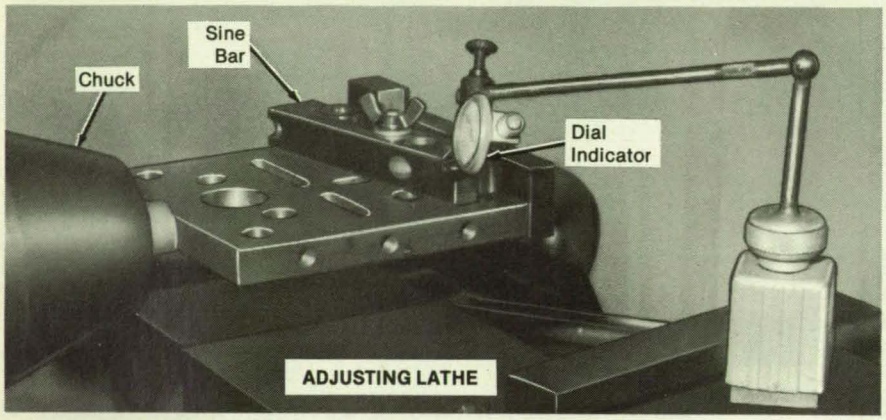


Figure 2. A **Milling Machine and a Lathe** are adjusted to precise angles with the help of the sine-bar attachment.

Uniform Etching for Polycrystalline Photoconductor Films

Prewetting the film surface can help overcome nonuniformity.

Goddard Space Flight Center, Greenbelt, Maryland

Prewetting the surface can overcome the problem of the nonuniformity of etching that often occurs in such polycrystalline films as PbS and PbSe. These films exhibit variations in the size and packing of crystallites. Prior to the prewetting method, severe undercutting of detector material occurred when single-element photodetectors and arrays were etched on preprocessed silicon wafers.

For example, in attempts to delineate 128-element arrays of PbS with a 30-μm pitch (22 μm wide with 8-μm separations) on preprocessed silicon wafers (92 chips per wafer), undercutting was so severe that many elements were washed away. If etching were stopped just short of the undercutting, some areas would remain coated with the unwanted PbS.

When the prewetting method is applied to these arrays, the substrates are soaked for one minute in a suitable wetting agent; for example, Kodak Photo-Flo (or equivalent) mixed in the ratio of one part agent to 200 parts of water. Then the substrates are immersed in etching solution. The unwanted PbS, which, in this case, covers 99.9 percent of the substrate, is removed entirely, with only a few micrometers of undercutting.

It is believed that prewetting causes the etchant to attack the film uniformly. Because this process involves wet chemistry, it is both inexpensive and easy to use.

The prewetting method has also been used successfully on PbSe films. The Photo-Flo (or equivalent) wetting agent used in the tests is compatible with the AZ1450J (or equivalent) photoresist that is used for delineating photoconductor patterns.

This work was done by John Barrett of Itek Corp. for **Goddard Space Flight Center**. *For further information, Circle 24 on the TSP Request Card.* GSC-12969

reference-bar-mounting edge perpendicular to the three edges already available. Compound-angle setups could then be made without reindexing the collet adapter.

This work was done by Franklin D. Mann of **Marshall Space Flight Center**. *No further documentation is available.*

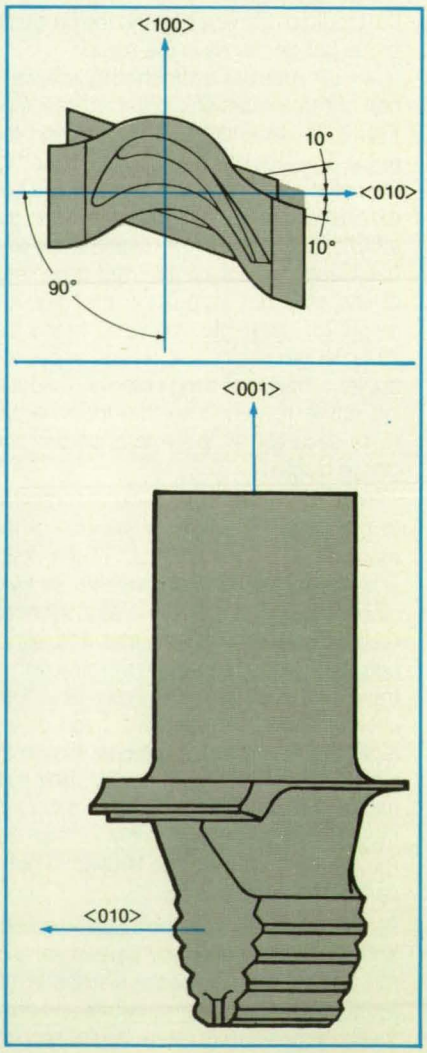
Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 18]. Refer to MFS-28253.

Preferred Secondary Crystal Orientation for Turbine Blades

Fatigue life increases when secondary orientation is not left to chance.

Marshall Space Flight Center, Alabama

The directional solidification of single-crystal turbine blades, so that the second-



A **Turbopump Blade** is made with attention to both the primary <001> and secondary <010> crystallographic orientations. Previously, the <010> axis was allowed to be oriented randomly.

ary, as well as the primary, crystallographic orientation occurs on a preferred axis, greatly increases the resistance to fatigue. A <001> primary, <010> secondary orientation yields as much as a tenfold improvement in fatigue life over the usual <001> primary, random secondary orientation.

The <010> crystallographic direction, ± 10°, is oriented perpendicular to the face of the component where a failure or stress is expected (see figure). Preferred-orientation single-crystal parts can be made by seeding at minimal additional cost. The technique not only lengthens the lives of parts but also reduces the variation in longevity among parts.

This work was done by Leslie G. Fritzemeier and Jon D. Frandsen 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 18]. Refer to MFS-29253.

Stabilizing Silicon-Ribbon Growth at Early Stages

A simple mechanism prevents silicon buttons from tipping.

NASA's Jet Propulsion Laboratory, Pasadena, California

A device mechanically stabilizes the buttons from which silicon ribbons are grown by the dendritic-web process. The device eliminates the tendency for a button to tip and interrupt a pull because of asymmetry.

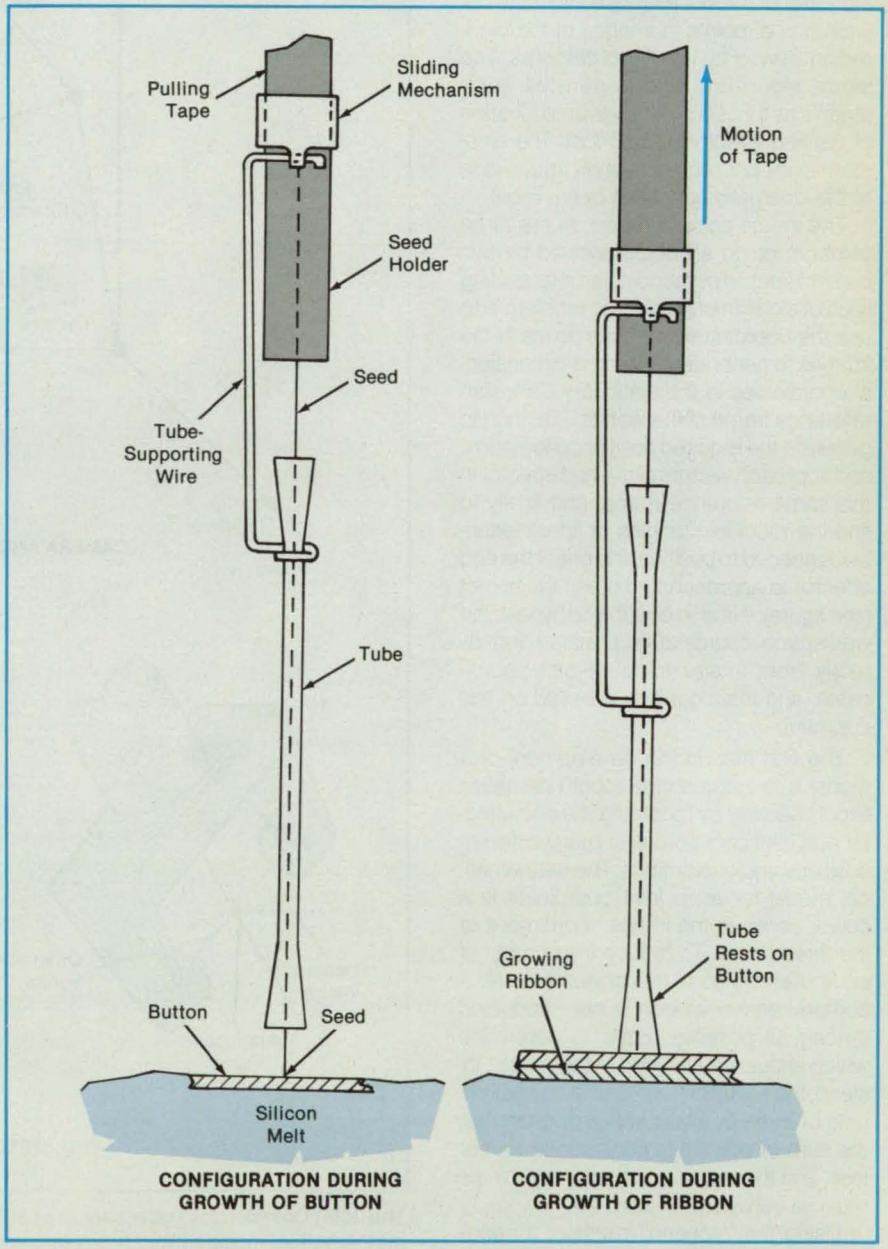
Previously, the buttons used to start growth had to be kept narrow to minimize the effect of asymmetry. Several hours of growth were then needed to approach full ribbon width. With the new device, a large button can be used. Even if the button assumes a highly-asymmetrical weight distribution in the early stages of growth, there is little danger of tipping and breakage of the nascent ribbon.

The device includes a tube with enlarged ends, made of quartz, molybdenum, or other refractory material (see figure). A supporting wire attaches the tube to a sliding mechanism, which in turn is attached to a tape that pulls the ribbon from the molten silicon. A seed holder on the pulling tape suspends a silicon seed that extends to the surface of the melt by passing through the tube. The button grows from the seed across the surface of the melt. When the button reaches the proper size, pulling begins; the tape carries the seed, the entire stabilizing mechanism, and the button upward.

After about 2 mm of upward travel, the sliding mechanism is moved downward until the supporting wire releases the full weight of the tube onto the button. The weight is enough to offset the unbalancing effect of any asymmetrical weight distribution in the button.

This work was done by Paul K. Henry and Edward P. Fortier of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 44 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 18]. Refer to NPO-17074.



A Silicon Seed Hangs From a Holder through a stabilizing tube. While the button is growing, the tube is elevated above the melt surface. When the button is ready for the pulling of the ribbon, the tube comes to rest on the button and prevents it from tipping.

Mathematics and Information Sciences

Calculating Robot-Joint Coordinates From Image Coordinates

Detailed knowledge of the robot joints is not required.

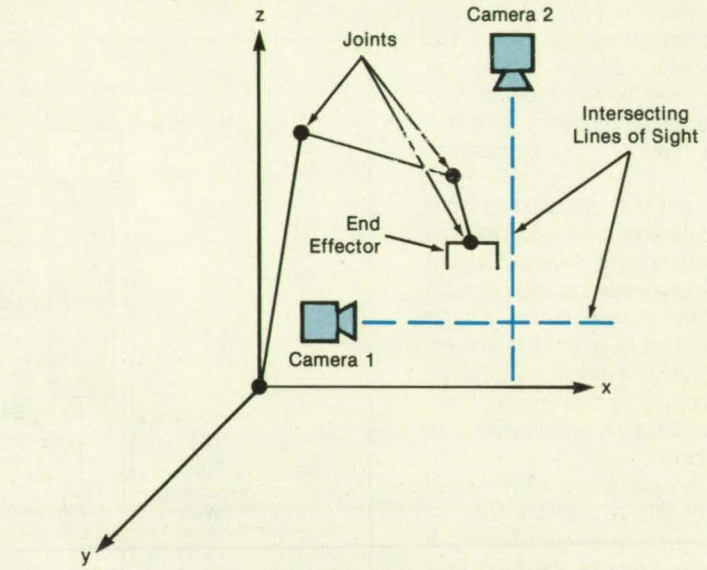
Marshall Space Flight Center, Alabama

An algorithm generates approximate mathematical models of the coordinates of the joints of a robot as functions of the coordinates of points in images of the work region viewed by television cameras. The same algorithm also generates such models as functions of the desired location of the end effector of the robot. The algorithm does not require a priori knowledge of the kinematic equations of the robot.

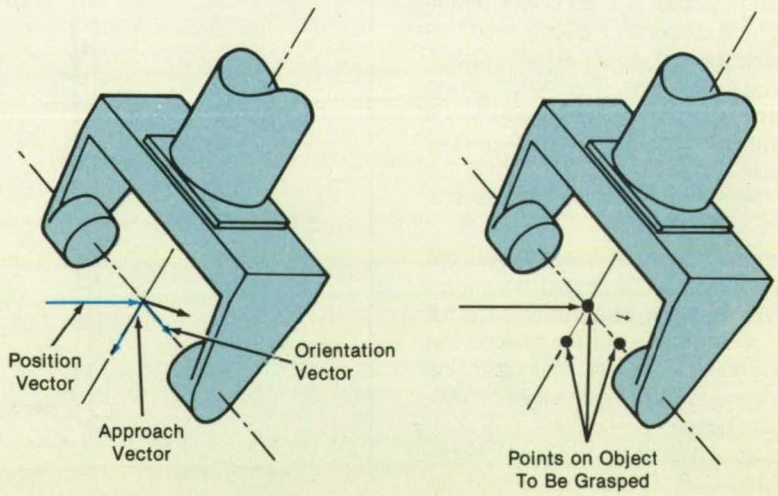
The image points in question are three points in or on an object viewed by two cameras set on perpendicular, intersecting lines of sight. In principle, the problem is to use the coordinates of these points in the images to generate their three-dimensional coordinates in the stationary Cartesian reference frame of the workspace; then to generate the required position, orientation, and approach vectors of the end effector in this same reference frame; and finally to find the robot-joint angles or linear extensions needed to position and orient the end effector to approach and grasp the object (see figure). It is also possible to bypass the workspace coordinates, transforming directly from image to robot-joint coordinates, and the algorithm is based on this approach.

The first step in the development of a model is to establish the robot kinematics experimentally by recording the end-effector and joint coordinates at many different positions and orientations. The mathematical model for each joint coordinate is a power series in the image coordinates of the three points. To reduce the number of computations to a manageable level, a comprehensive search is not conducted among all possible terms to determine which should be included in the model. Instead, the selection is limited to cross products of three or fewer image coordinates, the sum of powers is constrained to 4 or less, and the exponent of each coordinate must lie between -1 and $+3$.

Using the "append" method, a candidate term is appended to the model if it compares favorably with other candidate terms according to a least-squares or other performance index that measures the error between the measured coordinates and the coordinates predicted by the model. The process is repeated until the desired number of terms, n, is reached. The resulting n-term model is not necessarily optimum but is only the optimum model given the previous $n-1$ terms.



CAMERA AND ROBOT ARM (SIMPLIFIED)



END EFFECTOR MAGNIFIED

The **Joint Coordinates** necessary to position and orient the end effector are calculated by mathematical models fitted to experimentally determined data on positions, orientations, and joint coordinates.

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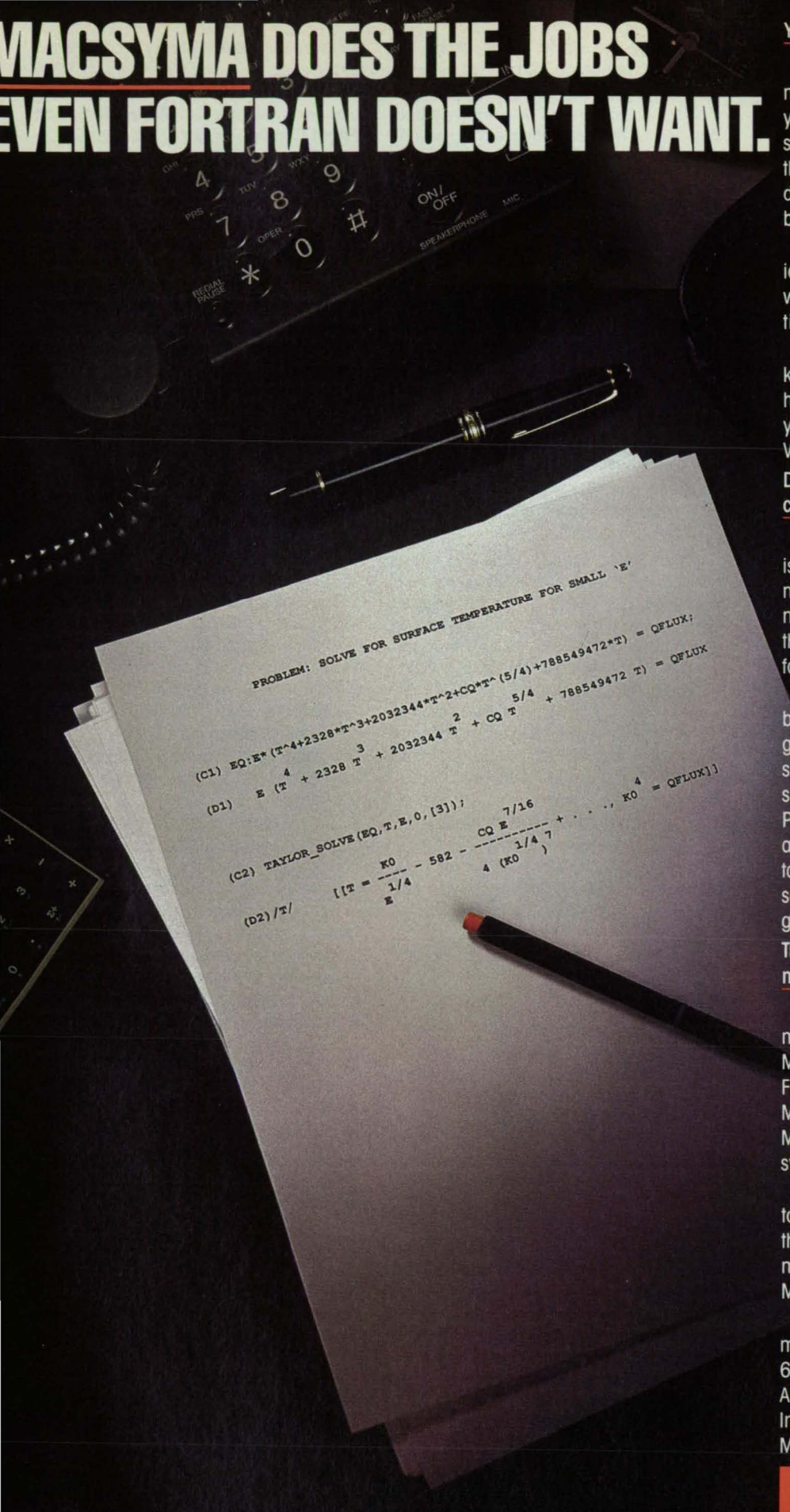

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The algorithm has significant advantages over prior analytical and iterative-transformation techniques. The models can be evaluated much faster than analytical joint equations because the models involve only numerical operations and no transcendental functions. The algorithm enables the models to adapt readily to changes in reference frames, robot configurations, grippers, and the like. It may enable the modeling of flexibility in robot links and of manufacturing errors, which are too complicated to model analytically. It may also provide closed-form solutions for joint coordinates that cannot be obtained analytically.

This work was done by Advanced Control Technologies for **Marshall Space Flight Center**. *For further information, Circle 107 on the TSP Request Card.*
MFS-27194

Books and Reports

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

Linear-Quadratic Controller for Aiming a Large Antenna

Independent control and estimator gains are selected for optimal performance.

A report describes the use of the techniques of linear-quadratic optimal control to design a digital controller that would aim a large antenna. The controller would be based on a closed-loop concept that includes a mathematical model of the plant (that is, the antenna and the associated aiming motors, gears, and related equipment) and an independently-selectable mathematical model that estimates the state of the system.

The report begins by reviewing the theory of linear-quadratic optimal control, in which one seeks to minimize a quadratic performance index that penalizes the transient deviation of the state from the desired state and the control effort expended in fighting the deviation. In this application, the controller uses state feedback so that it can specify arbitrarily the eigenvalues of the closed position-control loop.

The control system is represented as a set of first-order differential state equations, and each state is multiplied by a gain. The summed results are used as a commanded rate for the rate-control loop.

Because it is impossible or too expensive to measure many states, the system includes a dynamic estimator, which estimates the value of each state based on measurable states and a mathematical model of the plant. The dynamics of the closed-loop system depend on the combined eigenvalues of the controller and the estimator. However, the design of the controller is independent of the design of the estimator because the gains of the estimator do not alter the dynamics of the controller and the gains of the controller do not alter the dynamics of the estimator.

A simplified transfer-function model of the rate-control loop of the plant was developed and verified by fitting curves to measurements of gain and phase as functions of frequency-response data. The model was mapped into a diagonal canonical set of state equations, which were augmented to include position and integral-of-position states. Weighting matrices were selected, and families of optimal gains were calculated on the basis of the augmented model. The closed-loop system was simulated with each gain vector, and the "best" gain was selected according to the performance index and the performance specifications.

The integral-of-position state was eliminated, and the third-order model was used to design a new state estimator. Estimator dynamics were selected and estimator-gain vectors calculated. The selected control-gain vector was simulated with each estimator-gain vector using a high-order model of the plant with mismatch of the model, structural resonances, and effects of quantization in the analog-to-digital angle encoder. An estimator-gain vector was selected to minimize the effects of quantization and the estimator error.

This work was done by Jackson A. Nickerson of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "A New Linear Quadratic Optimal Controller for the 34-Meter High Efficiency Antenna Position Loop," Circle 119 on the TSP Request Card.*
NPO-17388

Reducing Errors in Processing GPS Measurements

A fully-redundant double-differencing algorithm yields minimum-variance estimates.

A paper presents analyses of techniques for the minimization of errors in estimates based on Global Positioning System measurements at multiple locations. It presents a fully-redundant double-differencing algorithm for the generation of a weighted, double-differenced regression system that yields minimum-variance estimates.

The report addresses two complications that have arisen in previous double-differencing approaches, namely:

- rank-deficient double differencing caused by the undersampling that is done to avoid colored-measurement-error statistics; and
- the nondiagonal covariance matrix that results from the colored noise introduced by the redundancy in full-rank double differencing.

The algorithm is based on the full-rank approach, in which the double differencing, in a matrix-operator sense, has maximal rank and therefore spans the linear vector space defined by the regression system. The algorithm produces equivalent full-rank estimates, yet features a diagonal weighting matrix in certain cases, even though the differenced measurement statistics are highly colored.

The mathematical development begins with a general description of the regression problem. This is followed by a discussion of the double-differencing operations and the equivalence, under certain conditions, of the resulting least-squares estimates to estimates obtained by other techniques. The paper then discusses minimally- and fully-redundant double-difference matrix operators.

The paper develops the white-noise equivalent diagonal weighting matrix that corresponds to the fully-redundant double-difference matrix. It shows that analytic forms of the diagonal matrix can be obtained in some cases. It notes that theoretically a composite stripe-diagonal and antisymmetric weighting matrix can be generated in all cases, though in practice, analytic forms can be generated only with the help of restrictive assumptions about the topological properties of the undifferenced-measurement-error covariance.

The paper analyzes the problem of missing data streams or outages in double differencing. This problem is important in practice because satellites come into and go out of view and receivers occasionally lose data because of instrument failures and environmental disturbances. In general, as the number of terminals experiencing outages increases, the algebraic expressions for the weighting matrix become increasingly complex.

This work was done by W. G. Melbourne of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "A Fully Redundant Double Difference Algorithm for Obtaining Minimum Variance Estimates From Global Positioning System Observations," Circle 116 on the TSP Request Card.*
NPO-17038

Life Sciences

Control Algorithms for Liquid-Cooled Garments

Three schemes control the transfer of heat to and from the wearer's body.

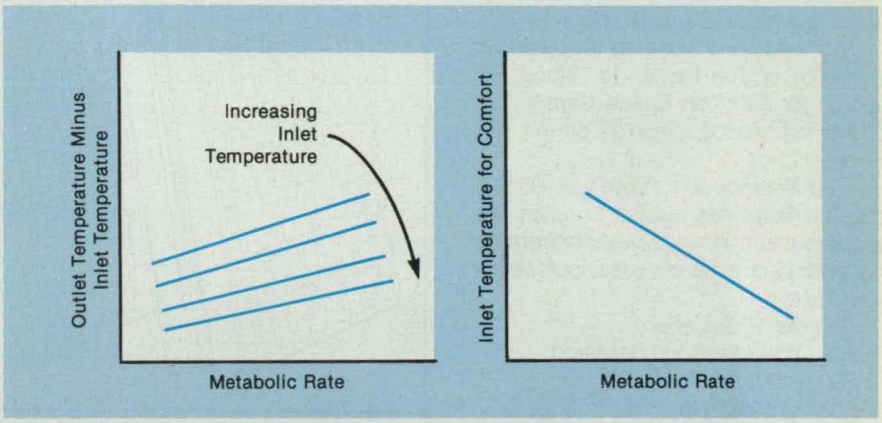
Lyndon B. Johnson Space Center, Houston, Texas

Three algorithms have been developed for the control of cooling in protective garments. Although the algorithms are directly applicable to space suits, they can also be used for automatic control of cooling in suits worn by workers in radioactive, polluted, or otherwise hazardous environments. The algorithms are expected to be more effective than manual control, which is subject to frequent, overcompensated adjustments as the level of activity varies.

All three algorithms follow a comfort curve of inlet-liquid temperature versus metabolic rate based on tests of human subjects. The first algorithm controls the average of the inlet and outlet temperatures of a water-cooled garment. It eliminates the effects of heat from the environment in the sense that it reduces the inlet temperature to compensate for the increase in the outlet temperature caused by the surroundings. If the environment is cold, the algorithm compensates for heat lost to it by raising the inlet temperature.

The algorithm is designed for a maximum metabolic rate of 1,300 Btu/h (380 W). At this rate, the wearer's body produces a rise of only about 2 °F (1 °C) in the temperature of the coolant. The average temperature of the coolant is therefore almost the same as the effective temperature felt at the skin.

The second algorithm adjusts the inlet temperature to follow the comfort curve. While this algorithm does not compensate for environmental heat loads, it is similar to the first algorithm in other respects.



The **Metabolic Rate Is Inferred** from the temperatures of the cooling liquid at the outlet and the inlet, suitably filtered to account for the thermal lag of the human body. The temperature at the inlet is then adjusted to the value that gives maximum comfort at the inferred metabolic rate.

Both the first and the second algorithms use the metabolic rate as a control variable. The rate is determined from a respiratory measurement — either the consumption of oxygen or the production of carbon dioxide.

The third algorithm is based in part on the empirically determined proportionality between the steady-state rate of metabolism and the difference between the inlet and outlet temperatures. This algorithm raises or lowers the inlet temperature according to the inferred metabolic rate (see figure). It compensates for the environmental heat load indirectly by interpreting the environmental component of the inlet-to-outlet temperature rise as being caused by metabolic heat load.

All of the algorithms incorporate delays in the form of thermal time constants characteristic of human bodies (about 15 to 20 min). The delays take into account the tendency of the human body to store heat instead of heating up immediately when it suddenly increases its level of activity. The delay prevents overcooling while the body is storing heat as it starts a higher level of activity and prevents overheating while the body dissipates stored heat as it starts a period of reduced activity.

This work was done by B. Drew, K. Harner, E. Hodgson, J. Homa, D. Jennings, and J. Yanosy of United Technologies Corp. for **Johnson Space Center**. *For further information, Circle 106 on the TSP Request Card. MSC-21349*

Extending the Shelf Life of Blood Platelets

Storing the platelet suspension in a thin layer allows the exchange of metabolic gases.

Lyndon B. Johnson Space Center, Houston, Texas

A new method of storing human blood platelets extends their vitality for transfusions. The method ensures that platelets receive ample oxygen and that expiratory carbon dioxide from the platelets is removed before the pH drops to harmful levels.

The platelets are packaged as a suspension in sterile liquid in plastic blood bags. Each bag is placed between a pair of plastic grids, and rubberbands are placed around the sandwich thus formed to hold it together. The sandwiches are stored upright (see figure) in open air or in a container through which air is pumped at a rate of at least 45 L/min.

The grids compress the bag to a uniform ⅛-in. (0.3-cm) thickness, thin enough that air diffusing through the plastic bag can penetrate to the innermost platelets and that carbon dioxide can readily leave the inner region and diffuse through the bag to the outside. Without the support of the grids, a bag would sag and distend at its bottom to about ½-in. (1.3-cm) width. This thickness prevents the effective exchange of gases, and the platelets quickly deterio-

rate when they are stored this way.

The grids are strong and rigid but open enough to provide a large area of contact between the bag and external air. The solid mass of a grid occupies only 16 percent of the 13- by 14.5-cm grid area.

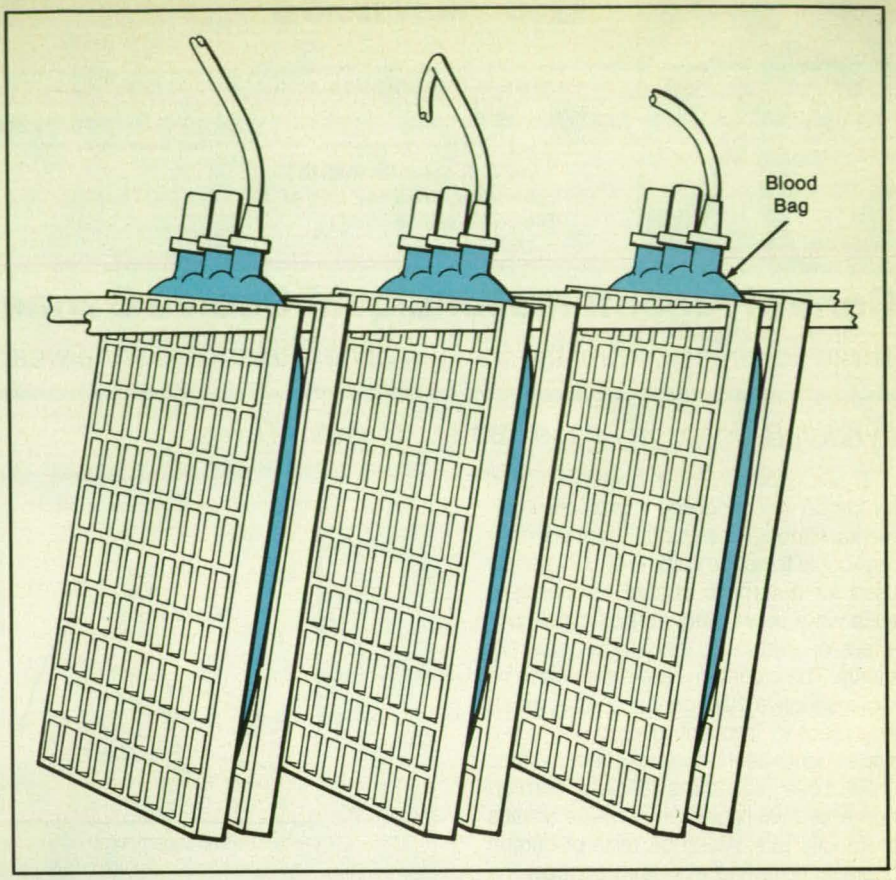
The grid-sandwich storage method makes it unnecessary to agitate blood bags to induce gas circulation. Bag agitation is virtually impossible when the bags are transported between storage places, and agitation itself tends to destroy some platelets. In 7-day comparison tests, the posttransfusion yield and survival of the platelets stored in grids without agitation were equal to those of platelets stored in uncompressed but agitated blood bags.

This work was done by Douglas M. Surgenor of The Center for Blood Research for **Johnson Space Center**. *For further information, Circle 26 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

Douglas M. Surgenor
The Center for Blood Research
800 Huntington Avenue
Boston, MA 02115

Refer to MSC-21157, volume and number of this NASA Tech Briefs *issue, and the page number.*



Flattened by Grids, standard blood bags allow air to enter and nourish blood platelets and allow carbon dioxide and other metabolic wastes to expire through the bag. As an added benefit, the inexpensive grids make the blood bags easier to handle.

Books and Reports

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

Solar Refrigerator/ Freezers for Vaccines

Photovoltaic systems store vaccines in remote regions where powerlines are unavailable.

A report presents the results of field tests of solar-cell-powered refrigerator/ freezers for vaccines. The refrigerator/ freezers were developed to bring the benefits of vaccination to developing countries so that such diseases as poliomyelitis, diphtheria, and measles can be controlled or eradicated.

To remain potent, most vaccines must be maintained at temperatures between 0 and 8 °C. For the more-sensitive polio and measles vaccines, a temperature of −20 °C is recommended for extended storage. The solar-powered refrigerators would ensure the proper storage temperatures in places where electricity is unreliable or unavailable. They would replace kerosene-fueled units, which offer poor temperature control, need frequent maintenance, and rely on a fuel that is often costly, in short supply, and of questionable quality.

The report covers the following topics:

- An explanation of the project;
- Descriptions of the refrigerator/freezer systems;
- An account of installation experiences;
- Performance data for the 22 systems for which field-test data were reported;
- A summary of operational reliability;
- Comments of users of some of the systems tested; and
- Recommendations for design and future use.

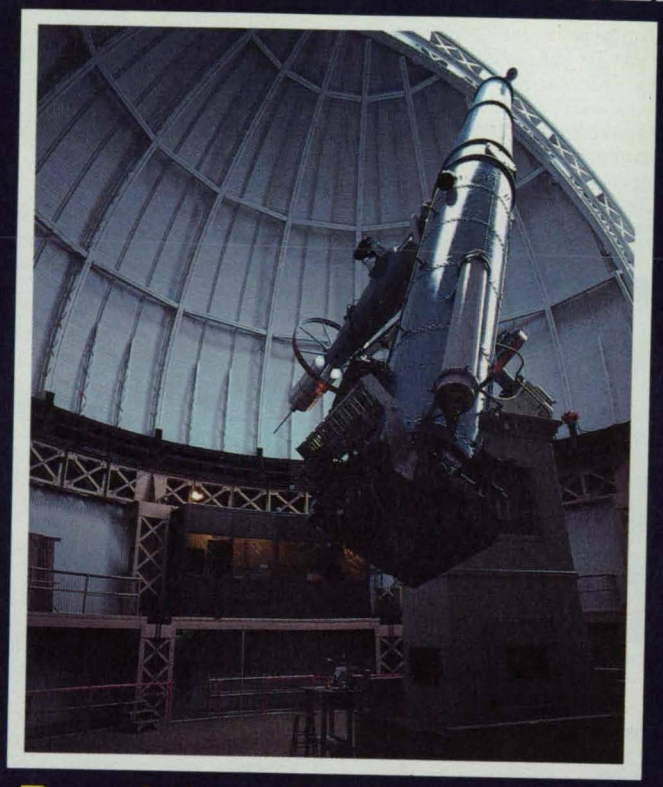
A solar-powered vaccine refrigerator/ freezer system consists of a 12-volt photovoltaic array, a power cable from the array to the refrigerator/freezer, one or more voltage regulators, batteries, the refrigerator/freezer unit, and, for the field tests, instrumentation. The systems were designed for fully automatic operation and minimum maintenance: it is necessary only to wash the photovoltaic modules when they are dirty and to remove frost from the evaporator plate in the freezer compartment of the refrigerator freezer. Spare parts, toolkits, and user manuals were supplied to each field-test site. The sites were in Latin America, the Caribbean, Africa, the Near East, and other Asian countries.

The systems had a high level of reliability. Over a 33-month period, the reporting sites accumulated 488 system-months of operation and were in service 83.6 percent of the time. The refrigerator compartments were within the recommended temperature range 80 percent of the time; operator-induced causes contributed to much of the time out of range. There were no failures of photovoltaic modules or refrigerator compressors and only a few failures of other components. The chief problems were the need for initial training for both users and technicians, for reinforcement training, and for training of replacement users and technicians.

This work was done by Anthony F. Ratajczak of **Lewis Research Center**. *Further information may be found in NASA TM-86972 (Revised) [N86-11666/NSP], "Photovoltaic-Powered Vaccine Refrigerator-Freezer Systems Field Test Results," and NASA TM-88830 [N87-18230/NSP], "User Evaluation of Photovoltaic-Powered Vaccine Refrigerator/Freezer Systems."*

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-14549

SCHOTT GLASS... HELPING OUR WORLD SEE OTHER WORLDS



Precision Optical Glass of uncommon dimensions.

When the University of Pittsburgh's Allegheny Observatory was developed around the turn of the century, Schott was the only company capable of making the lens blanks for the Observatory's refracting telescope. Three quarters of a century later, that telescope is still the third largest in the world.

Today, as the lenses of that refracting telescope are being replaced, glass from Schott Glass Technologies — a United States company — is the choice.

In fact, Dr. George Gatewood, director of the Allegheny Observatory, said that there wasn't much of a choice at all. "Schott is the only company in the world capable of producing the glass we need for our refracting telescope lenses."

He's not alone in his thinking. Because of Schott's world-wide involvement and award-winning Research and Development department, Schott glass has been chosen for use in many of the most advanced optical systems man has ever known. Including some of the world's biggest stargazers; like the University of Pittsburgh's Allegheny Observatory.

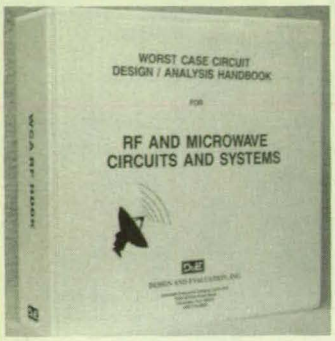
Schott Glass Technologies is a United States manufacturer of many types of glass. If you're involved in astronomy, space exploration, aerospace, precision measurements or optics, Schott can help you with the right glass for these and many other fields.

SCHOTT GLASS TECHNOLOGIES INC.

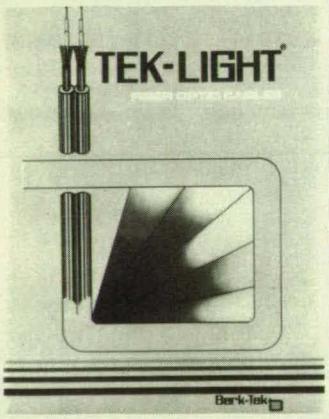
400 York Avenue
Duryea, Pennsylvania 18642
(717) 457-7485 TWX 510-671-4535
Telefax (717) 457-6960

Circle Reader Action No. 383

New Literature



A new handbook published by Design And Evaluation Inc., Voorhees, NJ, illustrates procedures and guidelines for **designing, analyzing, and testing radio frequency (RF) and microwave circuits and systems.** The 500 page handbook provides strategies for handling test and measurement procedures, offers tips on management and cost control, and includes case studies for high-frequency oscillators, RF amplifiers, modulators, frequency synthesizers, transmission lines, phase locked loop design, traveling wave tube amplifiers, and filters.
Circle Reader Action Number 712.



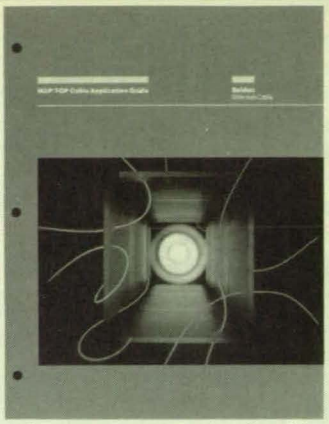
More than 20 types of Tek-Light® **fiber optic cables** are featured in a free catalog from Berk-Tek Marketing Services, New Holland, PA. The 36 page publication highlights Tek-Light applications in office and industrial automation, audio and video communications, security, process control instrumentation, and Tempest environments.
Circle Reader Action Number 710.

Sector Systems Company Inc., Marblehead, MA, is offering a **free catalog of public domain PC software for engineers.** The featured programs are available for a copying fee of four dollars per disk and contain fully usable software and documentation. Subject areas include communications, desktop publishing, graphics, project management, programming, spreadsheets, and much more.
Circle Reader Action Number 702.

The Intelligent Qualifier 2000®, a **knowledge-based video coordinate measuring system**, is highlighted in a free brochure from Optical Gaging Products, Rochester, NY. Unlike measuring systems that rely on pre-set discrete points, the IQ 2000 measures a part using all available data points to find geometric elements, identify contours, and construct a graphic model. The measuring process—from data acquisition to plotting and measurement—takes less than one second.
Circle Reader Action Number 726.

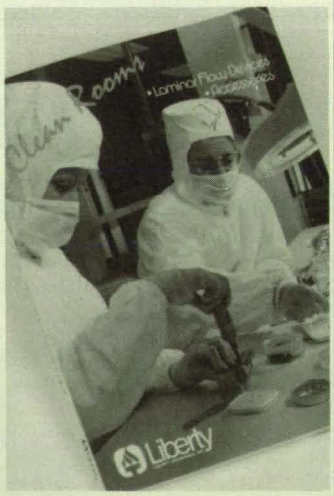
The Fluorocarbon Company, Seattle, WA, has published a brochure describing Flourocore 3A3™, a self-rising **polyimide foam** designed for aircraft/aerospace use as insulated ducting, core material for composite panels, honeycomb core filler, and formed shapes for heat deflection and insulation. Available in 5 and 80 pound kits, Flourocore 3A3 can withstand temperatures to 600°F with low smoke emissivity.
Circle Reader Action Number 724.

A free catalog from the Tekmar® Company, Cincinnati, OH, spotlights new **scientific instrumentation and equipment** for analytical, biological, and environmental research laboratories. Featured products include digital temperature monitors, homogenizers, magnetic stirrers, rotary shakers, constant temperature baths, and microcentrifuge tubes and racks.
Circle Reader Action Number 706.



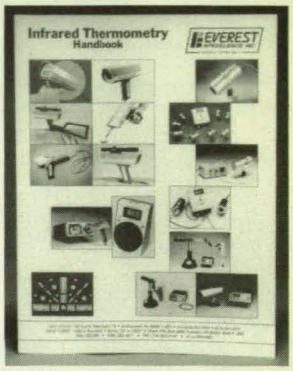
A free application guide offered by Belden Wire And Cable, Richmond, IN, explains the technology and cable considerations of both Manufacturing Automation Protocol (MAP) and Technical and Office Protocol (TOP) **communication networks.** The full-color guide oulines the system requirements of MAP and TOP networks and illustrates the relationship between MAP/TOP technology and IEEE 802.4 and 802.3 network standards. Charts and graphs are used to demonstrate cable performance values. A MAP/TOP product selection guide is also included.
Circle Reader Action Number 708.

Sensor Developments Inc., Lake Orion, MI, has published "The Forces In Machines," **a guide to the various uses of sensors in measuring force.** The 12 page booklet illustrates the application of electro-mechanical transducers to oil well drilling, aircraft simulation, robotics, and many other areas. A second volume, entitled "The Forces In Automobiles," describes applications of strain gauge-based sensors to brake pedals, transmission shafts, steering systems, and other automobile components.
Circle Reader Action Number 716.



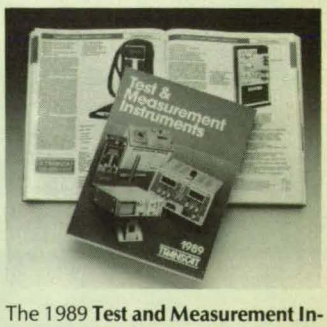
Liberty Industries' new 1989 catalog features more than 1900 **clean room and laminar flow products,** including 50 new items. The catalog also contains a full-color section illustrating clean room operations.
Circle Reader Action Number 718.

A new brochure from Janos™ Technology Inc., Townshend, VT, summarizes the company's line of **precision optical products and components**, including lenses, mirrors, mounts, positioners, translation stages, and beam expanders. Janos' diamond machining, thin film coating, and optical grinding and polishing capabilities are also highlighted.
Circle Reader Action Number 722.



The **Infrared Thermometry Handbook** from Everest Interscience Inc., Fullerton, CA, explains how infrared thermometry works and discusses typical applications. Infrared transmission, absorption, reflectance, and emissivity are also covered. Available free of charge, the handbook includes a table of emissivity values for various metals and a temperature conversion chart.
Circle Reader Action Number 720.

A new research report from Solar Trade International, San Francisco, CA, reviews the state of the art in **photovoltaic technology** and highlights United States exports of photovoltaic cells and modules in 1987. Entitled "Photovoltaic Export Trade of the USA—1987, Technology and Trade Assessment," the report analyses the top photovoltaic markets world-wide and lists all U.S. commercial PV manufacturers by product and location.
Circle Reader Action Number 714.



The 1989 **Test and Measurement Instruments catalog** from TRANSCAT® Rochester, NY, describes more than 500 instruments and accessories from 200 manufacturers, and includes over 50 new products. The free 480 page catalog provides technical, pricing, and ordering information for each item.
Circle Reader Action Number 704.

New on the Market

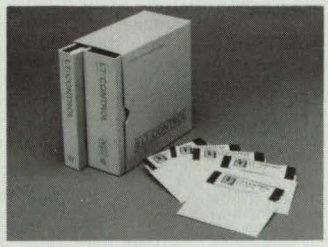
The Electro-Lite Corp., Danbury, CT, has developed an ultraviolet **spot-curing system** that provides controlled energy at a peak wavelength of 365 nanometers. The ELC600 generates up to 500 milliwatts per square centimeter of output, which results in shorter curing times and makes possible the curing of thicker films. Applications include fiber optics, optoelectronics, sealing connectors, lens mounting, and wire tacking on PC boards.
Circle Reader Action Number 780.

Xytrex® Polymer Systems, a family of high-performance, engineered **thermoplastic compounds** has been developed by the EGC Corp., Houston, TX. The new compounds are self-lubricating and feature high temperature tolerance, strength, and chemical resistance. EGC offers a variety of processing methods for Xytrex, including compression molding, injection molding, continuous profile extrusions, and coatings.
Circle Reader Action Number 790.

The OMNI **Distributive Graphics Link** (DLG) from Omnicomp™ Graphics Corp., Houston, TX, enables users of IBM PC- or PS/2-compatibles and DEC VAX midrange computer platforms to communicate and process large graphics files at direct memory access (DMA) speeds. The DMA bus-to-bus connection provides a faster interface than possible with standard local area networks. The OMNI DLG consists of a parallel interface board and interprocessor software, which is loaded onto both the PC or PS/2 and the VAX hosts.
Circle Reader Action Number 788.

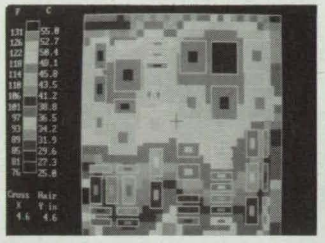
The MATLAB **integrated analysis program** from the MathWorks Inc., Sherborn, MA, combines graphic and data manipulation capabilities to turn a Macintosh computer into a scientific and engineering workstation. MATLAB specializes in matrix computation, numerical analysis, signal processing, and graphics, and features a novel user interface that accepts commands in the standard mathematical notation for matrix operations. The program runs on the Macintosh Plus, Macintosh SE, or Macintosh II and requires 1M byte of memory.
Circle Reader Action Number 782.

Lasertechnics' 300D **continuous tone printer** produces photographic quality real-time images from a variety of sources, including tape, optical disc, hard disc, and active memory. The unit internally processes either paper or film. Designed for digital radiography, satellite remote sensing, facsimile transmission, and other forms of electronic image processing, the 300D features digital resolution of 256 pixels per inch, a 256-level dynamic grey scale, multi-gamma correction, and a built-in GPIB interface.
Circle Reader Action Number 776.

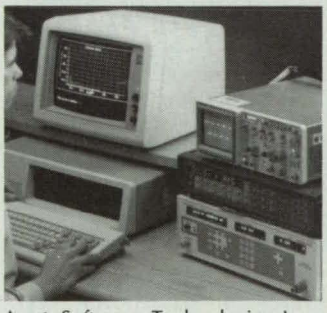


Burr-Brown, Tucson, AZ has introduced LT/CONTROL, a **software package** for real-time industrial process control and monitoring. Features include data logging, unit conversion, on-line analysis, and a pixel-based drawing facility that allows users to design custom color graphic displays of the actual process. Real-time animation can be employed to depict parameters such as flow, tank level, and position.
Circle Reader Action Number 796.

The Electronics Division of Cohu Inc., San Diego, CA, has introduced a two-piece color **CCD camera** featuring a remote imager that connects via cable to a Camera Control Unit. The lightweight remote head is suited for robotics and microscopy applications and is easily incorporated with borescopes and other measurement/inspection instruments. The camera also features nine lux sensitivity, a selectable AGC range, auto/manual color balance, and optional color lock.
Circle Reader Action Number 778.



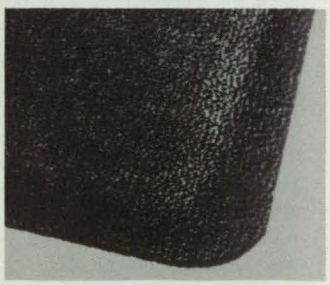
Visionics Corp., Sunnyvale, CA, has introduced a three-dimensional **thermal analyzer package** for the company's EE Designer III™ CAE/CAD electronic design software package. The new option allows circuit board designs produced with the EE Designer III to be checked for potential thermal problems. The PC-based package models component conduction, convection, and radiation characteristics, and enables users to predict thermal distributions and locate thermal problems in their designs after component placement.
Circle Reader Action Number 784.



Asyst Software Technologies Inc., Rochester, NY, has unveiled the **ASYSTANT GPIB** for scientists and engineers who need to control GPIB instrument clusters and analyze or graphically represent data in a single, integrated environment. The menu-driven GPIB software allows GPIB device definition, interactive execution of bus commands, serial polling, and display and analysis of data. The ASYSTANT GPIB runs on IBM PC/XT/AT or compatibles.
Circle Reader Action Number 786.

Interlock Inc., San Leandro, CA, has introduced the EasyStick® , a **cursor positioning tool** that simplifies computer keyboard functions. The EasyStick is mounted on the keyboard over the arrow keys. Toggling the device's knob moves the cursor on the screen. Unlike conventional joysticks, the EasyStick requires no ports, boards, cables, driver software, or system modification. The adjustable device works with any DOS, application, and computer and retails for $29.95.
Circle Reader Action Number 800.

In the photo above, a beaker of uncured **TRIPLUS™ resin** is subjected to the heat of a blowtorch without burning. A product of the General Electric Company's Silicones Division, Waterford, NY, TRIPLUS offers thermal performance to 1200°F in its cured state. Targeted for the coatings and paint industries, the silicone-based resin blend features low viscosity (50-150 centerpoise in average mixes) for easy application.
Circle Reader Action Number 798.

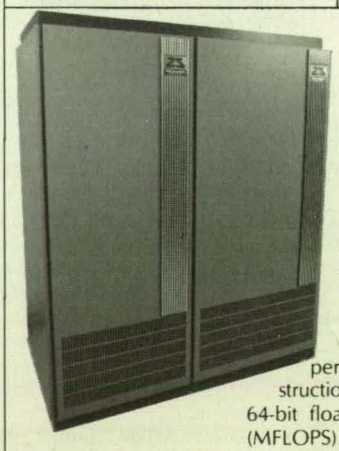


New **Anti-Static, Anti-Fatigue Rubber Matting** from Lancaster Colony Commercial Products, Columbus, OH, decreases electrical charge and provides a cushioned surface for workers situated near electrical equipment. The matting's textured surface is highly resistant to abrasion and chemical spills. All four sides of the mat are beveled for safety.
Circle Reader Action Number 792.

New on the Market

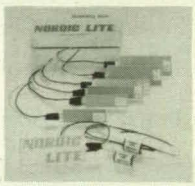
The first **neurocomputing coprocessor board** for Sun workstations has been unveiled by Hecht-Nielsen Neurocomputers, San Diego, CA. With the ANZA Plus/VME, Sun users can now apply neural network technology in areas where high-speed processing is crutial, such as image processing, industrial inspection, and signal processing. The new coprocessor board enables researchers to run neural networks on Sun computers at speeds 500 times greater than software-only implementations, and features software for the integration of neurocomputing into C programs.
Circle Reader Action Number 764.

Dawn VME Products, Fremont, CA, has introduced the DS Series of VME-compatible and Sun-compatible **computer memory storage subsystems**. Each of the two product lines includes six models: two Fujitsu 5¼ inch full high disk drive systems offering 144 megabyte capacity, and four Maxtor 5¼ inch full high disk drive subsystems with either 320 or 602 megabyte capacity. Users can daisy-chain up to four of each configuration for additional capacity. Data transfer rates range from 10 to 15 megabytes per second.
Circle Reader Action Number 762.



The new ZS-1 **computer system** from the Astronautics Corp. of America, Madison, WI, features a unique decoupled architecture; its CPU fetches instructions at a rate of two per clock period and splits them into two instruction streams—one for fixed point/memory address computation and the other for floating point operations. This allows new floating point operations to be issued every clock period, resulting in a major increase in computational throughput. The unit provides peak performance in excess of 45 million instructions per second (MIPS) and 22.5 million 64-bit floating point operations per second (MFLOPS). **Circle Reader Action Number 794.**

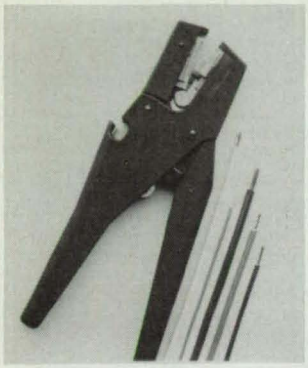
The T2492-B Printstation, a high-volume **laser printer** targeted for multiuser and networked computer systems, is now available from Talaris Systems Inc., San Diego, CA. The new printer is based on the 24 page per minute Xerox XP-24 engine and the Talaris Printstation Control System, which features an optional high-speed Ethernet connection. To achieve maximum speed and flexibility, the T2492-B employs a dual processor architecture; a Graphics Systems Processor from Texas Instruments performs the graphics processing, while a National Semiconductor 32016 CPU manages the I/O and command interpretation.
Circle Reader Action Number 754.



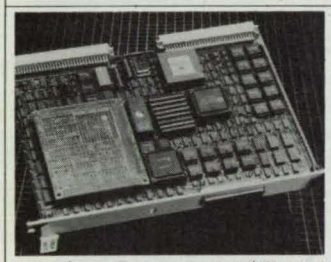
Nordic Lite Inc., Warren, MI, is offering a desktop sample kit that demonstrates new advances in **electroluminescent (EL) lighting**. The kit contains an AC inverter and a variety of EL product samples, each featuring an innovative lamp design that incorporates lighting and termination paths in a single, flexible polyester package.
Circle Reader Action Number 770.

The BeamAlloy Corp., Dublin, OH, has developed a method of placing extremely hard **diamond films** on metallic, ceramic, plastic, and glass surfaces at processing temperatures under 150°F. The DIOND process uses a proprietary electron beam deposition technique to create diamond thin films for abrasion-resistant, corrosion-resistant, and thermal transfer surfaces. The transparent films are bonded tightly to the treated surface to eliminate chipping.
Circle Reader Action Number 752.

New on the Market



A new fiberglass-reinforced **wire stripper** designed to cut and strip fiber optic cable, flexible and solid PVC, multi-core ribbon cables, and 10 to 22 gauge wire is now available from the Paladin Corp., Encino, CA. Insulated to 600 volts, the PA 1101 Maxi-Stripax® features 66 stainless steel stripping blades as well as a built-in wire cutter and wire stop.
Circle Reader Action Number 756.

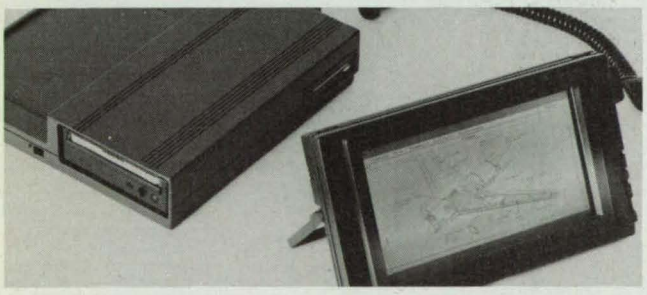


Interphase Corporation's V/IPI 4260 Cougar is the first commercial **Intelligent Peripheral Interface (IPI)** Level 2 controller for VMEbus computer systems. IPI Level 2 is a peripheral device interface specification that offers much faster data rates than today's peripheral standards can support. The Cougar features a 32-bit achitecture which includes a Motorola 68020 processor, and can control up to eight IPI Level 2 devices from different manufacturers and with different data rates.
Circle Reader Action Number 766.

The Design Generator™ from the Computer Sciences Corp., Falls Church, VA, helps systems analysts and designers save time in the early stages of software development by automatically transforming a structured specification into an initial design. The **CASE tool** features "modeless" operation using multi-paned browsers, pop-up windows, and a digital mouse, and includes a knowledge-based data dictionary. The Design Generator requires minimal training and runs on standard PC hardware.
Circle Reader Action Number 750.

Classic Aircraft Collector Cards from Universal Games, Yakima, WA, feature **color reproductions of paintings** by aviation artist Bob Hill. The back of each card gives the history and specs of the aircraft illustrated on the front side. These "baseball cards" of aviation history are available in 6, 12, 18, and 48 card packages.
Circle Reader Action Number 768.

The Model 310 **Electro-Optic Laser Beam Deflector** from Conoptics Inc., Danbury, CT, features a deflection sensitivity of 1.0 milliradian per kv. The deflector's useful aperture is 2.0 mm with a spectral range of 400 to 800 nm. Applications include facet to facet connection of high-speed rotating mirrors, dither of spot location on film recorders, and coding on optical disks.
Circle Reader Action Number 760.



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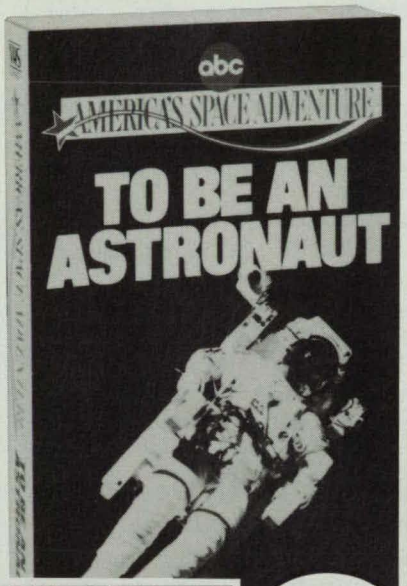

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Photo courtesy Philips Medical Systems, Inc.

The Digital Cardiac Imaging (DCI) system uses NASA-originated image processing techniques to improve the safety of delicate medical procedures.

A new computer system uses the space-based art of digital image processing to create high-resolution pictures of the human heart. The computer images help doctors perform a delicate heart procedure called balloon angioplasty, an alternative to coronary bypass surgery.

The angioplasty procedure involves inserting a catheter tipped with a small deflated balloon into blood vessels to clear fatty deposits that can stop blood flow and cause heart attacks. The balloon is inflated when it passes across the vessel's restricted area and the deposits are scraped away, allowing blood to flow freely. Because the procedure is safer and less expensive than bypass surgery, its use has increased dramatically in the United States. Last year, 195,000 procedures were performed here, more than double the 82,000 in 1985. By 1992, the number is expected to reach 560,000.

This growth has fueled demands by cardiologists for higher quality imaging in the catheterization lab. In the past, cardiologists have relied on a technique called cine angiography to create x-ray pictures of heart functions. Low-dose x-rays record the images on 35-millimeter film, which is then developed and used by the physician to determine a diagnosis. Since the film must be processed, it is only available after the angioplasty. During the procedure itself the cardiologist watches low-resolution television images that are seen only once and stored on a standard videotape.

The new digital computer offers a faster and safer alternative. Called the Digital Cardiac Imaging (DCI) system, the computer was designed by engineers at Philips Medical Systems Inc., in Eindhoven, the Netherlands, and has been installed in 130 hospitals and clinics worldwide. DCI employs an image intensifier to convert x-ray pulses traveling through the patient's body into detailed movies that are shown on a bank of monitors. Because the DCI images are stored in digital form, rather than analog video, they can be displayed instantly as part of a process known as roadmapping. This involves using a freeze-frame image of a blood vessel section to guide the catheter's progress.

"The cardiologist now has diagnostic-quality images at arm's length," said Jost Bakker, a Philips physicist. "For the first time, he can make assessments while the patient is still on the examining table."

The real-time x-ray images allow cardiologists to analyze heart functions throughout the angioplasty. Using a cordless hand-held viewpad, the physician can scan images or compare live x-ray and "roadmap" images by placing them side-by-side on monitors.

By providing detailed pictures of coronary arteries, DCI enables the cardiologist to complete the procedure more quickly, thereby reducing the patient's exposure to x-rays, as well as limiting the amount of dye injected into the patient to visualize the arteries.

The digitization process alone does not give physicians enough information to assess a patient's condition. Instead, image enhancement techniques developed for NASA satellite photography are used to bring out added detail.

"Even a seasoned cardiologist could miss a tiny blood vessel if relying only on cine film," Bakker said. "The digital system's enhanced images greatly increase the chances of detection."

DCI's images not only improve the cardiologist's precision, but also his confidence, according to Bakker. "It gives cardiologists more control over the entire procedure," he said. "As a result, they're now performing extremely delicate angioplasties that they wouldn't have dared attempt in the past." □

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