NASA Tech Briefs

National Aeronautics and Space Administration

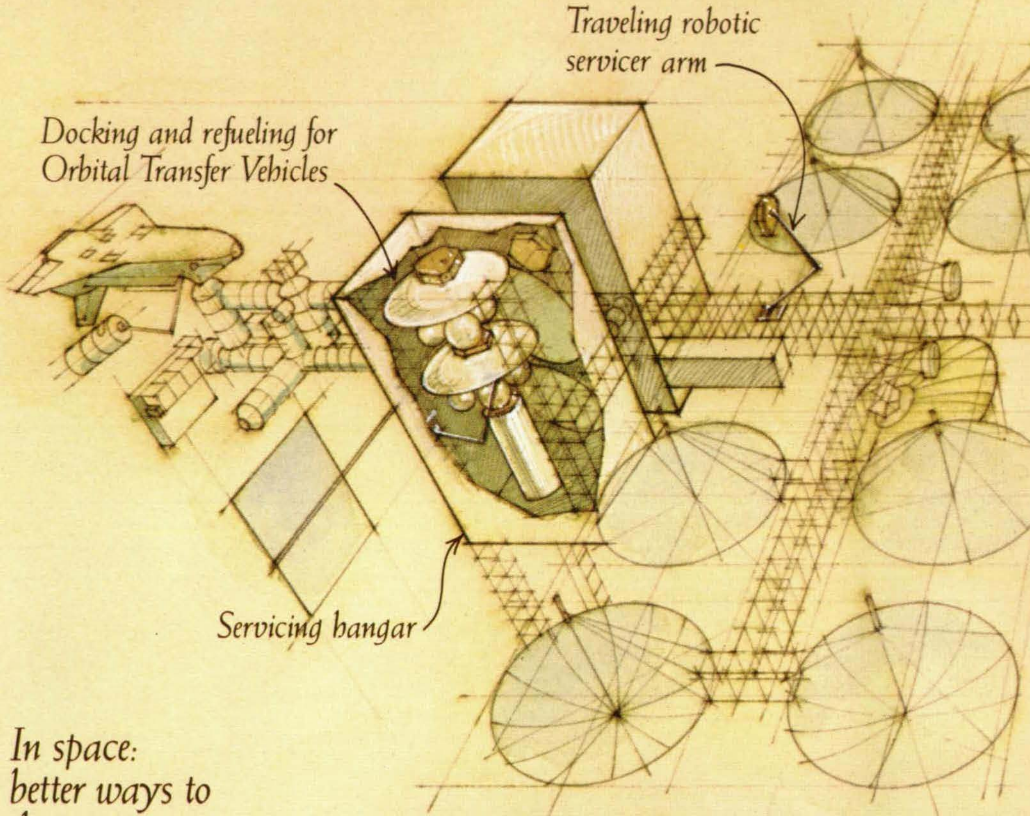
April 1987
Vol. 11 Number 4

CRYSTALLIZING THE FUTURE:
A Robotic Hand with Human Dexterity

COMPETITIVENESS:
America's Challenge

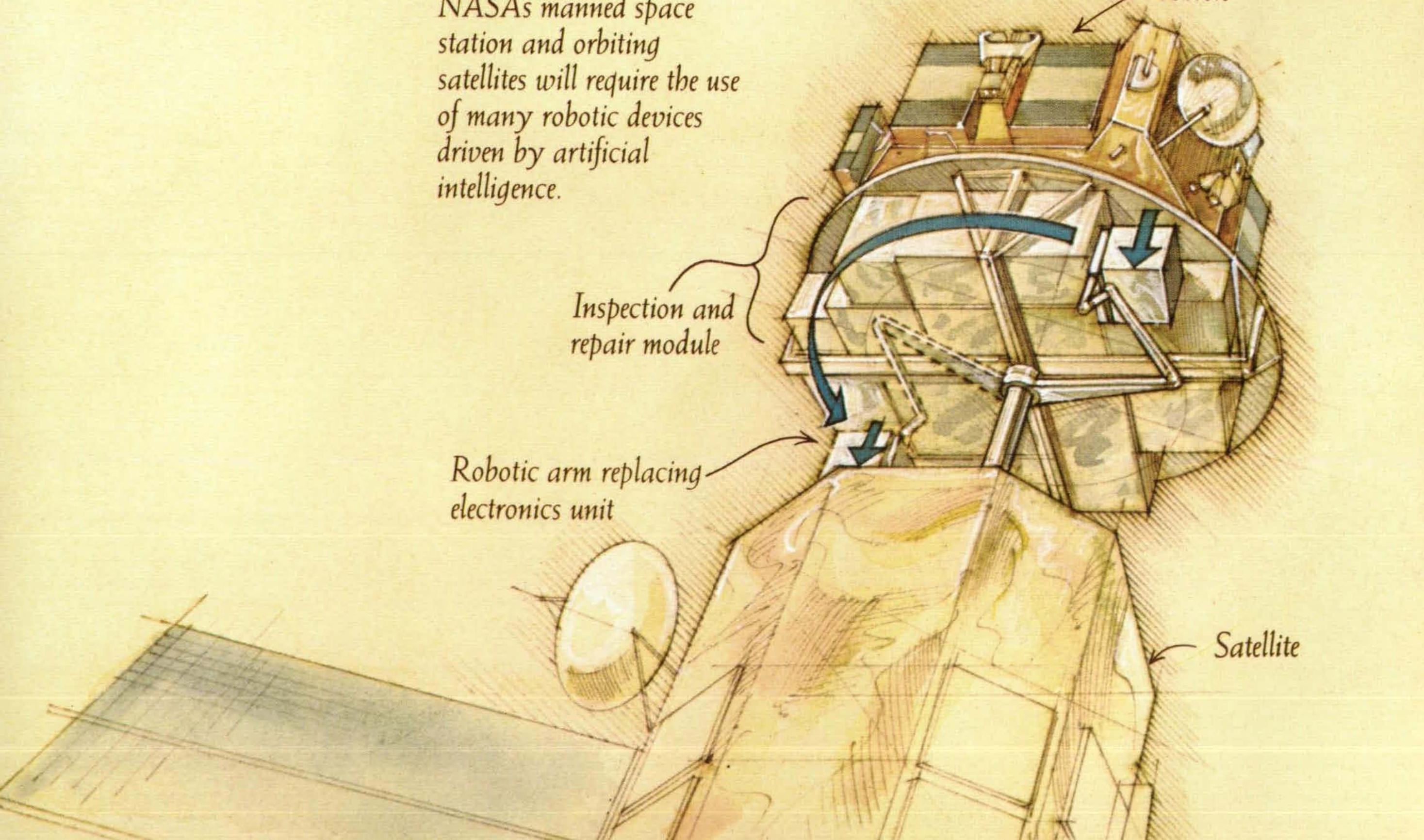
Artificial intelligence and robotics: giving machines the ability to sense, reason and act.

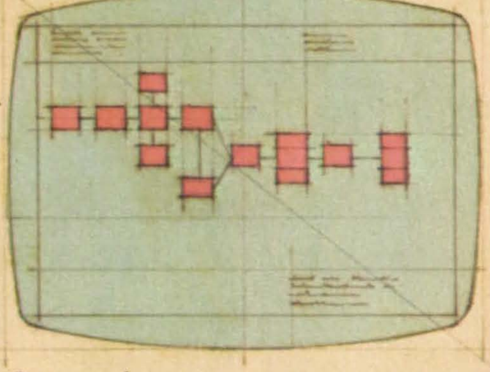
Much as it may hurt to think so, many things might be done better by independently functioning machines than by humans. Certain tasks may require superhuman precision or speed, or need to be done where humans can't go. Martin Marietta is creating systems that combine the ability to sense, reason and take action — to function autonomously and intelligently. And we are exploring ways to put them to work on a variety of tasks.

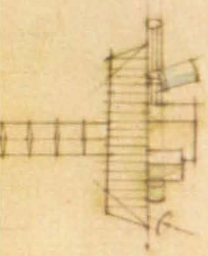


In space: better ways to do servicing.

NASA's manned space station and orbiting satellites will require the use of many robotic devices driven by artificial intelligence.

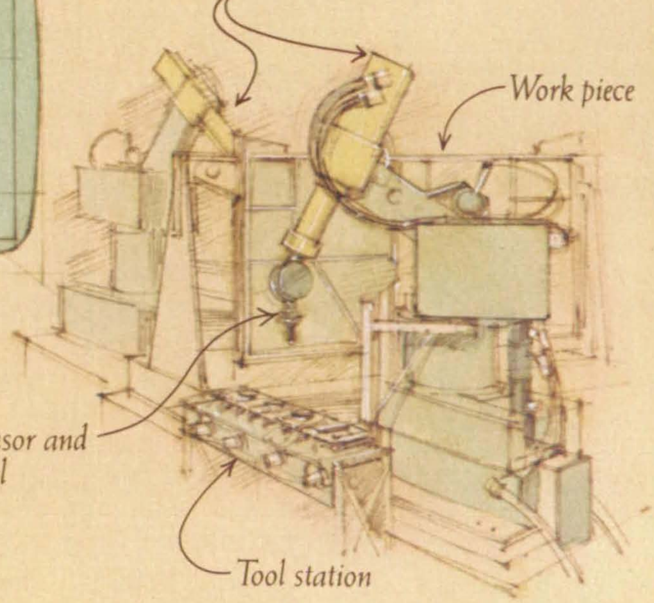


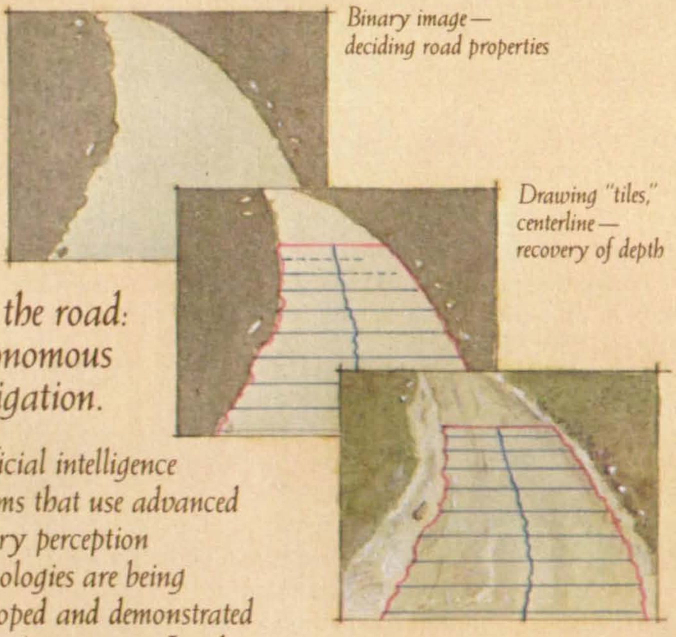




On earth: faster manufacturing and inspections.

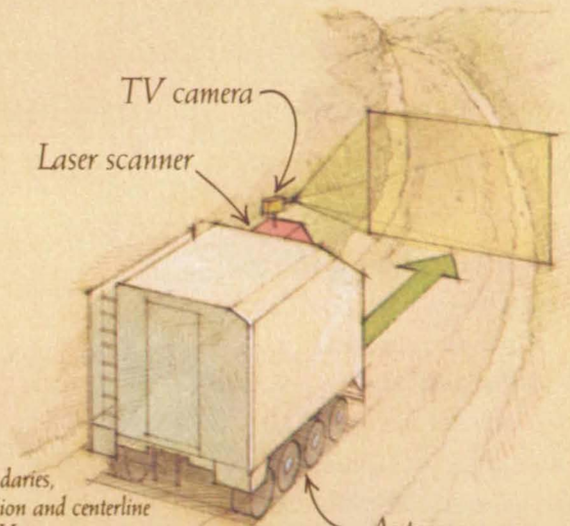
With creative intelligence stemming from software that we are developing, autonomous robots can quickly and efficiently perform batch manufacturing and precision inspections, even choose their own tools.





On the road: autonomous navigation.

Artificial intelligence systems that use advanced sensory perception technologies are being developed and demonstrated in the Autonomous Land Vehicle. Already able to follow roads, this mobile test bed will eventually be able to plan its route, avoid obstacles and even thread its way across country.



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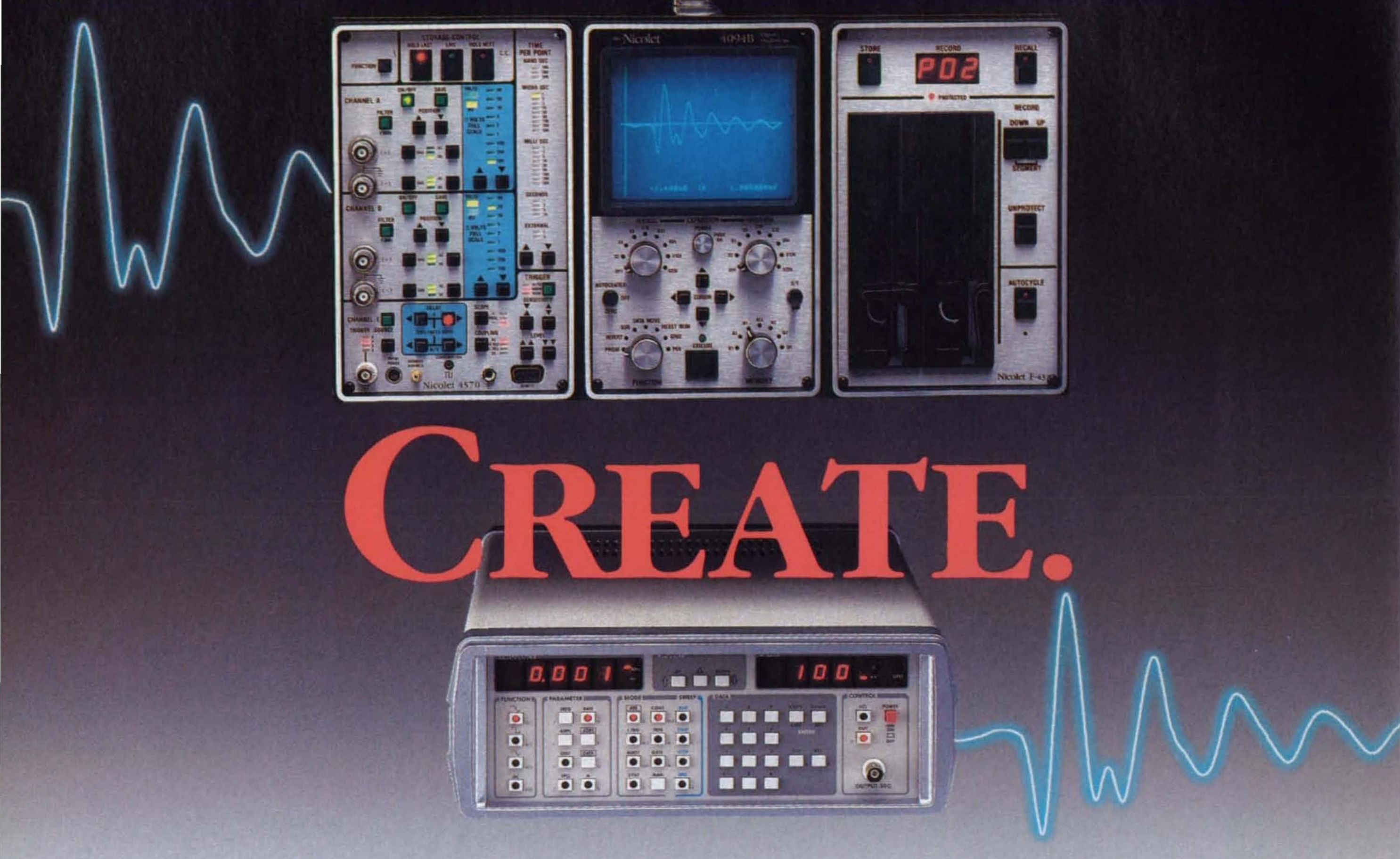

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Stimulate experiments with real-time analog waveforms reproduced from your actual captured data!

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Nicolet Digital Oscilloscopes

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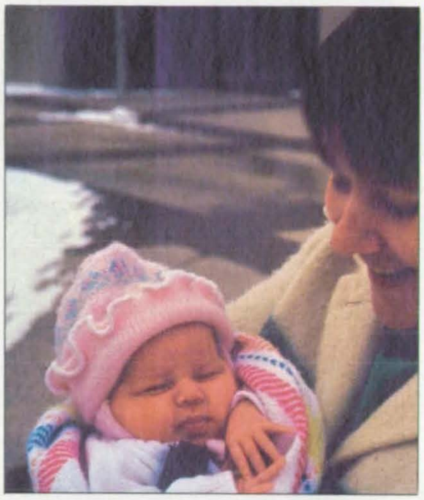
National Aeronautics and Space Administration

APRIL 1987
Volume 11 Number 4

ABP BPA

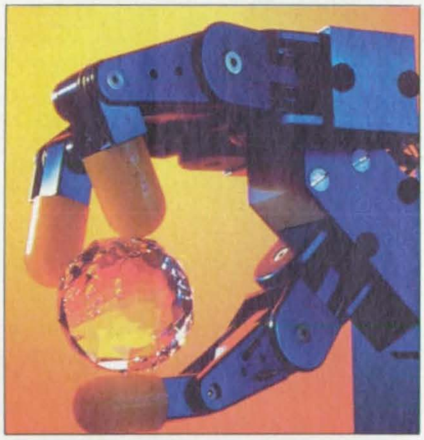
Special Features and Departments



Though this infant doesn't know it, she's taking part in an important study relating sunshine exposure to vitamin D intake. See page 85.

PHOTO COURTESY MARY ANNE FACKELMAN-MINER, THE WHITE HOUSE

In his recent State of the Union address, President Reagan outlined his plans to increase America's competitiveness. With continued technological excellence a prerequisite for success, **NASA Tech Briefs** *readers have an important role to play. Our story begins on page 8.*



On The Cover: Capable of grasping and manipulating a wide variety of shapes, the "Salisbury Hand" was developed at the Jet Propulsion Laboratory and Stanford University. Here, the robot maps the faceted surface of a crystal ball based on input from fingertip sensors.

Technical Section Thumb Index

Thumb Index Technical Section

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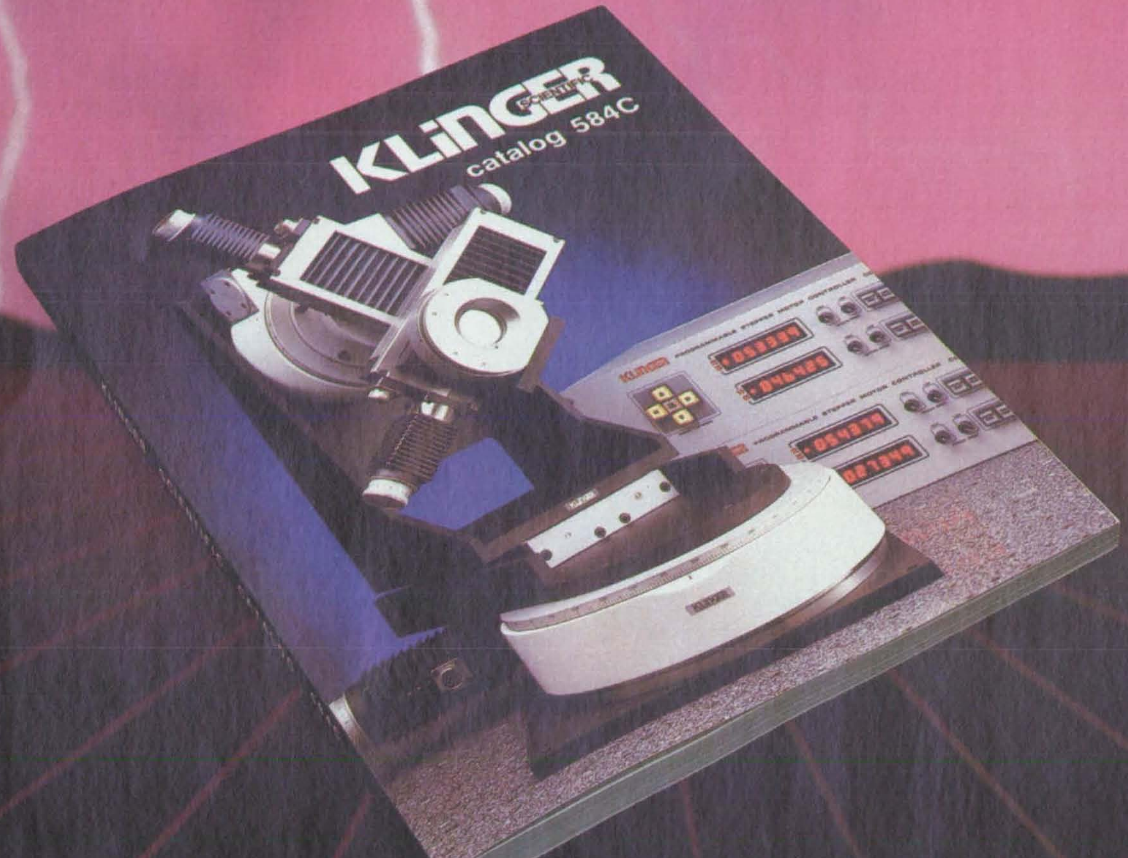

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A QUEST FOR EXCELLENCE

The first cherry blossoms have long heralded the coming of spring, but this year, they marked another important event—the President's competitiveness initiative. In his January 27 State of the Union address, the President launched a six part program designed to increase our country's competitiveness.

While setting a national agenda, the President's speech also holds special relevance to *NASA Tech Briefs* readers. The National Science Foundation's science and technology centers, increased emphasis on technology transfer, through people or paper exchanges—all these mean increased opportunity for the inspired engineer, scientist or technical manager. We think you'll find the following excerpts stimulating and thought provoking.

"Science and technology are fundamental to U.S. competitiveness. America's pre-eminence in research and innovation has long been the envy of the world and a critical source of our national strength. But, we must recognize that our trading partners, in their desire to improve their standards of living and market share, are catching up. We must ensure that adequate incentives are in place that will not only maintain our pre-eminence in initiating ideas and know-how, but also our lead in setting the pace at which these are translated into new products and processes.

Our policies must serve three broad objectives:

- Generating new knowledge in advanced technologies;
- Swiftly transferring new technologies to the marketplace; and
- Expanding the Nation's talent base in the sciences and technologies.

We will initiate a number of measures to achieve these objectives. I am proposing that we double over five years the budget of the National Science Foundation. My Administration will establish a number of new government-private "science and technology centers" based at U.S. universities. These centers will focus on fundamental science that has the potential to contribute to our Nation's economic competitiveness.

I am directing the Departments of Agriculture, Commerce, Energy and Health and Human Services and the National Aeronautics and Space Administration to initiate a "Technology Share" program involving multi-year, joint basic and applied research with consortia of U.S. firms and universities. We will also initiate a "People-to-People" exchange program in which scientists and engineers from Federal laboratories and the private sector will be encouraged to make their expertise available to each other through temporary assignment exchanges.

In addition to improved access to the know-how of our Federal scientists, the U.S. private sector must be encouraged to take advantage of our Federal science and technology enterprise. Since 1982 we have taken several actions to help commercialize the results of federally funded research by transferring management of Federal technology to those closest to its invention and encouraging cooperation on basic research between government and industry and among businesses. To enhance these efforts, I will issue an Executive order containing a number of measures:

- To encourage scientists working in Federal laboratories to patent, license, and commercialize their research so that the private sector, including consumers, can benefit, Federal agencies must implement royalty sharing programs with Federal inventors;
- To fully exploit foreign science and technology, the Department of State will develop a vigorous recruitment policy that encourages scientists and engineers from other Federal agencies, academia, and industry to apply for assignments ►

PHOTOS COURTESY PETE SOUZA, TERRY ARTHUR/THE WHITE HOUSE.

in U.S. embassies abroad; and

- To promote technology transfers and commercial spin-offs from Federal research and development efforts, Federal agencies and federally operated laboratories will seek out "science entrepreneurs" to act as conduits between the laboratories and business, venture capitalists, and universities.

My Administration will implement a policy permitting all Federal contractors to own software, engineering drawings, and other technical data generated by Federal contracts in exchange for royalty-free use by government. This will help commercialize non-patentable results of federally funded research."

Several of the President's proposed programs directly relate to *NASA Tech Briefs* readers and others involved in science and technology. NASA TECH BRIEFS spoke to several policy analysts and other technology transfer experts to amplify some of these areas:

Many see consortiums as the means for America to maintain her competitive edge. "What the President's initiative means across the board is an increased emphasis on increasing the linkages, the cooperation between the universities, the government labs and the private sector. They're going to find increased interest in the other sectors of networking and collaborating," says Dr. Don Myers, Director of the Center for Technological Development.

Science Entrepreneurs: Who Will They Be?

Within a research community's environment, golden ideas with market potential come and go, all too often without any commercial followup. Here, science entrepreneurs can make a big difference. Douglas Henton, a Senior Policy Analyst for economic competitiveness at SRI International, feels that the best science entrepreneurs are those in the research community. "In the university setting, or in a national lab, reforms are underway that encourage and allow people to commercialize," he says. Even when a university-based innovator chooses not to bring his idea to the market, he still has an important role to play. Enthusiastic about his invention, and with a broad vision of its opportunities and advantages, he can pass the baton, developing interest on the part of other people willing to commercially exploit the technology.

Don Jared, Manager of the Technology Transfer Program at Martin Marietta Energy Systems, which runs the Department of Energy's Oak Ridge National Laboratory, cites a program designed to help the entrepreneur: The Tennessee Innovation Center, a for-profit organization in which "You can walk in the door with an idea, and they will help you write a business plan, furnish you with an office and secretary, give you advice, and create a board of directors." The Center has seed money of its own, adds Jared, and will help raise venture capital when needed. Readers interested in learning more about the Tennessee Innovation Center can call David J. Fitzgerald, President, at 615-482-2440.

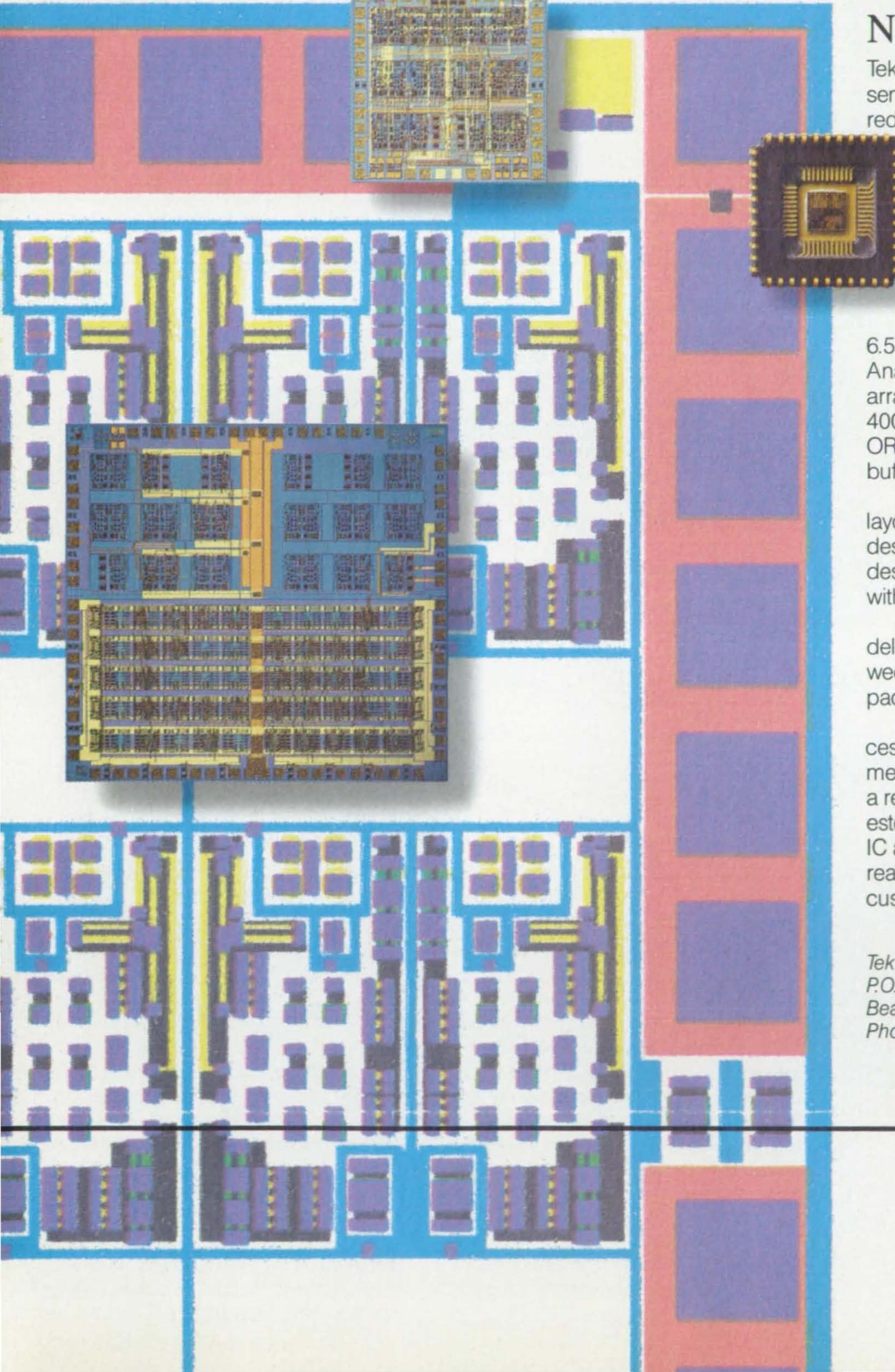
International Resources

According to Vid Beldavs, Executive Director of the Technical Transfer Society, "the flow of technology know-how from overseas comprises half or more of the technology generated worldwide." To take advantage of this foreign information, the President plans to employ American technologists in U.S. embassies. It's only fair. Other nations scoop up U.S. technology with ease, leapfrogging technical obstacles that American researchers labored over. Progress must be made not only to enhance technology transfer within the U.S. but also to bring parity to the exchange of information between ourselves and foreign countries.

Certain elements of the President's initiative are not new, but Mr. Reagan has given national recognition and impetus to a comprehensive goal. The President's plans should encourage the *NASA Tech Briefs* reader, from laboratory technician to CEO. His unprecedented doubling of the NSF budget shows a firm committment to basic research and the generation of new knowledge. By bridging the gaps between elements of the technology infrastructure, the President paves the way for greater opportunities, commercial and professional.

One of the best aspects of cherry blossoms is that, in time, they ripen and mature into edible cherries. So too will the President's plans develop and bear comprehensive fruits that enhance America. □

The QuickCustom™ approach to bipolar ICs.



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Tektronix has developed a way to design semi-custom analog ICs that will greatly reduce your development time and cost.

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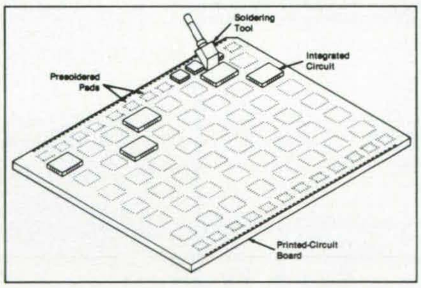
New Product Ideas

New Product Ideas are just a few of the many innovations described in this issue of *NASA Tech Briefs* and having promising commercial applications. Each is discussed further on the referenced page in the appropriate section in this issue. If you are interested in developing a product from these or other NASA innovations, you can receive further technical information by requesting the TSP referenced at the end of the full-length article or by writing the Technology Utilization Office of the sponsoring NASA center (see page 17). NASA's patent-licensing program to encourage commercial development is described on page 17.

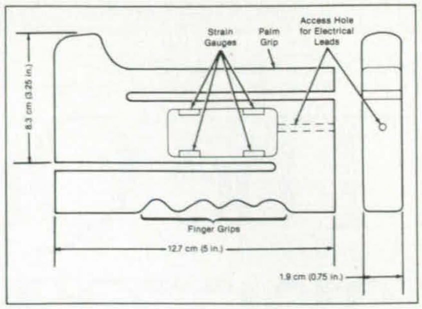
VLSI-Chip Tester

A test set performs functional tests on very-large-scale integrated (VLSI) circuits. It can make tests from points within a VLSI chip as well as at the input and output pins. The set consists of special-purpose hardware, firmware, and software. It is contained in a microprobe station consisting of a high-power stereoscopic microscope, a set of four probes, and a device for measuring the thickness of layers on the chip. The microscope is used to position the probes on the chip. Signals to and from the chip may be routed through the input/output pins, the probes, or both. *(See page 24).*



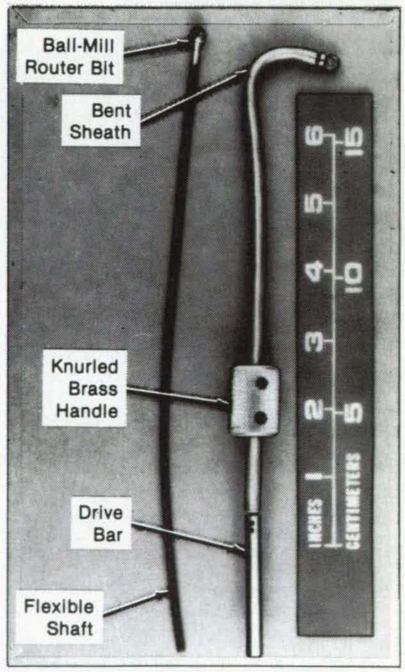
Soldering Tool for Integrated Circuits

An improved soldering tool bonds integrated circuits onto printed-circuit boards. It is intended especially for use with so-called "leadless-carrier" integrated circuits. The tip of the new tool is a cooper prism shaped to form a wedge that fits between adjacent integrated circuits. The wedge is thin enough to prevent the conduction of heat to the wrong chip and wide enough to enable the soldering of several connections at once. *(See page 72).*



Hand-Strength Meter

A special grip-strength meter has been designed for accurate, reproducible measurement of hand rehabilitation. The meter is machined from a one-piece aluminum block. The upper and lower parts of the block are contoured for the proper grip. These two parts connected by two parallel measuring beams to which four strain gauges are cemented. The strain gauges are connected in a Wheatstone bridge to measure the deflection caused by a gripping hand. *(See page 80).*



Bendable Routing Tool

A bendable routing tool extends a routing bit into internal cavities or passages so that burrs and similar defects can be removed in areas accessible through curving channels. The tool includes a copper sheath containing a flexible steel shaft like that in a tachometer cable. A steel drive bar, attached to one end of the shaft, is inserted in the chuck of a hand-held manual or power drill to turn the shaft. *(See page 67).*

THE TAU-TRON ADVANTAGE

Tau-tron Continues Its Tradition for Advanced Technology in Bit Error Rate Testing

BERTS-325C

The BERTS-325C provides accurate, quantitative, end-to-end bit error rate testing with standard NRZ or RZ codes for 1kHz to 325 MHz (BERTS-650 is available for applications up to 650 MHz). Tau-tron's TMI® family offers custom instrumentation with the BERTS-325C to meet your specific needs at off-the-shelf prices. Over 10 different plug-in modules for signal generation, conditioning and detection are available. Tau-tron's commitment to the TMI® modular design concept precludes obsolescence and is ideal for satellite, fiberoptic, high-density digital tape, digital radio and digital multiplexer applications. For full-system integration capabilities, a GPIB (IEEE-448) Interface is included to control all relevant front panel functions.

BERTS-1150

The BERTS-1150 is an advanced technology bit error rate test set designed to evaluate the performance of high speed lasers, fiberoptic links, satellite links and components such as GaAs logic devices with the frequency range of 90 to 1150 MHz. Consisting of Tau-tron's highly stable STX-1101 Transmitter and SRX-1101 Receiver, the BERTS-1150 incorporates many user features such as three selectable bit patterns and internal/external error inject which truly makes it a powerful, general purpose test set. The BERTS-1150 measures total bit errors, bit error rates, or clock frequency and may be remotely controlled through either a GPIB or RS-232C interface. The BERTS-1150 will also provide hard copies of measurement data through either of these interfaces.

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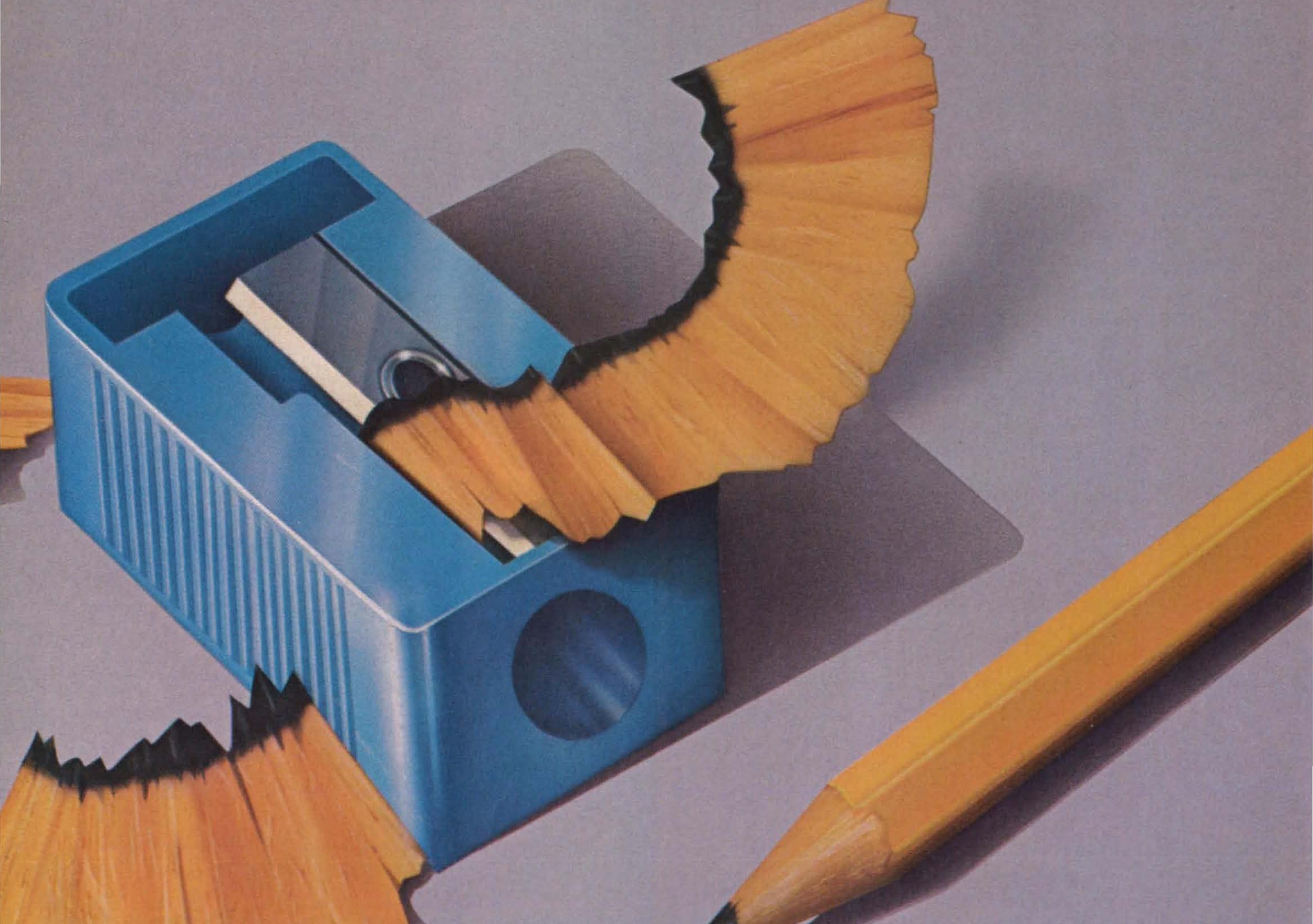

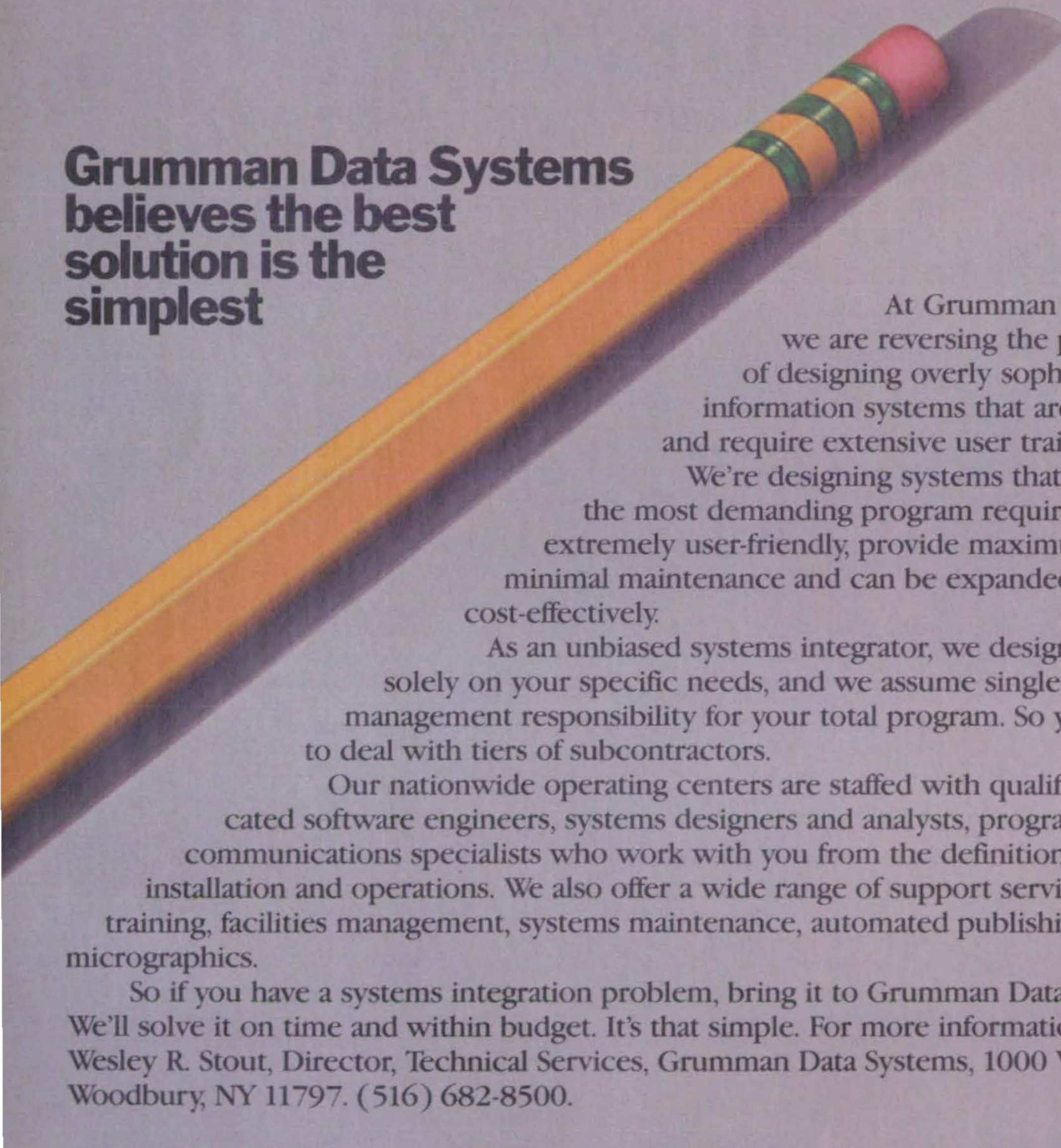

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On the following pages, we've outlined NASA's TU Network—named the participants, described their services, and listed the individuals you can contact for more information relating to your specific needs. We encourage you to make use of the information, access, and applications services offered by NASA's Technology Utilization Network. You can save time and money by doing so.

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A nationwide network offering a broad range of technical services, including computerized access to over 100 million documents worldwide.

You can contact NASA's network of Industrial Applications Centers (IACs) for assistance in solving a specific technical problem or meeting your information needs. The "user friendly" IACs are staffed by technology transfer experts who provide computerized information retrieval from one of the world's largest banks of technical data. Nearly 500 computerized data bases, ranging from NASA's own data base to Chemical Abstracts and INSPEC, are accessible through the nine IACs, which are located throughout the nation. The IACs also offer technical consultation services and/or linkage with other experts in the field.

You can obtain more information about these services by calling or writing the nearest IAC. User fees are charged for IAC information services.

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Electronic Components & Circuits

Hardware, Techniques, and Processes

Computer Programs

Overriding Faulty Circuit Breakers

A retainer keeps power on in an emergency.

Lyndon B. Johnson Space Center, Houston, Texas

A simple mechanical device can be attached to a failed aircraft-type push/pull circuit breaker to restore electrical power temporarily until the breaker can be replaced. The device holds the push/pull button in the closed position, making it unnecessary for a crewmember to hold the button in that position by continual finger pressure.

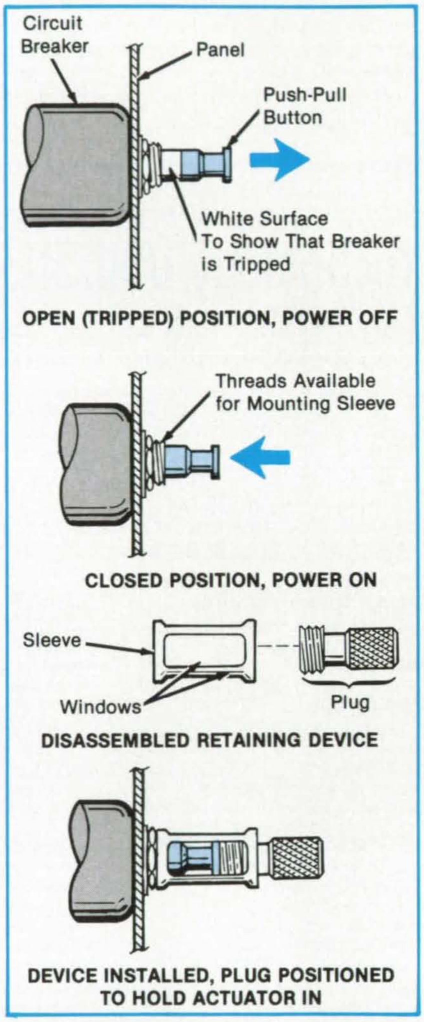
The circuit breaker normally operates in the closed position, which is maintained by an internal mechanism unless the breaker is intentionally opened or trips because of an overcurrent. If the mechanism malfunctions or breaks, a spring on the actuator opens the breaker and keeps it open. This type of mechanical failure is overcome by the retaining device.

The retaining device consists of an internally threaded sleeve and a threaded plug (see figure). One end of the sleeve fits over the circuit-breaker button and is screwed onto the threads that extend from the circuit-breaker mounting nut. The plug is screwed into the open end of the sleeve. As the plug is sufficiently advanced into the sleeve, it pushes the button, closing the circuit breaker. Left in this position, the plug maintains a closed circuit.

The plug can be inserted in the sleeve after a failure, or it can be held in the sleeve and tightened when a failure occurs. If the plug end of the sleeve is left unthreaded, the plug cannot be removed from the sleeve and therefore cannot be lost. When the plug is turned fully counterclockwise, it clears the circuit-breaker button; in this configuration the device serves as a guard to prevent the circuit-breaker button position from being changed accidentally.

The retaining device does not interfere with the electrical function if the circuit breaker is of the "trip-free" type: an overcurrent will still trip the breaker to the open position even though the device is holding it closed.

This work was done by Richard L. Robbins of Rockwell International Corp. and Thomas E. Pierson of Ford Aerospace for **Johnson Space Center**. *For further information, Circle 20 on the TSP Request Card.*
MSC-20583



A Sleeve and a Plug Hold the Button In, overriding a mechanical failure in the circuit breaker. Windows in the sleeve show the button position.

Integrated Optical Processor

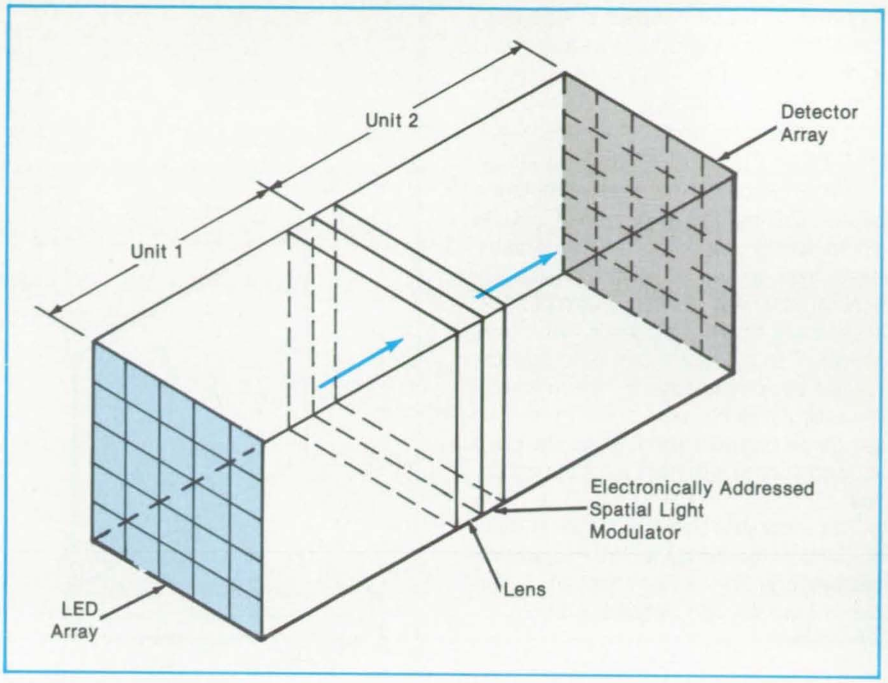
Images would be processed rapidly in a rugged, compact device.

NASA's Jet Propulsion Laboratory, Pasadena, California

A conceptual integrated optical image processor would perform complicated analog calculations, including Fourier transforms, convolutions, correlations, and matrix multiplications. In addition to being compact and rugged on account of its monolithic structure, the processor would be faster than equivalent all-electronic devices because calculations would require only the time for the light to travel across the device; the processing speed would be limited mainly by that of the electronic input and output circuits.

The processor would include an input array of light sources, a lens, a spatial light modulator, and an output detector array. The convolution kernel would be applied via the modulator. While this basic optical-processing configuration is well known, the proposed device differs from some others in that it uses incoherent rather than coherent light.

The advantage of incoherent optical processing is that the output is not sensitive to coherent noise or minor defects in the optical train. The disadvantage is that the system is linear in light intensity but not in complex field amplitude; therefore, the processor can convolve directly only those input arrays having real, positive (or zero) elements. Complex or negative values could be processed indirectly, but the data would first have to be encoded.



The **Integrated Optical Processor** would perform two-dimensional convolutions and other complicated analog operations at the speed of light.

The processor would be made in two units grown epitaxially on opposite faces of substrate crystals. One unit would include an input array of light-emitting diodes (LED's) and a monolithic lens, while the other would contain the spatial light modulator and the detector array. The units would be joined at a common face. In the present state of the art, the units would consist of thin films of $GaAs/Ga_xAl_{1-x}$ as grown epitaxially on Al_2O_3 (sapphire).

A variety of input/output schemes has been proposed. For example, a 512-by-512 input LED array would be connected to the signal-source by a row/column conductor matrix. This would reduce the number of input connections to 1,024, and electronic multiplexing could reduce the number further. In this scheme, an output detector array of charge-coupled devices would have to integrate the processed convolution signal over the time required to illuminate all LED's in sequence. The detector outputs would be time multiplexed into a single pixel stream.

Of the lens types considered, the best compromise appears to be a Fresnel lens of $Ga_{0.9}Al_{0.1}$ as grown by chemical-vapor deposition to a thickness of at least 10 μm on an Al_2O_3 surface. The Fresnel pattern would be cut into the lens material by ion milling or chemical etching.

The spatial light modulator is an electronically-addressable two-dimensional mask that modifies the traversing light. Further work is needed to establish the design concept; the choice has been narrowed to magneto-optic and electro-absorption designs.

This work was done by William E. Stephens of TRW, Inc., for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 155 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 17]. Refer to NPO-16684.

Injection Phase-Locked Laser-Diode Array

Coherent emission is stimulated by the holographically directed emission from a master laser.

NASA's Jet Propulsion Laboratory, Pasadena, California

Phase-coherent emission with negligible far-field supermodes might be produced by a proposed surface-emitting laser-diode array stimulated by the holographically directed emission from a single master diode. To achieve the same coherence and output power, a single laser diode would require a high power density, which would substantially reduce its working lifetime. The proposed integrated optical array would be useful in communications.

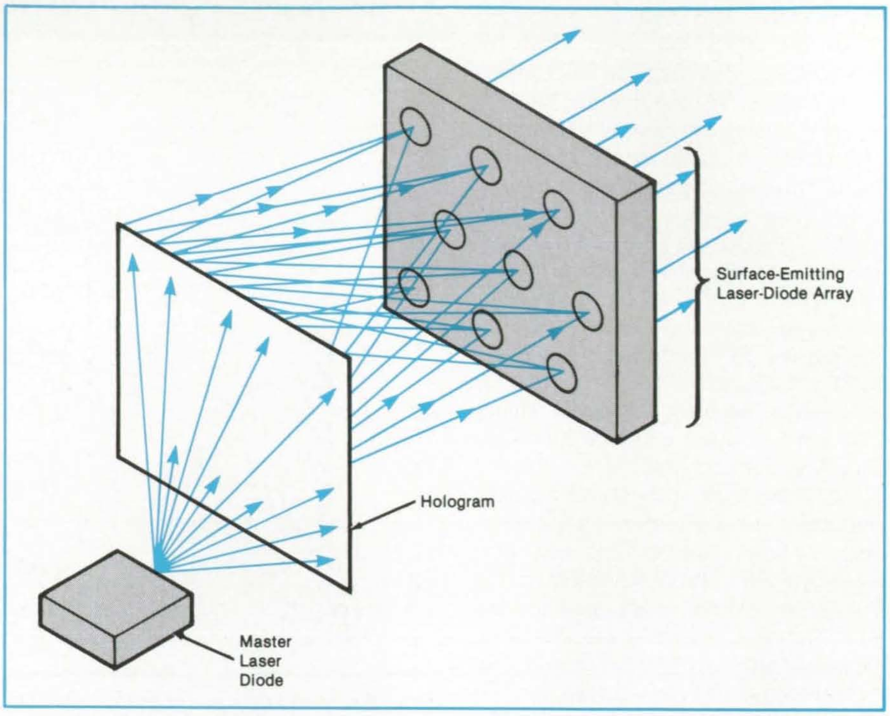
Much work has been devoted to the analysis, development, and fabrication of laser-diode arrays. The coupling required for phase coherence among the output beams of several diodes can be produced sometimes by simply placing the laser-diode stripes close enough together. However, such coupling often can lead to undesirable supermode patterns in the array far field.

A more positive method to achieve phase coherence is via injection locking, wherein a master laser is focused into the back facet region of the array, thereby injecting a phase-coherent stimulus into all the array channels. Some success already has been achieved with one-dimensional arrays of stripes spaced about 9 μm apart. Light is emitted from these arrays in directions parallel to the stripes.

Currently, research is underway on two-dimensional surface-emitting laser arrays, from which the light is emitted perpendicularly to the large substrate surfaces. In such a device, layers are first grown on a substrate, and then mirrors are deposited in holes etched from the bottom (through the substrate) and from the top. The separation between lasers (holes) is usually 25 to 100 μm. This is too large for spontaneous phase coupling of the lasers to each other.

In the proposed method of injection phase locking, a holographic grating would focus the output of the master laser into a set of distinct, spatially separated beams, each one directed into a separate hole in the laser array (see figure). The hologram can also be configured to compensate for the asymmetric output-beam shape of the master laser diode, thereby eliminating the need for complex (prism-pair) apodization optics.

This work was done by James R. Lesh of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 154 on the TSP Request Card.* *NPO-16542*



In this **Phase-Locked, Surface-Emitting Laser-Diode Array,** the emission from the master laser diode is holographically directed into the laser diodes of the array, stimulating coherent emission.

Improving Solar Cells With Polycrystalline Silicon

Thin layers arranged strategically would make cells more efficient.

NASA's Jet Propulsion Laboratory, Pasadena, California

In a proposed solar-cell design, layers of polycrystalline silicon would be grown near the front metal grid and the back metal surface. The net electrical effect should increase the open-circuit voltage and the short-circuit current, resulting in greater cell power output and energy-conversion efficiency.

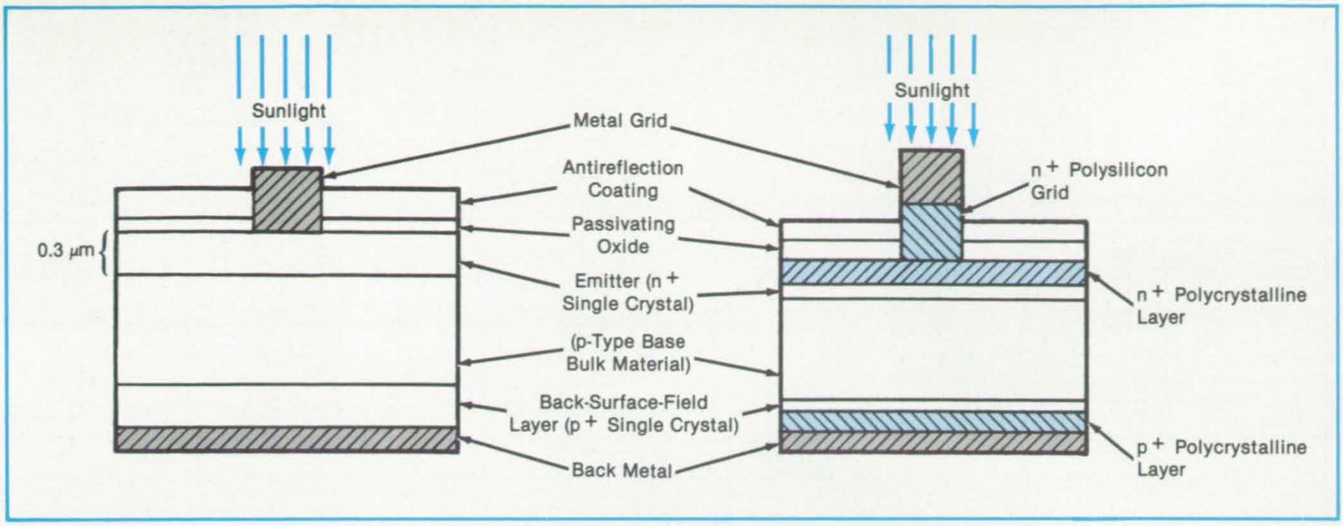
The figure shows the differences between the existing and proposed cell configurations. In the emitter region, a single-crystal layer of n^+-doped silicon, 0.3 μm thick, would be replaced by a 0.2-μm n^+ polycrystalline layer and a 0.1-μm n^+ single-crystal layer. This could be done by depositing first the polycrystalline layer on the p-doped base, then forming the n^+ region by diffusion through the polycrystalline layer. The polycrystalline layer should decrease recombination and reverse-saturation emitter current. In a typical surface-passivated cell with low base resistivity, high bulk lifetime, and a high ratio of reverse-saturation emitter current to reverse-saturation base current, the result should appreciably increase open-circuit voltage.

A second layer of n^+ polycrystalline silicon would be established under the metal of the front-surface contact grid. Although a typical grid covers only 5 percent of the front surface, it attracts many charge carriers from the surrounding regions, causing them to recombine at the metal/silicon interface. The interposition of the new doped polycrystalline layer creates a new polycrystalline/single-crystal contact interface with a recombination velocity much lower than that of the metal/silicon interface. To reduce the range of influence of the metal grid and thereby increase cell performance, the thickness of the polycrystalline layer should exceed the minority-carrier diffusion length in that layer.

To reduce recombination in the back-surface-field region, a p^+-doped polycrystalline layer would be added between the p^+ back-surface-field layer and the back metal contact. The decrease in recombination in the back-surface-field region should reduce the recombination at the p/p^+ interface, in turn reducing the base contribution to the total reverse saturation current. The net effect should appreciably increase open-circuit voltage in a cell that has a high-resistivity, low-lifetime base with a high ratio of reverse-saturation base current to reverse-saturation emitter current, or in a cell in which the polycrystalline layers have reduced the emitter recombination so much that the open-circuit voltage is limited mainly by recombination in the base side.

Experience with metal oxide/semiconductor devices has shown that polycrystalline layers can act as getter materials to remove impurities from the adjacent silicon during oxidation or high-temperature processing, consequently increasing carrier lifetimes from microseconds to milliseconds. Since the polycrystalline silicon layers in the improved solar cell are to be doped by high-temperature diffusion, similar increases in the bulk lifetimes of the solar cell are anticipated. Although this entails the gathering of impurities and defects into the polycrystalline layers, it has little adverse effect on cell performance because the polycrystalline layers are meant to be heavily doped (and therefore to have short lifetimes) in the first place.

This work was done by Ajeet Rohatgi, Robert B. Campbell, and Prosenjit Rai-Choudhury of Westinghouse Electric Corp. for **NASA's Jet Propulsion Laboratory.** *For Further information, Circle 2 on the TSP Request Card.* *NPO-16820*



The **Proposed Solar-Cell Configuration** differs from the existing one in that layers of doped polycrystalline silicon are added to reduce recombination in the emitter and back-surface-field regions.

Pressure-Transducer Simulator

Electrical outputs mimic transducer signals under different pressure conditions.

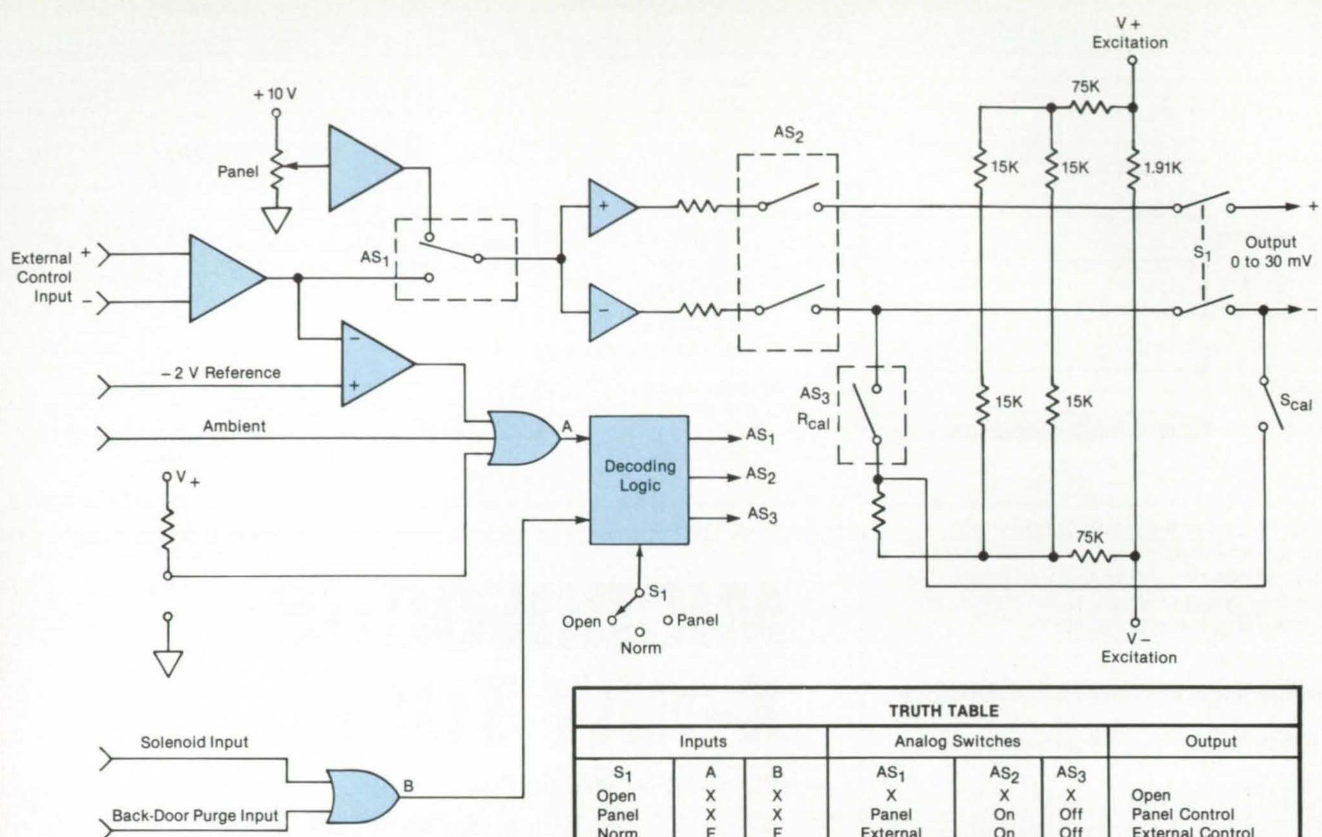
Marshall Space Flight Center, Alabama

A simulation circuit operates under remote, automatic, or manual control to produce electrical outputs similar to those of a pressure transducer. The specific circuit was designed for simulations of the Space Shuttle main engine. The general circuit concept may be adaptable to other simulation and control systems that involve several operating modes.

The simulation modes of the circuit correspond to the operating modes designated as ambient, calibration, solenoid valve, or back-door purge. The circuit (see figure) includes a resistive bridge that is driven differentially according to switch settings determined by the control signals and the associated logic circuits.

Because the drive is differential, the output voltage remains the same as long as the voltage difference between the excitation terminals remains the same; for example, the output is the same with an excitation input of (0 V, −10 V), as it is for an excitation input of (+5 V, −5 V). This feature makes the simulator compatible with control circuits that operate at different dc bias levels.

The circuit is built on a card with edge



NOTES:
1. R_{cal} = 10Ω or 30Ω
2. "AS" means analog switch

TRUTH TABLE

Inputs			Analog Switches			Output
S_1	A	B	AS_1	AS_2	AS_3	
Open	X	X	X	X	X	Open
Panel	X	X	Panel	On	Off	Panel Control
Norm	F	F	External	On	Off	External Control
Norm	F	T	External	On	Off	External Control
Norm	T	F	X	Off	Off	Ambient
Norm	T	T	X	Off	On	80 Percent of Full Scale = 24 mV

(T = True and F = False)

Switches and Amplifiers respond to external control signals and panel control settings to vary the differential excitation of a resistive bridge. The bridge output voltage or passive terminal resistance is made to equal that of a pressure transducer in any of four operating modes.

connectors so that it can be interchanged easily with similar circuits and readjusted for the desired ambient and calibration outputs. The complimentary metal-oxide/semiconductor logic and analog-switching circuits make the overall circuit efficient and reliable. The balanced-bridge configuration makes the circuit more accurate and less susceptible to temperature changes than previous simulation circuits.

This work was done by Richard A. Simon of Rockwell International Corp. for **Marshall Space Flight Center.** *For further information, Circle 17 on the TSP Request Card. MFS-29169*

Electronic Systems

Hardware, Techniques, and Processes

Computer Programs

VLSI-Chip Tester

A compact test set is integrated in a computer-aided design system.

NASA's Jet Propulsion Laboratory, Pasadena, California

A test set performs functional tests on very-large-scale integrated (VLSI) circuits. It can make tests from points within a VLSI chip as well as at the input and output pins. It is used for both quality control and design; in the latter capacity, it can check internal logic functions on a chip and feed results directly to a computer-aided design system for correction. It can also simulate the operation of a chip design before the chip is made.

The set consists of special-purpose hardware, firmware, and software. It is contained in a microprobe station (see Figure 1) consisting of a high-power stereoscopic microscope, a set of four probes, and a device for measuring the thickness of layers on the chip. The microscope is used to position the probes on the chip. Signals to and from the chip may be routed through the input/output pins, the probes, or both.

The chip to be tested is inserted in a 64-pin socket on the microprobe station. The socket protrudes through an opening in the probe platform, allowing access to the chip for the microscope and probes.

The set can generate eight independent test sequences of up to 4,096 bits at a time. The set generates several clock signals in synchronism with the test sequences. Clock rates can be selected up to 20 MHz — ample for metal-oxide/semiconductor chips. The set can monitor eight chip outputs for up to 4,096 bits at a time.

A user can control the set from a local terminal, using the terminal to define and

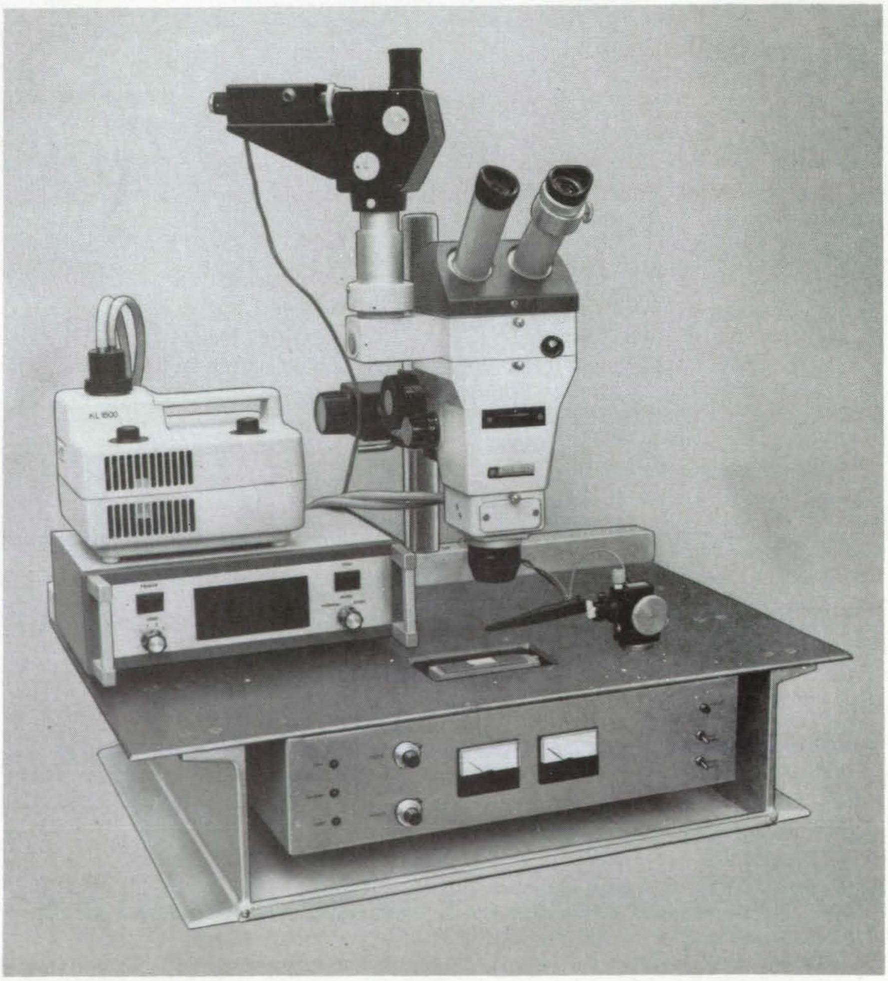


Figure 1. The **VLSI Tester** contains three power supplies, control logic, and a standard multibus circuit board in an aluminum chassis. The chassis fits under the platform of a microprobe station. The multibus board links the tester to interactive terminals and to a host computer.

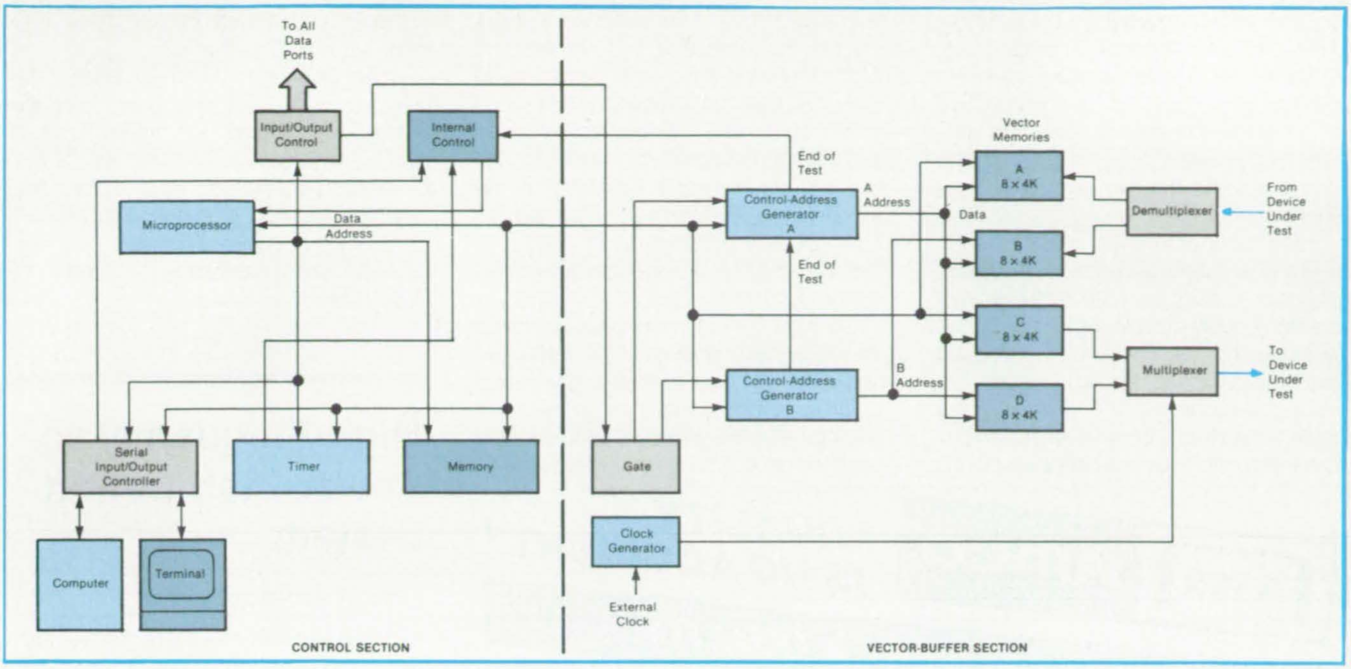


Figure 2. The **Tester Circuitry** includes the control section, which acts as an interface between the user and the vector-buffer section. The vector-buffer section generates the test-vector signals and records the responses of the device under test.

edit the tests, to run the tests, and to display the results. Alternatively, the test set may be completely controlled by a host computer. The test software is interactive and can be run from any user terminal on the computer-aided design system.

The core of the tester is the vector-buffer section (see Figure 2) — the part of the hardware that presents and records stimulus and response vectors during a test. It contains a static random-access memory in the form of four groups of chips, each chip being 4 kilobits deep and 8 bits wide. The memory and its supporting circuitry are organized to maintain two groups of two parallel memories, one group to produce vectors from the device under test and the other group to receive vectors from it. The parallel memories in a group are cycled 180° apart so that they can send and receive vectors at twice the rate of a single memory.

This work was done by Leslie J. Deutsch and Erlend M. Olson of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 69 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 17]. Refer to NPO-16740.

Reducing Color/Brightness Interaction in Color Television

The luminance- and chrominance-signal bandwidths are reduced, without proportionally reducing the horizontal-brightness and -color resolutions.

John F. Kennedy Space Center, Florida

A proposed digitally sampled scan-conversion scheme for color television would reduce unwanted interactions between the chrominance (color-difference) and luminance (brightness) signals. The incomplete separation of these signals causes such spurious picture effects as colors near the edges of black or white stripes and false brightness changes in regions of sharp color contrast. The new scheme would reduce the luminance bandwidth and the chrominance bandwidth to increase the frequency separation between the signals. To avoid proportionally reducing horizontal brightness resolution and horizontal color resolution, horizontal interlace (in addition to conventional vertical interlace) of the luminance signal and the two color-difference signals would be used.

In a U.S. standard NTSC (National Television System Committee) television signal, the chrominance signal consists of the two color-difference components transmitted in quadrature on a subcarrier about 3.58 MHz above the luminance carrier. To a human observer, a loss of color resolution is less noticeable than is a loss of brightness resolution; the conventional color-television system takes advantage of this phenomenon by reducing the horizontal color resolution to decrease the chrominance bandwidth. This enables the assignment of more of the available frequency spectrum to the luminance sidebands to augment the brightness resolution. The new scheme reduces the chrominance-signal-frequency components further by smoothing out the vertical color variations among neighboring horizontal scan lines, in effect reducing the vertical color resolution to more nearly the equal of the horizontal color resolution.

The picture is divided into picture elements in 784 columns and 525 rows, of which (at least) 644 columns and 483 rows would be visible (active). All the picture elements are progressively sampled during one vertical-scanning period (about one-sixtieth of a second). The red, green, and blue color signals from the camera are fed through a conventional scanning-matrix circuit to obtain horizontally and vertically progressive wideband versions of the luminance and the two color-difference signals.

Each color-difference signal is processed in a scan converter that samples groups of 49 neighboring picture elements in progressively moving regions of 7 rows by 7 columns. The average of the sampled values is assigned to each group. The color-difference signals, in effect, are made to represent larger, overlapping picture elements (lower resolution) requiring less bandwidth. The scan converters change the luminance and narrow-band color-difference signals from progressive to horizontally and vertically interlaced scanning. These signals are then amplified and used to modulate the luminance carrier and chrominance subcarrier in the usual way. (The transmitted signals are compatible with conventional signals, in that they may be displayed on unmodified conventional receivers.)

Scan converters in the receiver change the horizontally and vertically interlaced scans back into horizontally and vertically progressive scans matching those of the camera. A conventional matrix circuit is used to convert the luminance- and color-difference signals into the red, green, and blue signals of the display.

This work was done by Robert H. Marchman of Lockheed Corp. for **Kennedy Space Center**. *For further information, Circle 38 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Kennedy Space Center [see page 17]. Refer to KSC-11346.

High-Frequency ac Power-Distribution System

Loads are managed automatically under cycle-by-cycle control.

Lewis Research Center, Cleveland, Ohio

Electrical-power-distribution systems for aerospace applications have to be efficient, lightweight, and flexible to accommodate a variety of electrical sources and loads. For example, the power system for the Space Station is initially to be a combination of photovoltaic arrays supplying dc, and a solar dynamic system supplying low-frequency ac. The power requirements for the living areas, research projects, computers, and manufacturing facilities will be greatly varied.

Studies made at General Dynamics for NASA in the late 1970's indicated that a high-frequency ac distribution system would offer significant advantages for many aerospace applications. Since then, General Dynamics and NASA Lewis Research Center have developed a 440-V rms, 20-kHz ac power system. The system is flexible, versatile, and "transparent" to user equipment, while maintaining high efficiency and low weight.

Any electrical source, from dc to 2,200-Hz ac may be converted to 440-V rms, 20-kHz, single-phase ac. Power is distributed through low-inductance cables. The output power can be either dc or variable ac (both voltage and frequency can be varied).

Due to the high operating frequency, the energy transferred per cycle is reduced by a factor of 50, compared to conventional 60-Hz or 400-Hz power systems. The number of parts is reduced by a factor of about 5 relative to conventional three-phase converters. The power loss is reduced by two-thirds. These factors result directly in increased reliability and reduced costs.

Although designed for aerospace use, this system could be used in any power-distribution system that requires high efficiency, high reliability, low weight, and flexibility to handle a variety of sources and loads. This system enables cycle-by-cycle control of energy at multikilowatt power levels, with all load management under computer control. This combination presents a fertile ground for centralized control, artificial intelligence, or the combination of power systems with "smart" electronics. A 25-kW system has been built and tested by General Dynamics and NASA Lewis Research Center.

This work was done by Irving G. Hansen of **Lewis Research Center** *and James Mildice of General Dynamics. Further information may be found in NASA TM-87314 [N86-24747/NSP], "Space Station 20-kHz Power Management and Distribution System."*

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

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Lewis Research Center [see page 17]. Refer to LEW-14465.

Baseband Processor for Communication Satellites

A satellite can route messages individually among different locations.

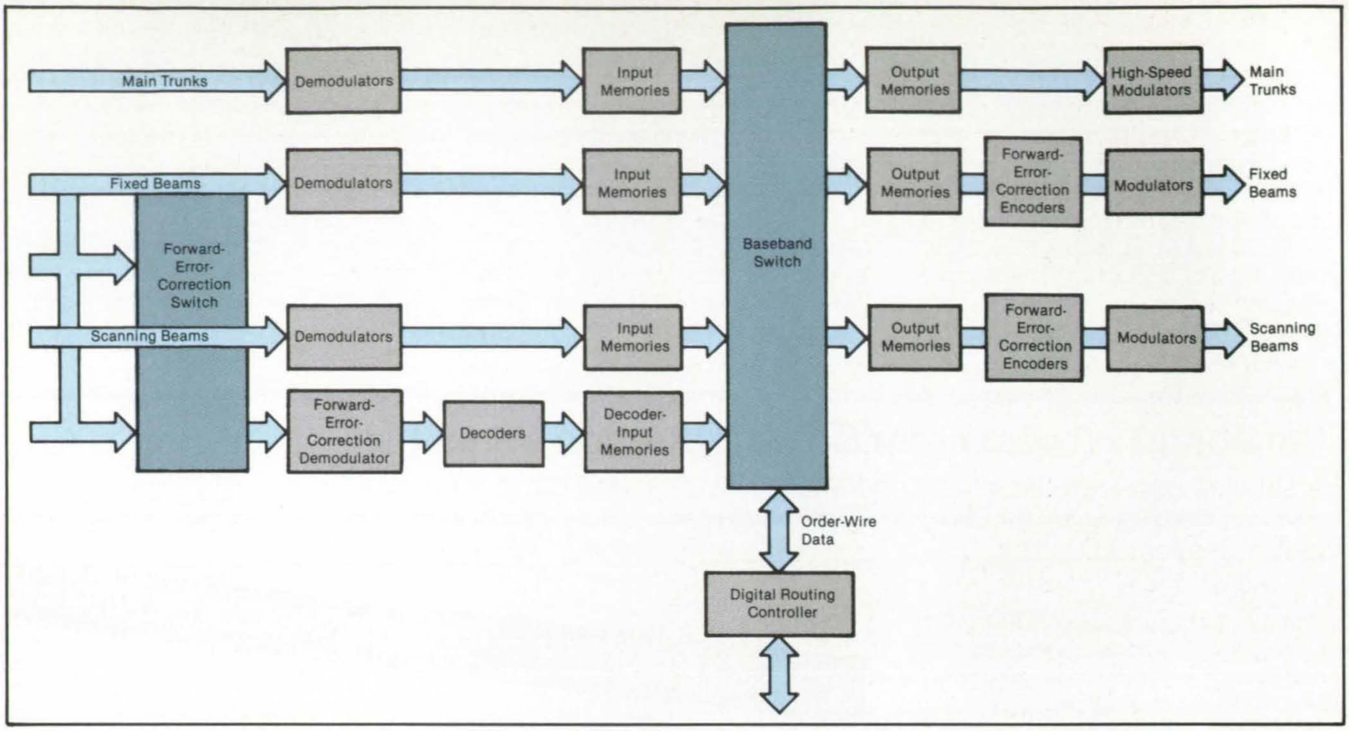
Lewis Research Center,
Cleveland, Ohio

A baseband processing (BBP) system for advanced satellite communications has been successfully demonstrated. This system provides increased data capacity through frequency-reusing multibeam antenna systems, using time-division multiple access (TDMA) and onboard satellite switching. Large numbers of thin-route trunking stations and user-based Earth terminals are handled efficiently by satellite baseband switching. The baseband processor that performs this function is one of the primary subsystems for the next generation of satellite communication systems. With the BBP system, the satellite can route data messages individually among locations anywhere in the continental United States.

The function of the BBP system as a part of the satellite transponder system is to process, control, and route message traffic among individual users equipped with onsite ground terminals and among thin-route trunking terminals served by both the scanning-beam and fixed-beam antennas. The BBP system is required to include the nonblocking switching of data on individual channels, the interconnection of any terminal to any other terminal on a point-to-point basis, and interconnection of any terminal to any other set of terminals in a limited broadcast mode.

A description of the operation of the baseband processor begins with the incoming uplink traffic. Messages are transmitted to the satellite in a TDMA format. The messages arriving at the input of the BBP system are demodulated down to baseband. Messages that may have been encoded for rain-fade compensation are decoded. The messages are then stored in one of two input memories. While one memory is being loaded, the other is being unloaded.

The 64-bit-word messages being unloaded from the input memories are routed to the output memories through the routing switch on a word-by-word basis. The output memories work like the



The **Baseband Processor** processes, controls, and routes message traffic among users. Time-division multiple access and baseband switching are used.

input memories: one is unloading while the other is being loaded. The message stream of 64-bit words being unloaded from the memories is encoded where needed for rain-fade compensation and modulated to the downlink frequency, whereupon it exits the BBP system. The BBP-system digital routing controller, as programed from the master-control ground station, routes the messages properly through the BBP system, and controls the uplink and downlink scanning-beam sequencing.

The user, although his/her messages are being broken down, compressed into bursts, and time-division multiplexed with many other messages, sees a continuous, unbroken connection with whomever he/she is communicating. The figure shows the functional diagram for the BBP system.

This demonstrated system has opened the door to the design of advanced satellites, which provide multiple frequency reuse, allows many small users full access to the satellites, and greatly increases the total data capacity of the satellite. The successful demonstration of the functionality of the BBP system has significantly reduced the risk involved in the development of this new system for satellite communication. Flight models of the BBP system are now being built based on this demonstration model. The ACTS satellite will be the first to fly a BBP system and thereby provide a flight demonstration of the BBP system.

This work was done by Russell J. Jirberg of **Lewis Research Center** *and Patrick C. Armstrong of Motorola Government Electronics Group. Further information may be found in NASA CR-174632 [N84-38251/NSP], "30/20 GHz Communication System Baseband Processor Subsystem."*

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

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Lewis Research Center [see page 17]. Refer to LEW-14239.

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Physical Sciences

Hardware, Techniques, and Processes

Books & Reports

Increased Accuracy in Ultrasonic Material Characterization

It is necessary to determine the frequency dependence of the reflection coefficient.

Lewis Research Center, Cleveland, Ohio

Ultrasonic evaluation techniques are being used in a variety of applications. Recent improvements in ultrasonic measuring technology have been obtained at the Lewis Research Center.

Ultrasonic technology is used in a variety of ways, including the following:

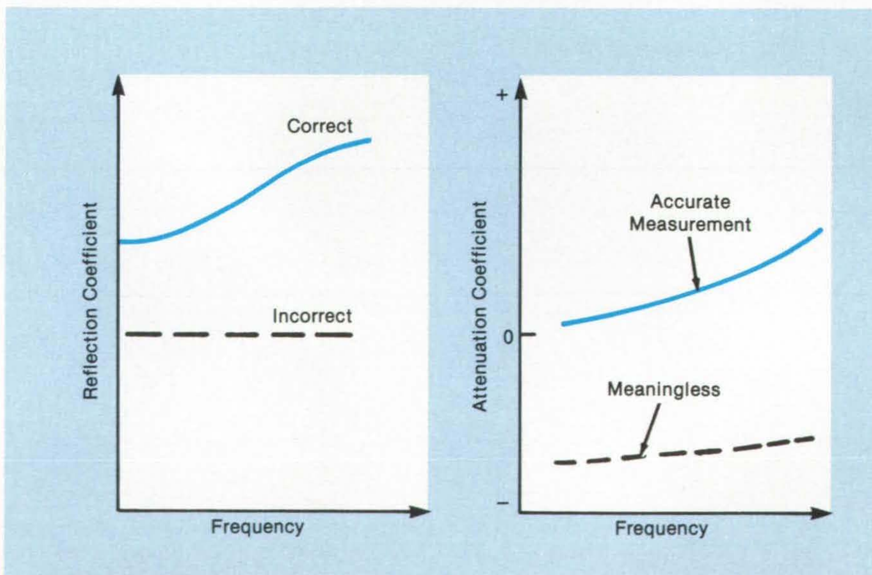
- Determination of the ultrasonic attenuation and velocity in heat-engine ceramics and advanced metals;
- Verification of the accuracy of ultrasonic measurements; and
- Real-time in situ ultrasonic monitoring of microstructural changes.

It is known that surface roughness affects ultrasonic data. It can be shown that even relatively smooth surfaces must be accounted for in ultrasonic investigations. Ultrasonic measurements using contact pulse-echo techniques are sensitive to surface microroughness and corresponding couplant-thickness variations. This can produce considerable inaccuracies in the measurement of the attenuation coefficient as a function of frequency.

Even for frequency ranges for which wavelengths are large compared with microroughness, detrimental effects on attenuation are found. The reflection coefficient has been examined as a function of the surface roughness and corresponding couplant-thickness variations. It has been shown that reliable attenuation measurements are obtained only when the frequency dependence of the reflection coefficient is incorporated into the signal analysis.

In a contact pulse-echo ultrasonic measurement, an ultrasonic pulse travels through a buffer rod and is transmitted into the sample being investigated, after traversing the interface between the buffer rod and the sample. Signal transmission across the interface is facilitated by tight intimate contact and use of a liquid couplant.

Accurate measurement of the attenuation coefficient is strongly dependent on the correct determination of the reflection coefficient and the effect of surface roughness on its frequency dependence. It is usually assumed that the reflection coefficient is constant and independent of frequency. This can lead to measurement errors and misinterpretation of data. The source of the errors becomes evident by close examination of the interface between the buffer rod and sample. Even though this couplant layer is rel-



These **Reflection and Attenuation Coefficients** characterize a heat-engine ceramic. The dashed curves represent erroneous values obtained from measureinents without correcting for the frequency dependence of the relfection coefficient. The solid curves represent the correct values.

atively thin, it plays a crucial role in forming a frequency-dependent reflection coefficient.

The figure shows the reflection and attenuation coefficients for a heat-engine ceramic. The dashed curves are erroneous experimental results obtained when the frequency dependence of the reflection coefficient is ignored. Correct results are shown by the solid curves where the reflection coefficient is determined as a function of frequency. The accuracy of these results may be verified by prediction of the waveform of later-occurring echoes. This technology should be of interest to the producers and fabricators of metals and ceramics for aerospace and other critical applications.

This work was done by Edward R. Generazio of **Lewis Research Center.** *Further information may be found in NASA TM-83788 [N84-32849/NSP], and paper accepted for publication in Materials Evaluation: "The Role of the Reflection Coefficient in Precision Measurement of Ultrasonic Attenuation."*

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-14288

Fuel-Rich Catalytic Combustion

A two-stage combustion system reduces particulate emissions.

Lewis Research Center, Cleveland, Ohio

The soot produced in practical combustion systems has become a problem because of its effect on combustor life and because it fails to meet environmental standards. This problem is expected to become worse as the quality of fuel deteriorates. The amount of soot formed in a gas-turbine combustor varies approximately as the inverse ratio of the hydrogen to carbon in the fuel (i.e., the smaller this ratio, the more soot produced). The ratio can be altered either at the refinery or in the combustion process.

An experimental program on the catalytic oxidation of iso-octane demonstrated the feasibility of a two-stage combustion system for reducing particulate emissions. With a fuel-rich (fuel/air equivalence ratios of 4.8 to 7.8) catalytic-combustion preburner as the first stage, the combustion process was free of soot at reactor-outlet temperatures of 1,200 K or less.

Although soot was not measured directly, three data indicated its absence: first, the measured reactor-outlet temperatures followed closely those calculated by an equilibrium-combustion computer program when carbon was omitted as a product, second, the hot reaction products were completely transparent and emitted none of the radiation associated with carbon, and finally, a good carbon-atom balance across the reactor was calculated from the measured reaction products.

Reaction products collected at two positions downstream of the catalyst bed were analyzed on a gas chromatograph. The comparison of these products indicated that the pyrolysis of the larger molecules continued along the drift tube and that benzene formation was a gas-phase reaction.

The effective hydrogen/carbon ratio calculated from the reaction products increased by 20 to 68 percent over the range of equivalence ratios tested. Such an increase in a poor fuel could produce an excellent fuel. The catalytic partial oxidation process also yielded a large number of smaller molecules containing carbon. The percentage of fuel carbon in compounds having two or fewer carbon atoms ranged from 30 at 1,100 K to 80 at 1,200 K.

These experiments demonstrated that changing the hydrogen/carbon ratio of a fuel does not necessarily require the addition of hydrogen. It can be accomplished by the removal of carbon atoms from the soot-forming process.

In addition, fuel-rich catalytic oxidation is a unique technique for preheating a hydrocarbon fuel to high temperature. The process is superior to most heat-exchanger techniques and produces much higher temperatures. Although the present experiments were limited to an outlet temperature of 1,200 K, it is suggested that the soot-free nature of the process may extend to temperatures as high as 1,500 K.

This work was done by Theodore A. Brabbs and Sandra L. Olson of **Lewis Research Center.** *Further information may be found in:*

NASA TP-2498 [N85-31244/NSP], "Fuel Rich Catalytic Combustion" and NASA TM-87042 [N85-28983/NSP], "Fuel Rich Catalytic Combustion — the First Stage of a Two-Stage Combustor."

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-14367

Separating Peaks in X-Ray Spectra

A deconvolution algorithm helps to identify chemical elements.

Marshall Space Flight Center, Alabama

A deconvolution algorithm assists in the analysis of x-ray spectra from scanning electron microscopes, electron microprobe analyzers, x-ray fluorescence spectrometers, and the like. The outputs of these instruments often contain overlapping spectral lines or lines of disproportionate strength, with no clearly identifiable free spectral lines on which to base chemical analyses. Some of the existing spectral-deconvolution routines require considerable intervention and subjective judgement by the analyst. The new algorithm automatically deconvolves an x-ray spectrum, identifies the locations of the spectral peaks, and selects the chemical elements most likely to be producing the peaks.

The algorithm fits the energy spectrum in the vicinity of each spectral line to the spectral density of a damped sinusoid.

The fitting routine can be used in conjunction with a digital filtering routine and a least-squares fitting procedure to locate automatically and determine the intensities of the raw spectral lines. The algorithm operates fairly well even when plotted spectral peaks overlap to such a degree that they are visually indistinguishable. Little or no intervention by the operator is required: It is not necessary to exercise subjective judgement to set parameters that depend on the type of spectrum being analyzed.

The technique is based on the similarities between the zero- and second-order terms of the Taylor-series expansions of a Gaussian distribution and of a damped sinusoid (the first-order terms are zero): The two zero-order terms and the two second-order terms become equal when the peak amplitudes of the two distributions are set equal at the sinusoidal-oscillation frequency, and the standard deviation of the Gaussian is matched, on the frequency scale, to the damping constant of the sinusoid. Thus, the two distributions are made to approximate each other in the vicinity of the peak (see figure). However, the two distributions differ far from the peak, where the damped sinusoid is more consistent with measured data.

A principal advantage of the algorithm is that there is no requirement to adjust weighting factors or other parameters when analyzing general x-ray spectra. Thus, there is no erroneous subjective bias. All spectra, no matter how complicated, are analyzed with the same routine. The algorithm uses only the magnitude Fourier spectrum to calculate the distribution parameters, whereas some analytical procedures require the use of complex (phase and magnitude) spectral data. In this case, only the magnitude data are available from the spectral densities.

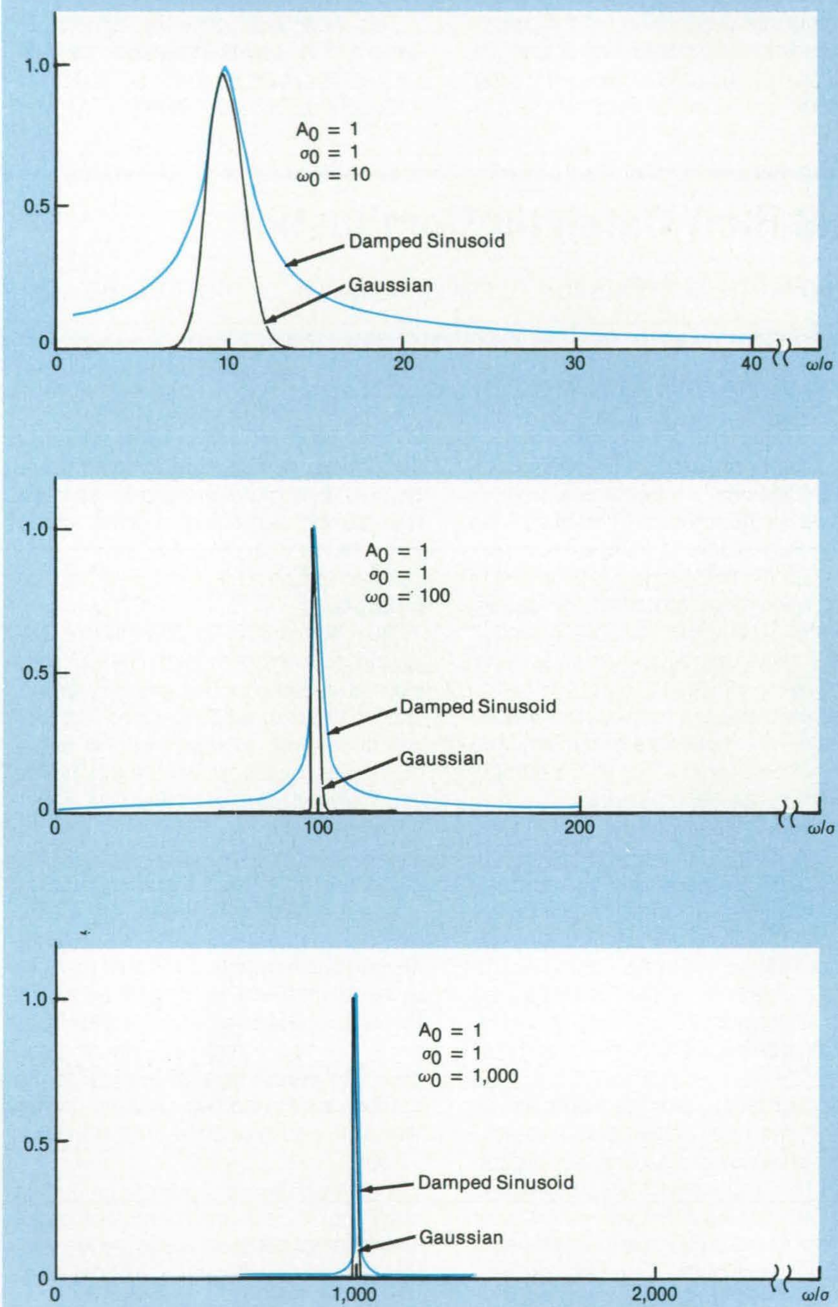
This work was done by David Nicolas, Clayborne Taylor, and Thomas Wade of **Marshall Space Flight Center**. *For further information, Circle 22 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 17]. Refer to MFS-26039.

NOTES: Gaussian spectral density: $p(E) = (2\pi\sigma) - ½\ N_0 \exp [-(E - E_0)\ ^2/2\sigma^2]$
damped sinusoid: $f(t) = A_0 \exp [\sigma_0 + j\omega_0)t]$
spectral density of damped sinusoid: $|F(\omega)| = |A_0|/[\sigma_0^2 + (\omega - \omega_0)^2] - ½$

For matching of special densities to second order about the peak, use $\sigma = \sigma_0 h$, $N_0 = (h/\sigma_0)^{½}|A_0|$, and $E_0 = h\omega_0/2\pi$, where

t	= time,	h	= Planck's constant,
σ	= standard deviation,	σ	= angular frequency,
N_0	= Gaussian line intensity,	A_0	= amplitude of sinusoid, and
E_0	= energy of spectral line,	σ	= damping constant.



The **Spectral Density of a Damped Sinusoid and a Gaussian** approximate each other near the peak when the parameters of the two distributions are chosen appropriately.

Pulsed Electron Gun

High-current pulsed-electron gun has subnanosecond rise times.

NASA's Jet Propulsion Laboratory, Pasadena, California

A magnetically-collimated electron gun generates electron pulses with peak instantaneous currents of approximately 70 μA with pulse widths of approximately 0.35 ns. Electrons are generated thermionically from a tungsten hairpin filament held at 0.7 V relative to the housing. Two coils of 1,000 turns of wire produce a magnetic field of 100 to 150 gauss, which increases the electron-beam intensity by a factor of 20 over that achieved by conventional electrostatic guns. The gun utilizes a double-pulsing scheme to eliminate space-charge buildup in the deflector region.

This work was done by Santosh K. Srivastava and Murtadha A. Khakoo of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 109 on the TSP Request Card.*

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

Edward Ansell,
Director of Patents and Licensing
Mail Stop 301-6
California Institute of Technology
1201 East California Boulevard
Pasadena, CA 91125.

Refer to NPO-16235, volume and number of this NASA Tech Briefs issue, and the page number.

Books and Reports

These reports, studies, and 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 Thermoelectric Converters

Existing technologies would be combined to exploit solar power.

A report discusses design concepts for alkali metal thermoelectric power converters that are heated by the Sun. Several alternative configurations of equipment are presented, with brief analyses of the engineering problems and important features of each.

Alkali metal thermoelectric converters have been developed for use with fossil-fuel and nuclear heat sources. Solar heat can also be used, provided that the incoming radiation is concentrated sufficiently to achieve the operating temperatures above 1,000 K required for efficient converter operation.

Most of the concepts involve batteries or modules of converter cells and their combinations. Modularity is not entirely optional: Because a single converter cell puts out less than 1 volt at typical operating temperatures, a series/parallel combination of units is required for the efficient transfer of power to inverters or other conventional power-processing equipment.

In a representative system, the sunlight is concentrated by a reflector into a receiver cavity. In one configuration, the converter modules line the cavity walls, and the working substance (usually sodium) receives the heat directly. In a similar but more indirect version, the solar flux is received by heat pipes that carry the heat to the converter modules elsewhere in the receiver head. Heat from a number of solar concentrators could also be transported to a central converter module by a fluid through a network of pipes.

To reach the high operating temperature, it is necessary to use a double-axis-tracking, point-focusing solar concentrator. The reflector surface must be accurate enough to focus the sunlight into the receiver cavity or other receptor with minimal spillage. Several tracking-concentrator concepts show promise. These include the following:

- A tracking parabolic reflector dish with the converter assembly mounted in the focal region;
- A central converter assembly on a tower that receives the sunlight reflected from a large field of tracking reflectors (heliostats); and
- A combination in which heliostats reflect sunlight into a parabolic dish that focuses the light into the receiver.

Each system concept involves significant advantages and disadvantages in output power, heat loss, difficulty or ease of operation, cost, endurance, safety, and other considerations. The development of a practical system will require the solution of such engineering problems as:

- The development of converter modules rated at 1 to 25 kW;
- Thermal design with controls and safety features appropriate to the variable solar input;
- Compatibility with existing power-processing equipment;
- Fail-safe design with redundant circuitry and concentrator controls and with protection of personnel and equipment;
- Ease of maintenance, low rate of degradation, minimization of moving parts, and infrequent, easy replacement of modules;
- Mass production of cells and modules; and
- Selection of materials for low cost, maximum lifetime, or both.

This work was done by M. Kudret Selcuk of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "A Solarized Thermoelectric Converter," Circle 142 on the TSP Request Card.*
NPO-16638

Ultraviolet Measurements of the Sun

A wealth of experimentation with a spaceborne spectroscopic and polarimetric instrument is described.

A compendium of papers and abstracts presents early experience with the ultraviolet spectrometer and polarimeter on the Solar Maximum Mission spacecraft. The instrument consists primarily of a telescope, spectrometer, polarimeter, and associated electronics. An onboard computer controls the acquisition of spectroheliograms, velocity measurements, spectral scans, and polarimetric data.

The instrument is intended to investigate extreme ultraviolet radiation from active regions, sunspots, flares, prominences, and the corona of the Sun. With it, the line-of-sight component of the magnetic field of the Sun was observed for the first time by means of the Zeeman effect in the transition region above a sunspot. The observation was made possible by the ability of the instrument to measure polarization in the ultraviolet spectrum — a novel feature for a spacecraft instrument.

The spectral lines of flares were also observed. These observations made it possible to study the evolution, in space and time, of spectral-line intensities, densities, and mass motions in the preflare and flare-transition-zone plasmas.

Other observations include the following:

- Impulsive and gradual phases of a solar-limb flare,
- Transition-region oscillations in sunspots, and
- Flows around large sunspots and large sunspot umbrae.

This work was done by W. Henze of Teledyne Brown Engineering and W.J. Wagner of the National Center for Atmospheric Research for **Marshall Space Flight Center**. *To obtain copy of the compendium, "Solar Maximum Ultraviolet Spectroscopy and Polarimetry," Circle 34 on the TSP Request Card.*
MFS-25909

Materials

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Books and Reports

Polyenamines for Films, Coatings, and Adhesives

A relatively easy process makes polymers with good mechanical properties.

Langley Research Center, Hampton, Virginia

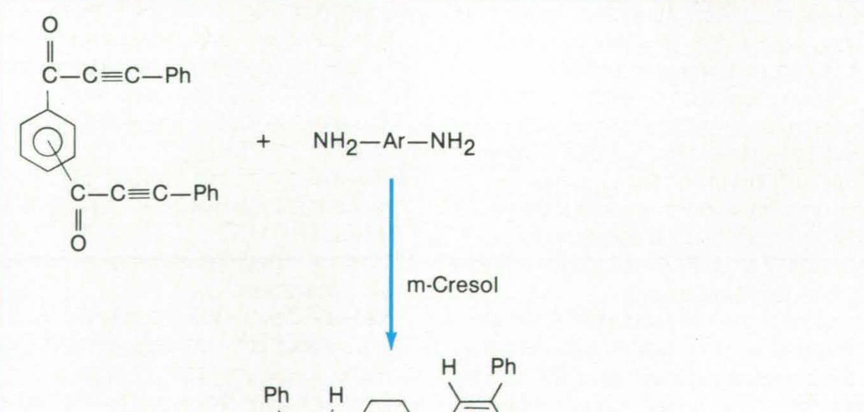
As part of an effort to develop high-performance/high-temperature polymers for functional and structural applications, the reaction of aromatic diacetylenic diketones with various monomers is under investigation. Polymers can be formed readily from the reaction of these diketones with a variety of such nucleophilic monomers as primary aromatic diamines to yield polyenamines. It was postulated that the six-membered ring formed by the hydrogen-bonded interaction in these enamines in a polymer could provide high thermal stability.

This synthesis involves the Michael-type addition polymerization (see figure) of two diacetylenic diketones: 1,1′-(1,3-phenylene)bis(3-phenyl-2-propyn-1-one) (1,3-PPPO) and 1,1′-(1,4-phenylene)bis (3-phenyl-2-propyn-1-one) (1,4-PPPO), with various aromatic diamines in *m*-cresol at 60 to 130 °C. Polyenamines with high molecular weights and inherent viscosities as high as 1.99 dl/g were prepared. Tough, clear, amber films with tensile strengths of 12,400 psi (86 MPa) and tensile moduli of 397,000 psi (2.74 GPa) were cast from solutions of the polymers in chloroform. Thermogravimetric analysis showed polymer decomposition temperatures of approximately 390 °C and 300 °C in nitrogen and air, respectively. The polymers exhibited glass-transition temperatures as high as 235 °C and weight losses of 14 percent after aging at 232 °C in circulating air for 60 hours.

This technique provides a synthetic route to high-molecular-weight polyenamines with moderate thermal stability and good mechanical properties. The polyenamines thus produced exhibit potential for use as films, coatings, adhesives, molding compounds, and composite matrices.

This work was done by Paul M. Hergenrother of **Langley Research Center** *and Robert G. Bass, Mark S. Sinsky, and John W. Connell of Virginia Commonwealth University. For further information, Circle 110 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 17]. Refer to LAR-13444.



The **Polyenamines** are synthesized by addition polymerization.

Cross-Linking Aromatic Polymers With Ionizing Radiation

The resistance to heat and solvents is increased.

Langley Research Center, Hampton, Virginia

Certain aromatic polymers (for example, aromatic polyesters) that contain radiation-sensitive methylene groups are cross-linked through those methylene groups upon exposure to ionizing radiation. The cross-linked polymers are then resistant to most organic solvents and are generally more resistant to high temperatures, with less tendency to creep under load. Additionally, there is no significant embrittlement of parts fabricated from these polymers when the degree of cross-linking, as controlled by the irradiation dose, is kept at a moderate level.

The key to this process is in the unusual response of the methylene ($-CH_2-$) functional groups to ionizing radiation. These methylene groups serve to connect the phenylene groups that constitute aromatic polymers. A methylene group that is connected to two phenylene rings is readily attacked (under high-temperature, oxidative conditions) by a reaction mechanism involving radical species of the diphenylenemethylene type. These radical species can, among other things, react with each other or with other radical species to form stable covalent bonds between adjacent polymer chains, thus crosslinking them.

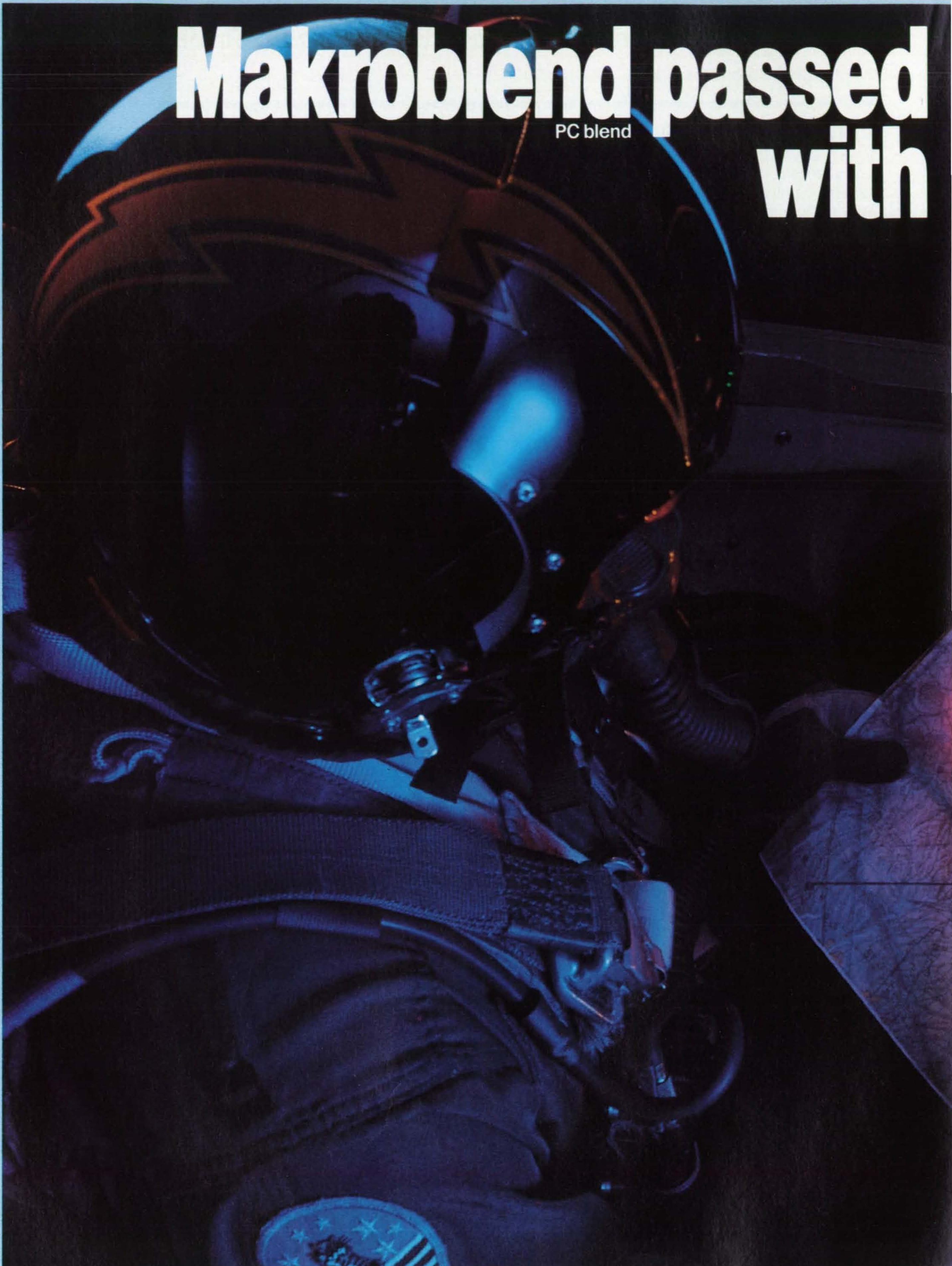
The diphenylenemethylene radical appears to be unique for this method of cross-linking aromatic polymers. Its high stability causes it to be quite specific in its reactivity. Thus, there is little chance that the radical generated from the diphenylenemethylene grouping in aromatic polymers will cause scission of the polymer chain when these polymers are exposed to ionizing radiation.

While polymers containing methylene can be cross-linked by heating in air, that type of cross-linking, involving polymer oxidation, is limited to very thin films, to fibers, or to surface cross-linking of thick laminates, because oxygen cannot penetrate these materials very easily. On the other hand, radiation-induced cross-linking can uniformly penetrate thick polymeric parts; the cross-linking depth is limited only by the selected energy of the irradiating particles or photons.

Such aromatic polymer types as aromatic polysulfones and polyethers, which are quite inert to ionizing radiation, can also benefit from this technique. By inserting methylene groups into their chemical structures, the resulting polymers can be made inherently responsive to ionizing radiation, with the ensuing cross-linking providing the same beneficial property changes demonstrated for the aromatic polyesters with radiation-induced cross-linking.

This work was done by Vernon L. Bell of **Langley Research Center** *and Stephen J. Havens of PRC Kentron, Inc. For further information, Circle 97 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Langley Research Center *[see page 17]**. Refer to LAR-13448.*


Makroblend passed
PC blend
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its flight tests flying colors.

Mobay's chemically resistant PC blend increased this penlight's durability.

A penlight designed for military pilots has to be ready for anything. From the hostile environment of the flight deck to conditions in the cockpit.

Makroblend UT-1018 resin was ready for both. This specially formulated PC/PET blend was soaked in *gasoline, oils* and *solvents*. And no stress cracks were observed. Little wonder. Makroblend resin was formulated to stand up to many chemicals, even JP-4 jet fuel, hydraulic fluid and cable oil. So it's perfect for the flight deck. *And Makroblend resin even meets military weapon's specification, WS-22474.*

Makroblend resin survives high humidity and low temperatures.

The penlight requires a material that would remain tough through a vast temperature range. At high altitudes a sudden loss of pressure due to mechanical failure or battle damage can cause temperatures in the cockpit to drop to -40°F. And these planes' ranges make arctic takeoffs and tropical landings everyday occurrences.

That's why it's comforting news to pilots that Makroblend UT-1018 PC blend passed five important tests with the elements. It survived temperatures of -65°F (16 hours). Highs of 160°F (48 hours). Ninety-five percent humidity for 15 long days. Even four strains of fungi were tested. *They* did not survive.

Of course, the acid test came with the nemesis of sea life: salt. Makroblend resin was evaluated for one week in a 5% salt solution with no effect.

Processibility that leaves other resins on the ground.

Makroblend resin's good melt strength and stability give it excellent processing versatility. It can be injection molded, extruded or blow molded.

Makroblend UT-1018 PC blend. It has the right stuff for your applications.

For more information, call Lillian Pavlovich, 412/777-4814.

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Circle Reader Action No. 503

NON-DESTRUCTIVE TESTING: NOBODY ELSE OFFERS SO MANY WAYS TO LISTEN.

The extensive use of composite parts in the aerospace industry has created a need for fast, reliable, cost-efficient methods of testing.

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We've developed four highly effective, state-of-the-art ultrasonic testing systems for our own needs. These systems are now available to you.

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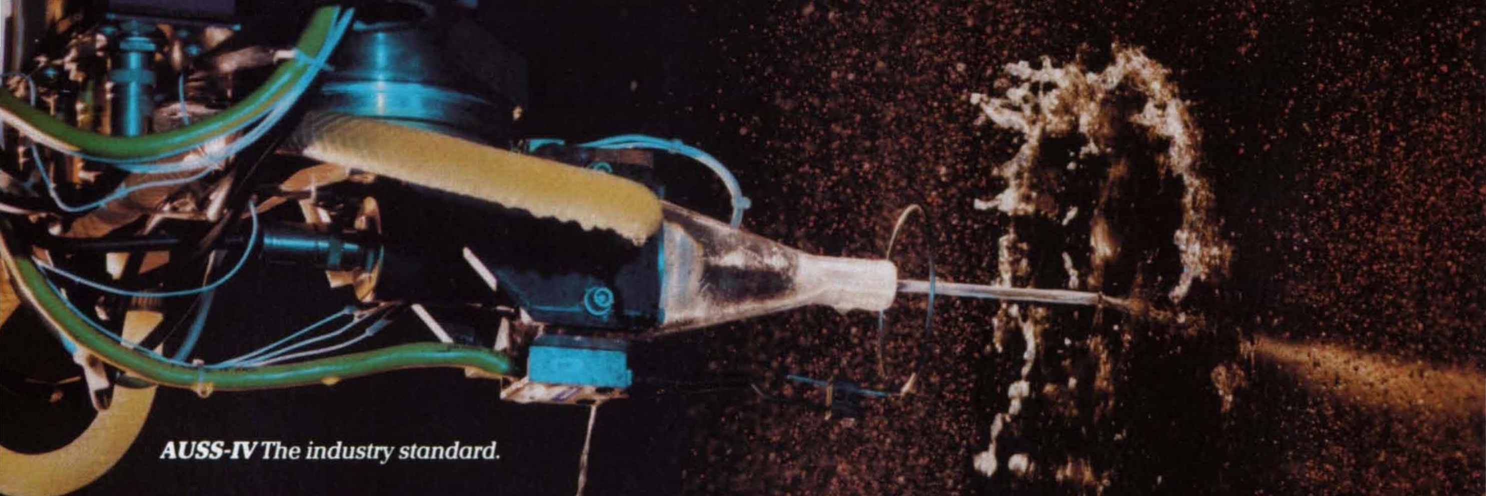


***AUSS-IV** The industry standard.*

***AUSS-V** Adds new dimensions to ultrasonic testing.*

***ADIS** Updates existing inspection units.*

***MAUS** Provides fast, in-place inspection of composite parts.*

MCDONNELL DOUGLAS

Circle Reader Action No. 501

Oxygen-Barrier Coating for Titanium

Submicron Al/SiO_2 coating significantly reduces titanium embrittlement.

Langley Research Center, Hampton, Virginia

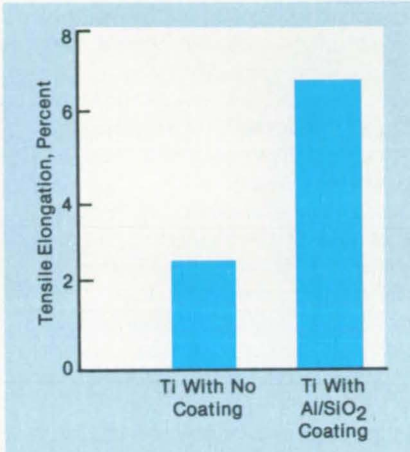
Titanium and titanium alloys are of prime interest for aerospace applications because of their favorable strength-to-density and high-temperature strength characteristics. However, titanium reacts with oxygen at elevated temperatures, leading to embrittlement and degradation of mechanical properties. Because of the loss of ductility of titanium alloys exposed to environments containing oxygen, long-term uses have been limited to temperatures below 800 °F (430 °C) and short-term uses have been generally limited to temperatures below 1,000 °F (540 °C). Because of these limitations, the oxygen-barrier coating for titanium was developed to provide an effective and low-cost means for protecting titanium alloys from oxygen in the environment when the alloys are used in high-temperature mechanical or structural applications.

The oxygen-barrier coating for titanium provides a protective surface layer, which reduces the extent of surface oxidation of the alloy and forms a barrier to the diffusion of oxygen, thereby limiting the contamination of the substrate alloy by oxygen. The coating consists of a submicron layer of aluminum deposited on the surface of the titanium by electron-beam evaporation, with a submicron layer of silicon dioxide sputtered onto the aluminum to form a top coat. On exposure to high temperatures, the titanium alloy interacts with the aluminum and silicon dioxide layers to form aluminide and silicide compounds that are nearly impervious to oxygen, even during exposure to temperatures as high as 1,300 °F (700 °C). This blocking of oxygen diffusion to the alloy substrate restricts oxygen contamination of the alloy in the region near the surface, thereby reducing the source of embrittlement of the alloy.

Test results indicate that the level of oxygen contamination in the coated material is only one quarter that in the uncoated material when exposed to air at 1,300 °F (700 °C) for 25 hours. The ductility (see figure) of coated titanium samples exposed at 1,150 °F (620 °C) for 24 hours is about 2.5 times that of uncoated samples.

This work was done by Ronald K. Clark of **Langley Research Center** *and Jalaiah Unnam of Analytical Services & Materials, Inc. For further information, Circle 99 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 17]. Refer to LAR-13474.



The **Ductility of Titanium Foil Coated With Al/SiO_2** foil is more than double that of the uncoated titanium after 25 hours exposure at 1,150 °F.

Processing Conjugated-Diene-Containing Polymers

Diels-Alder reaction is used to cross-link thermoplastics.

Langley Research Center, Hampton, Virginia

A process that uses the Diels-Alder reaction to cross-link and/or extend conjugated-diene-containing polymers by reacting them with bis-unsaturated dienophiles results in improved polymer properties. Since thermoplastic polymers, unlike the thermosets, are not normally cured or cross-linked, they are usually sensitive to certain common solvents, which can swell or even dissolve them. Also, they tend to creep or elongate, especially under load at high temperatures. The well known Diels-Alder reaction can be utilized for curing or cross-linking thermoplastic polymers.

The process involves synthesizing linear, thermoplastic polymers that have various quantities of conjugated 1,3-diene systems incorporated into their molecular structures and then reacting the diene groups in adjacent polymer chains with bis-unsaturated dienophiles; i.e., with bis-olefins that have a strong tendency to react with 1,3-dienes to give cyclohexene ring systems. The cross-linking reaction can be represented in a general manner as shown in the figure.

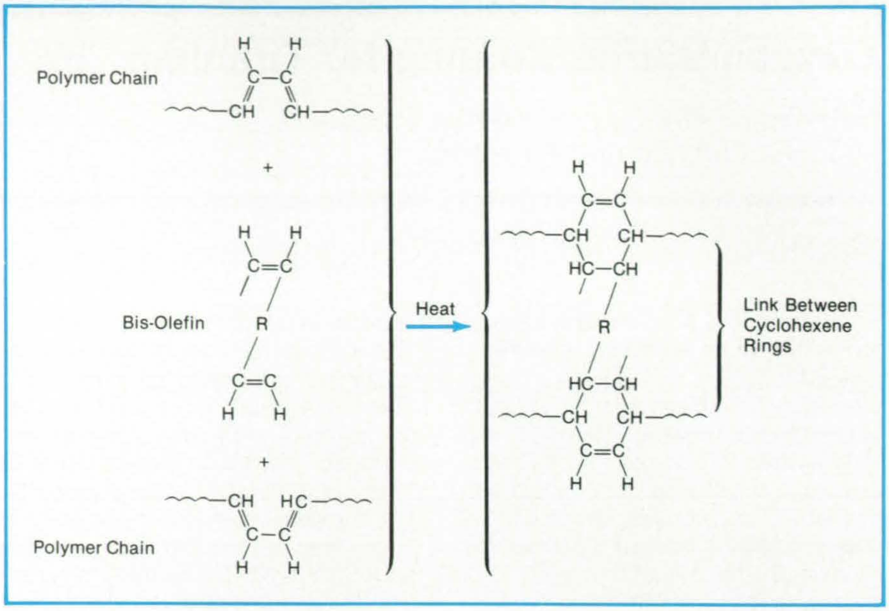
In addition, it is possible to synthesize and use suitable polymers that have the dienes attached pendant to the main polymer chains. This type of reaction is equally facile via the Diels-Alder route to produce a cross-linked polymer. In fact, in some cases the reaction may proceed more readily than when the diene is within the main polymer chain, where it may be sterically hindered.

The quantities of diene groups required for cross-linking may be varied from very low to very high concentrations, depending on the degree of cross-linking desired. Low concentrations of dienes require longer reaction times with the bis-dienophiles and result in lightly cross-linked polymers, which, though insoluble, may still be swollen by certain solvents. Polymers incorporating high concentrations of diene groups will cross-link more rapidly and yield more rigid materials because of the high density of cross-links. The highly cross-linked polymers will also have a much greater solvent resistance than those lightly cross-linked.

The process can also be used to extend,

or build up the molecular weights of, low-molecular-weight polymers by synthesizing low-molecular-weight linear polymers with terminal conjugated dienic groups. When these relatively short polymer molecules are reacted with a bis-unsaturated dienophile such as a bismaleimide, the short polymers are joined together to form much longer molecules. In contrast to the cross-linking of polymers, which leads to a less linear, more planar chemical structure with more rigidity, the chain extension of low-molecular-weight, short polymer chains generally leads to more flexible, stronger, and tougher polymers because the linearity of the extended polymer molecules has not only been preserved but enhanced.

This technique for expanding the molecular chains of thermoplastics is also advantageous for processing. The low-molecular-weight or short-chain form of thermoplastics has better melt flow than do the higher-molecular-weight types, so that molding and laminating operations can be done at the low-molecular-weight stage. After the preliminary operation has been completed, the processing temperature can be increased, causing the Diels-Alder chain extension to occur and resulting in conversion to the high-molecular-weight plastic, which has better strength and toughness for the completed end-use article. Another advantage lies in the absence of the release of volatiles during the Diels-Alder cross-linking/chain-extension curing reaction.



In the **Cross-Linking Reaction**, the diene groups in adjacent polymer chains react with a bis-olefin to form linked cyclohexene rings.

This work was done by Vernon L. Bell of **Langley Research Center** *and Stephen J. Havens of PRC Kentron Inc. For further information, Circle 96 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 17]. Refer to LAR-13452.

Colorless Polyimide Films for Thermal-Control Coatings

These films remain more transparent than commercial film after ultraviolet and electron irradiation.

Langley Research Center, Hampton, Virginia

A series of essentially colorless aromatic polyimide films have been synthesized and characterized with the objective of obtaining maximum optical transparency for applications in space: optical transparency is a requirement for high-performance polymeric films used in second-surface mirror coatings on thermal-control systems. The color intensity was lowered by reducing electronic interactions in the polymer molecular structure and by using highly purified monomers. The resulting lightly-colored-to-colorless polyimide films have been characterized by ultraviolet, visible, and infrared spectroscopy before and after exposure to 300 equivalent solar hours (ESH) of ultraviolet irradiation and varying doses of 1-MeV electron irradiation.

The experiments were conducted to simulate the use of a series of six transparent polyimide films as second-surface-mirror thermal-control coatings. The films, 0.50 mil (0.0127 mm) thick, were exposed to simulated solar ultraviolet radiation in a high vacuum of 1.3×10^{-5} Pa. A 1-kW xenon lamp served as the ultraviolet radiation source. Suprasil (or equivalent) quartz optics were used to transfer and focus the ultraviolet onto the film specimens. The intensity of xenon light for these exposures was 1.5 solar constants.

The specimens were irradiated for 100- and 200-h periods, resulting in 150 and 300 ESH of exposure. The film specimens were also irradiated with 1-MeV electrons at a pressure of 2.7×10^{-5} Pa. The specimens received doses of 1×10^8, 1×10^9, and 5×10^9 rad at a rate of 5×10^7 rad/h. Faraday cups mounted in the electron beam were used to measure the flux levels on the films. The films did not exceed a temperature of 30 °C during these exposures.

The six polyimide films proved to be 2 to 2.5 times as transparent as commercial polyimide film after both the ultraviolet and electron irradiation. Before irradiation, the films were approximately 95 percent transparent at 500 nm, the wavelength of peak intensity for solar radiation, compared to approximately 40 percent for commercial film. After 300 ESH of exposure to ultraviolet, the films retained a transparency between 62 and 82 percent, compared to 35 percent for commercial polyimide film. The films were less affected by electron irradiation, retaining 80 to 90 percent transparency at 500 nm after exposure to 5×10^9 rad of 1-MeV electrons, compared to 35 percent for commercial film.

No changes in the molecular structures of these films were discernible by Fourier-Transform infrared spectrometry after these exposures. Several of the polyimides were found to be soluble in low-boiling-temperature solvents, thus increasing their potential for spray-coating applications. The increased transparency and enhanced solubility of these optically transparent polyimides makes them viable candidates for use in thermal-control coatings.

This work was done by Anne K. St. Clair, Wayne S. Slemp, Robert M. Ely, and Robert M. Stewart of **Langley Research Center**. *For further information, Circle 92 on the TSP Request Card.*
LAR-13539

Elastomer Compatible With Oxygen

An artificial rubber resists ignition on impact and seals at low temperatures.

Marshall Space Flight Center, Alabama

A filled fluoroelastomer called "Katiflex" has been developed for use in the seals of vessels holding cold liquid and gaseous oxygen. According to impact ignition tests, the new material is more compatible with liquid oxygen than is polytetrafluoroethylene. It provides a dynamic seal at −196 °C with only 4 times the seal stress that would be required at room temperature. In contrast, conventional rubber seals can burn or even explode on impact in high-pressure oxygen, and because they turn hard or even brittle at liquid-oxygen temperatures, they do not seal reliably.

Preliminary studies in the development of the new elastomer are described in the article "Elastomers Compatible With High-Pressure Oxygen" (MFS-28124), which also appears in this issue of *NASA Tech Briefs*. The elastomer is made from Kalrez (or equivalent), a commercial tetrafluoroethylene/perfluoroalkyl ether polymer, reinforced with 20 parts per hundred of TiO_2. The filled polymer is cross-linked and postcured in an oven.

The cured material is washed in chloroform to extract fingerprint oils, low-molecular-weight polymer fragments that could be volatile, hydrocarbon oils, and other contaminants that contribute to flammability. Then the material is exposed alternately to room-temperature fluorine and to a vacuum for several days. The fluorination converts some of the hydrogen groups in Kalrez (or equivalent) to more stable fluorine groups, and the evacuation removes hydrogen fluoride and other volatiles. After fluorination, the elastomer is washed in boiling perfluorohexane. This removes additional impurities, including a waxy, low-volatility, low-molecular-weight fraction of the base polymer that appears to be generated by a slight depolymerization of the base polymer during fluorination.

According to differential-scanning-calorimetry tests, the product elastomer is compatible with liquid oxygen, even when the base polymer has been contaminated by materials commonly found in rubber-mixing-and-molding facilities. These materials include hydrocarbon oils, carbon black, and polyethylene fibers, which are very reactive with oxygen. According to Fourier-transform infrared spectroscopy, the elastomer does not react appreciably with pure oxygen at 200 °C. However, there is some oxidation and pyrolysis above 370 °C.

The elastomer passed impact flammability tests in liquid oxygen at −196 °C and pressures up to 20.7 MPa. It performed well as a valve seal at temperatures from −196 to +20 °C.

This work was done by Jon W. Martin of TRW Corp. for **Marshall Space Flight Center**. *For further information, Circle 55 on the TSP Request Card.* *MFS-28129*

Books and Reports

These reports, studies, and 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.

Elastomers Compatible With High-Pressure Oxygen

Compatibility is increased by fluorination.

A report describes experiments aimed at improving the compatibility of some fluorinated elastomers with high-pressure oxygen. Such elastomers are needed for seals, gaskets, and positive-expulsion devices used with high-pressure oxygen.

Oxygen-compatibility tests were carried out on five elastomers chosen on the basis of a literature survey. Attention was directed in particular to the effect of cleaning the samples by fluorination. Fluorine is highly reactive and is believed to burn slowly combustible materials absorbed in the elastomers. With the exception of one elastomer that was soluble in chloroform, fluorination was preceded by refluxing in chloroform to extract fugitive organic species. For all elastomers, the final step before the compatibility testing was the standard aerospace cleaning in liquid oxygen.

Compatibility with oxygen was determined by standard impact tests and differential-scanning-calorimetry (DSC) tests; both types of tests were carried out under an oxygen pressure of 1,000 psi (6.9 MPa). For the impact tests, which involved impacts of 95 Nm, failure was deemed to consist of two reactions in up to 20 samples. In the DSC tests, note was taken of the temperature of the initial exotherm, called the "lift-off temperature," and of the temperature at which the first major exotherm was initiated. In general, for the elastomers tested, results showed that the higher the major exotherm temperature, the less the tendency of the elastomers to fail the impact test. The results suggest that such elastomers may be compatible with high-pressure oxygen if, and only if, their major exotherm is above approximately 400 °C.

The baseline elastomer in these tests was Kalrez 1067 (or equivalent), a copolymer of tetrafluoroethylene and perfluoroalkyl ether. Even without fluorination, this copolymer passes the impact test and exhibits a major exotherm at 400 °C. Despite its compatibility with oxygen, its high cost and unsatisfactory engineering properties have stimulated the search for alternative elastomers.

The most promising of the other elastomers tested were a formulation consisting of 100 parts (by weight) Kalrez 1067 (or equivalent) and 20 parts TiO_2 and a formulation consisting mainly of Kel-F 3700 (or equivalent). Both fluorinated and unfluorinated samples of the first formulation passed the impact test. With fluorination, the second formulation passed the impact test.

This work was done by Jon W. Martin of TRW Corp. for **Marshall Space Flight Center**. *For further information, Circle 56 on the TSP Request Card.*
MFS-28124

Aircraft Seat Cushion Fire-Blocking Layers

Seam construction and type of fire-blocking fabric affect fire resistance.

A 229-page report describes the work done to determine the burning characteristics of present and proposed seat-cushion materials and types of construction. Those test specimens incorporating fire barriers and those fabricated from advanced materials, using improved construction methods, exhibited significantly greater fire resistance than did existing passenger aircraft seat cushions.

Thirteen different types of seat cushions were subjected to 23 full-scale burn tests in an aircraft cabin-fire simulator. The tested cushions can be classified in four groups: standard cushion construction, standard cushion construction with a protective covering enveloping the urethane-foam core, standard cushion construction with a protective covering enveloping a non-fire-retarded urethane-foam core, and standard cushion construction with the urethane-foam core replaced by an advanced fire-resistant foam.

The fire source comprised a quartz-lamp radiant-energy panel and a propane pilot flame. Cushion temperatures, radiant energy flux, cushion weight loss, and cabin temperatures were recorded during each test. In addition, each test was recorded on video tape. Finally, still photographs were taken of the cushion residue from each test.

The report includes the still photographs and presents the quantitative data from each test in graphs and tables. A narrative description of the test fires and their results identifies cushion characteristics that affected the progress of the fires.

The seam location and the permeability of the fire-blocking layer were found to determine whether or not liquid and gaseous decomposition products from urethane foam in the seat cushion are well contained. If the urethane liquid drips to the floor, it forms a puddle that gives off gases, which are ignited by burning debris. The resulting pool fire engulfs the seat in minutes. When the fire-blocking covering is able to contain the urethane decomposition products, a severe fire can be delayed.

This work was done by Kenneth J. Schutter, Fred E. Duskin, and Edward L. Trabold of McDonnell Douglas Corp. for **Ames Research Center.** *Further information may be found in NASA CR-166418 [N83-11097/NSP], "Study for the Optimization of Aircraft Seat Cushion Fire-Blocking Layers — Full Scale — Test Description and Results."*

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

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center *[see page 17]**. Refer to ARC-11494.*

Ceramic Parts for Turbines

Ceramics offer lightweight resistance to high temperatures and immunity to attack by combustion products.

The abilities of ceramics to serve as turbine blades, stator vanes, and other elements in the hot-gas flow of rocket engines are discussed in a report. Conventional materials for high-temperature components in these engines are approaching the limits of their performance, and ceramics are prime candidates as replacement materials because of their resistance to heat, low density, and tolerance of hostile environments. The ceramics considered in the report are silicon nitride, silicon carbide, and a new generation of such ceramic composites as transformation-toughened zirconia and alumina and particulate- or whisker-reinforced matrices.

The report concludes that the advantages of ceramics as structural members in rocket engines are the same as in automotive engines, namely:

- Greater fuel economy,
- Reduced cooling requirements,
- Compatibility with fuels and oxidizers,
- Lower costs,
- Less weight, and
- Less need for scarce materials.

The report discusses the turbine-operating environment, key design issues, and the processing and properties of ceramics. It identifies candidate ceramic materials for various engine components, including the first-stage nozzle vane, rotor blades, heat shield, bearing cap, turbine-blade platform seals, exhaust-straightening vanes, exhaust duct, inlet and exhaust strut cans, and inlet and exhaust struts. For each part, the report examines fabrication techniques, mechanical and thermal loads, attachment methods, and necessary research and development.

Sintered silicon nitride is selected as the prime candidate because of its superior resistance to thermal shock, which is more severe in rocket engines than in turbines for terrestrial use. The report predicts that properly designed ceramic components will be viable in advanced high-temperature rocket engines and recommends future work.

This work was done by R. D. Jones, Harry W. Carpenter, Jim Tellier, Clark Rollins, and Jerry Stormo of Rockwell International Corp. for **Marshall Space Flight Center**. *To obtain a copy of the report, "Ceramic Turbine Elements," Circle 8 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 17]. Refer to MFS-27081.

Effects of Monatomic Oxygen on Coatings

Tests were conducted on paints, metals, and reflective materials in the outer atmosphere.

A report describes tests in which paints, metals, and optical materials were carried in orbit around the Earth to determine how monatomic oxygen in the rare orbital atmosphere would affect them. Specimen disks were carried aloft on the Space Shuttle and exposed for 41.17 h at an altitude of 120 nmi (222 km).

The rate of loss of mass of one polyurethane paint was greater than that of any of the other materials. This glossy black paint is intended to minimize scattered light entering a space telescope. Its post-exposure texture — and, therefore, its optical properties — varied with the direction of the incident atomic oxygen. Other paints, which contained less filler, had lower mass-loss rates. Coating the paint with silicone reduced the severity of attack by atomic oxygen, although a room-temperature-vulcanizing silicone, unlike a glass-resin silicone, became slightly diffuse.

Nine specimens of mirror materials were tested, including thin films of magnesium fluoride over aluminum, silicon oxide films over aluminum and silver, and proprietary dielectric films over aluminum and silver. No changes in reflectivity due to atomic oxygen were noted for these materials.

Many silver specimens were exposed, including solar-cell interconnections and vapor-deposited films as well as disks. All exposed, unprotected silver specimens were affected by atomic oxygen, including those that had no direct exposure but were subject only to reflected oxygen atoms. The exposed surfaces changed to dark, loose scale or to thin interference films, depending on the temperatures of the specimens. A coating of lead/tin solder protected the silver at low temperatures, but a chromate coating failed, probably because it was thin and porous.

Other metals tested were copper, lead, magnesium, molybdenum, nickel, platinum, tungsten, an iron/chromium/aluminum alloy, and a nickel/chromium alloy. Copper had a measurable mass increase, but the others showed little reactivity.

This work was done by Ann Whitaker, Sally A. Little, Roger Harwell, Jack Smith, and Ed White of **Marshall Space Flight Center**. *To obtain a copy of the report, "Orbital Atomic Oxygen Effects on Thermal Control and Optical Materials — STS-8 Results," Circle 104 on the TSP Request Card.*
MFS-28084

Growth of Metastable Peritectic Alloys

The effects of directional solidification on microstructural, compositional, and magnetic properties are studied.

Two reports describe experiments to determine the effects of directional solidification on peritectic alloys. Of particular interest in these studies were the effects of gravitationally driven convection. In the first part of the investigation, the Pb/Bi peritectic was studied as a model solidification system. The results from the first part were used to guide the subsequent studies of peritectic solidification in other alloys.

Analyses of Pb/Bi peritectic samples directionally solidified in quartz tubes indicated that appreciable macrosegregation occurs due to thermosolutal convection and/or Soret (thermal) diffusion. The macrosegregation results in sequential changes of phase and microstructure as solidification progresses along the sample, in accordance with equilibrium phase relationships and interface-stability criteria.

Compositional banding, reported by previous investigators, was eliminated when the selected furnace conditions resulted in a planar solidification interface. These conditions, presumably, led to a concomitant reduction in the convection driven by radial temperature gradients.

The directional solidification that occurs in the vicinity of the Pb/Bi peritectic isotherm was found to be isocompositional and to consist solely of the equilibrium terminal solid solution and peritectic phases on an extremely fine scale. Evidence was found to support the peritectic supercooling mechanism. However, no evidence was found to support the proposed peritectic superheating mechanism.

In the last part of the investigation, emphasis was placed on ferromagnetic compounds of the commercially important Co/Sm and Al/Mn systems. In particular, bulk compositions corresponding to peritectic $SmCo_5/Sm_2Co_{17}$, Sm_2Co_{17}, eutectic Sm_2Co_{17}/Co, and peritectic $Mn_{55}Al_{45}$ were studied. Because these alloys have melting temperatures above 1,000 °C and are quite reactive to oxidizing environments, special containment techniques were developed. These included the use of pyrolytic boron nitride ampoules that were pumped to a vacuum of 10^{-6} torr (about 10^{-4} Pa) prior to directional solidification. The ampoule arrangement was housed within a specially constructed, high-temperature Bridgman/Stockbarger directional-solidification furnace consisting of three actively controlled heating/cooling zones.

Initial investigations were performed at modest thermal gradients in the liquid, $G_L \leqslant 60$ °C/cm, and over a range of solidification velocities, $0.8 \leqslant V \leqslant 45.4$ cm/h. Aligned dendritic microstructures were encountered in the Co/Sm system; this is consistent with the low values of G_L/V (which is a measure of interfacial morphological stability) observed. The primary dendrite spacing for eutectic Sm_2Co_{17}/Co scaled with $V^{-1/2}$ and varied from ~50 μm for $V \geqslant 20$ cm/h to hundreds of microns for $V < 10$ cm/h.

Because the crystal-growth mechanism was dendritic rather than cooperative, the associated permanent-magnet properties were rather poor; for example, remanence less than 3 kG and coercive force less that 1 kOe for the smallest dendrite sizes encountered. The easy axis of magnetization was primarily along the direction of solidification for the eutectic Sm_2Co_{17}/Co and peritectic $SmCo_5/Sm_2Co_{17}$ compositions.

The magnetic and microstructural characterization of $Mn_{55}Al_{45}$ samples suggested isotropic, polycrystalline growth for all solidification velocities studied, with appreciable macrosegregation observed in the range of growth speeds below 10 cm/h. Appreciable ferrimagnetic τ-MnAl phase was found to form at the higher solidification velocities (higher cooling rates), in agreement with previous studies. Annealing after solidification was found to enhance magnetic performance.

This work was done by David J. Larson, Jr., and Ronald G. Pirich of Grumman Aerospace Corp. for **Marshall Space Flight Center**. *To obtain copies of the reports, "The Growth of Metastable Peritectic Compounds," (second- and third-year final reports), Circle 118 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 17]. Refer to MFS-27091.

Computer Programs

COSMIC: Transferring NASA Software

COSMIC, NASA's Computer Software Management and Information Center, is the one central office established to distribute software that is developed with NASA funding. COSMIC's role as part of NASA's Technology Utilization Network is to ensure that NASA's advanced software technology is made available to industry, other government agencies, and academic institutions.

Because NASA's software development efforts are dynamic and ongoing, new programs and updates to programs are added to COSMIC's inventory on a regular basis. *Tech Briefs* will continue to report information on new programs. In addition, the 1987 edition of the *COSMIC Software Catalog* is available with descriptions and ordering information for available software. Several new programs for control systems/robotics, expert systems, thermal analysis, turbomachinery design, structural analysis, and computer graphics are offered.

For additional information on any programs described in this issue of *Tech Briefs*, circle the appropriate number on the TSP card at the back of the publication. If you don't find a program in this issue that meets your needs, you can call COSMIC directly at (404) 542-3265 and request a review of programs in your area of interest. There is no charge for this information review.

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John A. Gibson, Director

Computer Programs

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

Electronic Components & Circuits

Small-Signal ac Analysis

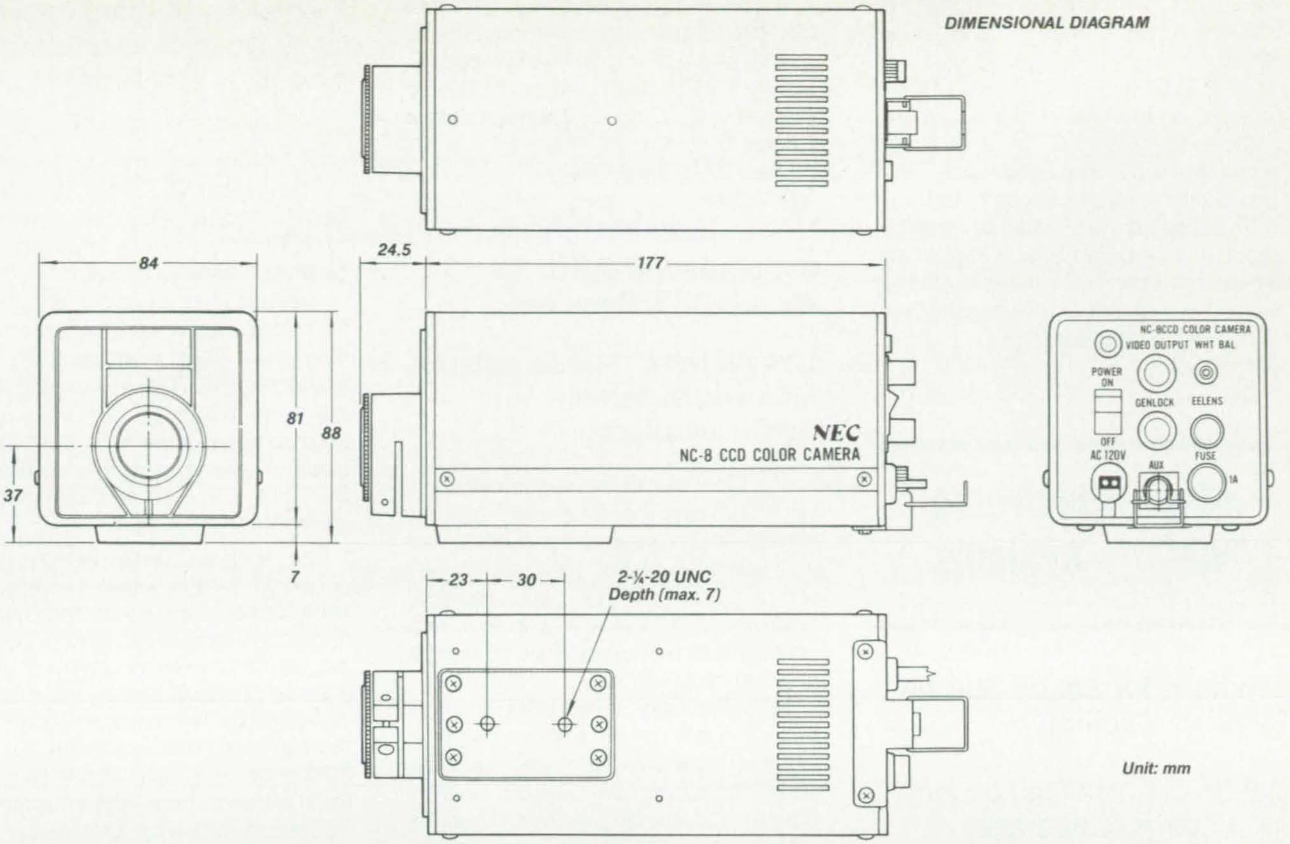
A program simulates power circuits and systems.

The Small Signal A.C. Analysis program (SSAC) is a valuable tool for the design and analysis of electrical-power-system circuits. By combining "black box" power-system components that operate in a specified manner, the user can characterize a system to be modeled. The menu-driven SSAC program has proved to be simple and cost effective in the development and modification of arbitrary power-system configurations. The SSAC package includes sample data from the Dynamic Explorer satellite family. Results from SSAC have compared favorably to calculations from such general circuit-analysis programs as SPICE.

SSAC allows an engineer to choose from the following library of parts: solar arrays, harnesses, filters, loads, linear voltage regulators, partially shunted solar arrays, batteries, and converters (buck, boost, etc.). These components are modeled in SSAC by canonical circuits. They may be in series, parallel, or cascades. The small-signal requirement ensures linearity and enables SSAC to use Fourier transform methods to perform analysis in the frequency domain.

The available analysis options are as follows: composite two-port parameters, two-port transient response, bus impedance, local stability, bus transient response, and system stability. SSAC can be used to obtain stability characterizations of feedback-control loops in terms of gain and phase margins. The SSAC program can be used in a generic mode (one without laboratory data) for conceptual design, determining such component specifications as power quality and transfer functions, and to perform sensitivity studies.

In the verification mode, experimental and/or manufacturers' data are entered for detailed system design and breadboarding of components. The input to SSAC consists of system layouts, component characteristics, input/output points, and input



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Specifications

Pickup	Interline transfer type CCD x1
Number of picture element	H427xV492
S/N ratio	47dB (illuminance channel, standard recording conditions, AGC: off)
Resolution	Horizontal: 280 lines Vertical: 350 lines
Sensitivity	1,600 Lux F4.0
Minimum illumination	10 Lux F1.4 AGC: ON (20% signal output level)
White balance adjustment	Manual/Remote
Lens mount	C-Mount
Power consumption	Approx. 6.5W (less than 9VA)
Weight	Approx. 1.4kg [3.1 lbs] (excluding lens)

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Circle Reader Action No. 369

waveforms. The input may be in response to questions asked by SSAC or held in files for easy modular maintenance.

SSAC is written in FORTRAN 77 for interactive and batch-mode execution and has been implemented on a DEC VAX-series computer operating under VMS. This program was developed in 1985.

This program was written by James M. Jagielski of **Goddard Space Flight Center** *and Jess Chen of Lockheed Missile and Space Co. For further information, Circle 13 on the TSP Request Card.*
GSC-13049

Electronic Systems

Program for Space Shuttle Payload Cabling

Cables are arranged according to complicated rules.

EXCABL is an expert-system computer program developed to route electrical cables in the Space Shuttle Orbiter payload bay for each mission. Manual cabling requires knowledgeable cabling specialists who must remember dozens of rules about the cable routing and planning, so that all slack is neatly folded in the cable trays without exceeding their limited capacities. EXCABL automates the cable-routing process and provides data for the cable-installation documents. This automation has increased the speed and accuracy of the payload-integration process. In addition, the expert system codifies the knowledge the cabling experts have acquired.

The cabling program closely parallels the problems of configuring VAX computers, which is solved using the successful XCON expert-system program. XCON carries out a synthesis involving configurations under constraints similar to those of the Shuttle Payload configuration problem. The payload cabling problem shares many of the aspects of the VAX configuration problem, including the need for a highly maintainable system due to changing requirements. EXCABL represents an application of expert-systems techniques to the specific problem of cabling for shuttle payloads.

EXCABL is written in ART (an expert-system framework language from Inference Corp.) and LISP for interactive and batch execution and has been implemented on a DEC VAX-series computer operating under VMS. Use of this program requires a Tektronix 4115B graphics terminal. The EXCABL program was developed in 1985.

This program was written by Roger D. Schultz and C. Rogers Saxon of Abacus Programming Corp. for **Johnson Space Center**. *For further information, Circle 164 on the TSP Request Card.*
MSC-21121

Simulation of AFC for a DMSK Receiver

Low bit rates may be suitable for low-cost satellite communications.

The LOOP computer program was written to simulate the automatic frequency control (AFC) subsystem of a differential minimum-shift keying (DMSK) receiver with a bit rate of 2,400 baud. The AFC simulated by LOOP is a first-order loop configuration with a first-order resistance-and-capacitance filter.

NASA has been investigating the concept of mobile communications based on low-cost, low-power terminals linked via geostationary satellites. Studies have indicated that low-bit-rate transmission is suitable for this application, particularly in view of the frequency and of the need to conserve power. A bit rate of 2,400 s^{-1} is attractive because it can be applied to the linear predictive coding of speech.

The input to LOOP includes the following five characteristics: (1) the initial frequency error, (2) the double-sided loop noise bandwidth, (3) the filter time constants, (4) the amount of intersymbol interference, and (5) the bit energy-to-noise spectral density. The LOOP output includes the following three characteristics: (1) the bit number and the frequency error of that bit, (2) the computed mean of the frequency error, and (3) the standard deviation of the frequency error.

LOOP is written in MS SuperSoft FORTRAN 77 for interactive execution and has been implemented on an IBM PC operating under PC DOS with a memory requirement of approximately 40K of 8-bit bytes. This program was developed in 1986.

This program was written by Faramaz Davarian of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 128 on the TSP Request Card.*
NPO-16800

Machinery

Simulating Flexible-Spacecraft Dynamics and Control

A versatile program applies to many types of spacecraft and dynamical problems.

The Flexible Spacecraft Dynamics and Control program (FSD) was developed to aid in the simulation of a large class of flexible and rigid spacecraft. FSD is extremely versatile and can be used in attitude dynamics and control analysis as well as in-orbit support of deployment and control of spacecraft. FSD has been used to analyze the in-orbit attitude performance and antenna deployment of the RAE and IMP class satellites, and the HAWKEYE, SCATHA, EXOS-B, and Dynamics Explorer flight programs.

FSD is applicable to inertially oriented spinning, Earth-oriented, or gravity-gradient-stabilized spacecraft. The spacecraft flexibility is treated in a continuous manner (not as finite elements) by employing a series of shape functions for the flexible elements. Torsion, bending, and three flexible modes can be simulated for every flexible element. FSD can handle up to 10 linear elements in an arbitrary orientation. FSD is appropriate for studies involving the active control of pointed instruments, with options for digital PID (proportional, integral, derivative) error feedback controllers and such control actuators as thrusters and momentum wheels.

The input to FSD is in four parts: (1) orbit construction — FSD calculates a Keplerian orbit with such environmental effects as drag, magnetic torque, solar pressure, thermal effects, and thruster adjustments — or the user can supply a GTDS-format orbit tape for a particular satellite and time span; (2) control words — for such options as gravity-gradient effects, control torques, and integration ranges; (3) mathematical descriptions of spacecraft, appendages, and control systems, including element shape and size properties, attitudes, libration damping, tip-mass inertia, thermal expansion, magnetic tracking, and gimbal-simulation options; and (4) desired state variables to output; i.e., angles, rates, displacements, bending moments, fast Fourier-transform plots, gimbal rotations, filter vectors, and others. All FSD input is of free format, namelist construction. No computer skills are required to operate the program.

FSD is written in FORTRAN 77, PASCAL, and MACRO for batch execution and has been implemented on a DEC VAX-series computer operating under VMS. The PASCAL library and MACRO routines (in addition to the FORTRAN program) are supplied as both source and object code, so the PASCAL compiler is not required for implementation. This program was last updated in 1985.

This program was written by: Joseph V.

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Fedor of the AVCO Corporation for **Goddard Space Flight Center**. *For further information, Circle 12 on the TSP Request Card.* *GSC-13006*

Mathematics and Information Sciences

Documenting the Development of Software

Some routine supervisory functions are performed automatically.

The Program Management Facility (PMF) computer program is an integrated software-development and -control system. PMF is applicable to large software systems involving as many as several hundred programmers and one million lines of codes. PMF ensures the timely and orderly planning, development, implementation, and documentation of software.

PMF was designed as a support tool and has many features that provide efficient processing and utilization of space for the development programmer. It incorporates a security system to prevent improper maintenance. PMF also provides a full set of cross-referenced reports and supervisory functions for detailed management information. PMF was written by IBM to track software modifications in the Shuttle Avionics project.

PMF has the following five major components:

1. A configuration data base that describes each application system in terms of subroutine elements, language, name, and locations of source and load modules, etc.;
2. An authorization data base that enables specific programmers to modify code and update specific production elements;
3. Routines that control and test the proposed changes, permit designated persons to modify code, add written justifications, and automatically invoke compilers, linkers, etc.;
4. Build routines that apply management-approved changes to application systems controlled by a single group director; and
5. Report programs that produce source-line-accounting statistics, track multiple versions, and log all functions invoked under PMF.

PMF stores data in an efficient, compressed format for the maximum utilization of storage space. The program can automatically generate archive tapes and microfiche of language-translator listings for each element included in a system-building process. Multiple versions of an element can be compared line by line, indicating insertions, deletions, etc. These versions may be temporary in nature (for testing changes) or may be historical archived releases. By containing an integrated, documented library of program elements in its data bases, PMF encourages programmers to use tested and authorized subroutines.

PMF is written in assembler for interactive or batch execution and has been implemented on an IBM mainframe computer operating under OS/MVS. The IBM program TSO is required. The documentation includes a PMF overview, a user's guide, design and test specifications, and a programmer's self-study course. Installation of the PMF system requires extensive knowledge of the OS/MVS operating system. This program was released in 1986.

This work was done by the IBM Group for **Johnson Space Center**. *For further information, Circle 158 on the TSP Request Card.*
MSC-21167

***Note:** Circle Appropriate Reader Action Numbers

Mechanics

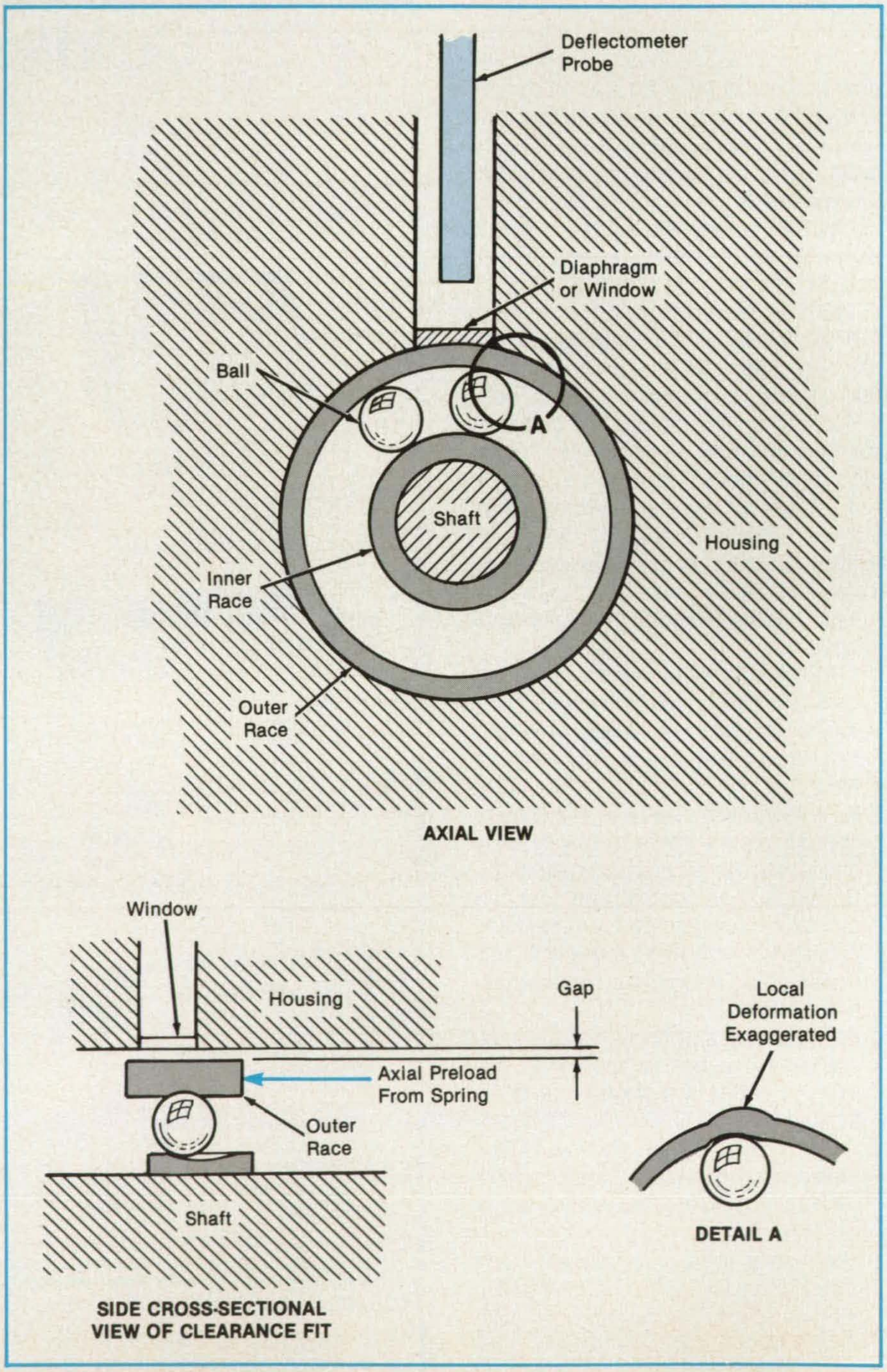
Hardware, Techniques, and Processes

Protecting a Ball-Bearing-Deflection Monitor

A thin barrier isolates a probe from liquid oxygen.

Marshall Space Flight Center, Alabama

A deflectometer probe monitors the deflection of a ball-bearing race in liquid oxygen with the aid of a small window or diaphragm. Until now, the practice has been to drill a port through the bearing housing so that an optical deflectometer probe can monitor the local, radially outward deformation of the race as each ball passes. In a turbopump or similar machine, the probe is in direct contact with the pumped fluid. However, this method cannot be used if the fluid is liquid oxygen



A **Diaphragm or Window Isolates** an optical deflectometer from liquid oxygen or other fluid in a ball bearing. At high pressures, the diaphragm—an integral part of the housing—is preferable to the window, since there would be no leakage.

or any other fluid with which the probe is incompatible.

When the outer race is press-fit into the housing, the problem can be avoided by not drilling the probe-access hole all the way into the bearing cavity; a thin wall of metal is left in the housing (see figure). The thin wall acts as a diaphragm in direct contact with the outer race. It therefore transmits the deformation of the race to the probe. At the same time, the diaphragm keeps the pumped fluid away from the probe. Of course, the diaphragm should not be so thin that it will rupture from fatigue or pressure. This can be determined from stress calculations.

When the outer race is not press fit, there will be a small gap between it and the housing. In that case, the diaphragm does not respond to race deformation. Instead, the access port is drilled through, and a window is inserted in it. The probe observes the race through the window, protected by it from the fluid.

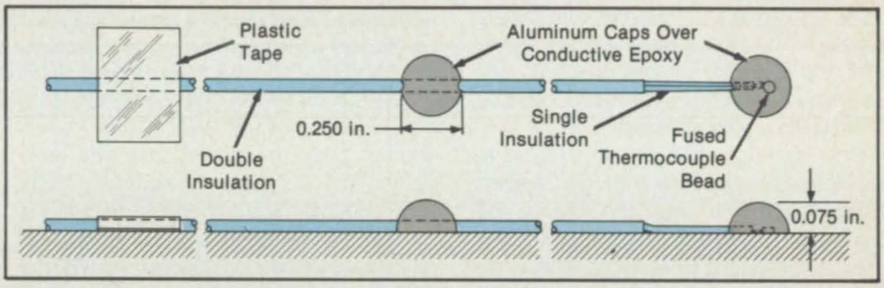
This work was done by George A. Kuhr of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*
MFS-19913

Heat-Conducting Anchors for Thermocouples

Metal particles in adhesive aid heat transfer.

NASA's Jet Propulsion Laboratory, Pasadena, California

Aluminum caps containing silver-filled epoxy are used as high-thermal-conductance anchors for thermocouples, the epoxy providing a thermal path between the mounting surfaces and the thermocouple measuring junctions. Normally, the epoxy-filled aluminum caps are used when measuring steady-state temperatures. The silver-filled epoxy can be used when a thermocouple does not have to be isolated electrically from the surface it is measuring.



Hemispherical Aluminum Caps cover globules of conductive epoxy adhesive. The left cap has two notches, and the right cap has a single notch for passage of the thermocouple wires. The plastic tape secures the wires during assembly and curing.

A cap containing the conductive epoxy is applied at each of two locations: the fused thermocouple bead and an anchor point on the thermocouple wires a few inches from the bead (see figure). The mounting surface must be clean and free of oil or else the adhesive will not stick. The mounting surface should be abraded with a fiber-glass brush to improve adhesion. The insulation (typically of polytetrafluoroethylene) on the thermocouple wires should be treated with a chemical etchant for a length of about 3½ in. (9 cm) from the bead. After the surface has been washed with a small amount of isopropyl alcohol or similar solvent, the thermocouple wires are placed in position and held down with plastic tape. The aluminum caps filled with conductive epoxy are then placed over the wires. The adhesive cures in 8 hours at 75 °F (24 °C) or 2 hours at 150 °F (66 °C).

Thermocouples of B&S gauge 26, solid Chromel (or equivalent), and constantan wire have been used primarily. However, other metals and sizes can be substituted. Aluminum caps as small as 1/16 in. (1.6 mm) in diameter by 1/32 in. (0.8 mm) in height have been used for smaller gauge wires.

This work was done by Kenton S. MacDavid of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 74 on the TSP Request Card.*
NPO-16317

Microprocessor-Based Valve Controller

A commanded mass-flow rate is maintained.

Marshall Space Flight Center, Alabama

A flow controller uses a microprocessor to adjust a valve to maintain a commanded mass-flow rate in a gas stream. It operates the valve with a stepping motor instead of the usual servomotor. The new controller is simpler, more precise, and lighter than its predecessors. It repeatedly compensates for changing supply pressure and temperature.

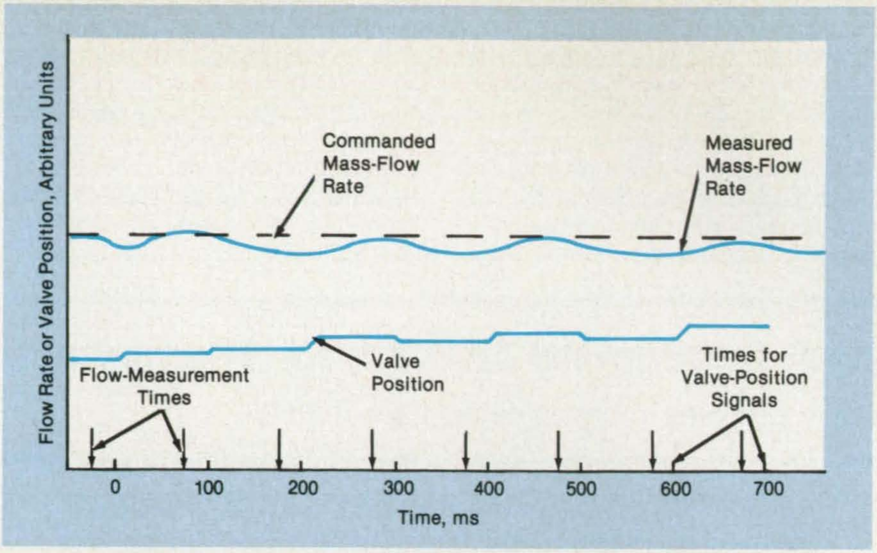
The controller measures the flow pressure and temperature between the throttle valve and a venturi tube. (For a gas, a sonic venturi is used; for a liquid, the venturi is of a cavitating type.) The processor calculates the rate of mass flow from these measurements and compares it with the commanded flow rate. It corrects the rate by sending stepping pulses to the valve motor, which changes the valve opening accordingly. The controller makes a rate correction every 100 milliseconds (see figure).

The microprocessor determines the actual mass-flow rate from a simplified equation of state. It then calculates the flow-rate change per step of the valve motor by dividing the difference between the previous flow rate and the current flow rate by the number of steps in the previous correction. Finally, it calculates the number of steps, at the newly determined flow-rate change per step, needed to produce the desired flow rate.

The desired flow-rate setting can be changed as necessary. When a large change is required, the valve sometimes cannot make the required number of steps before the next correction, which would therefore be in error. To prevent this, the processor compares the number of steps in the previous correction with the maximum number of steps possible in the 100-ms interval between corrections. If the required number of steps exceeds the maximum possible, the controller uses the previously calculated change per step to determine the required number of steps.

When the controller is started up, there is no previous flow-rate calculation available. At first, therefore, the present flow rate is checked against a predetermined minimum value. If the current flow rate is less than the minimum value, the processor calculates the change per step from an equation involving the supply pressure and temperature. It then calculates the required number of steps from this value and a correction factor found by an initial flow measurement.

Post-start-up oscillations can occur in the flow rate, depending on the system capacitance, the repetition rate of the calculations, and the valve speed. They can be eliminated or reduced to acceptable levels by simple programming techniques. Once the desired flow rate is attained, the controller is naturally stable, provided that the time between measuring pressure and temperature and sending the step pulses is short in comparison with the 100-ms update period.



The Mass-Flow Controller Compensates for a changing supply pressure and temperature such as occurs when a gas-supply tank becomes depleted. By periodically updating its calculation of the mass-flow rate, the controller determines the correct new position for the valve and keeps the mass-flow rate nearly constant.

This work was done by Arnold M. Norman, Jr., of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information, Circle 65 on the TSP Request Card.*
MFS-29172

Inflatable Perimeter Seal

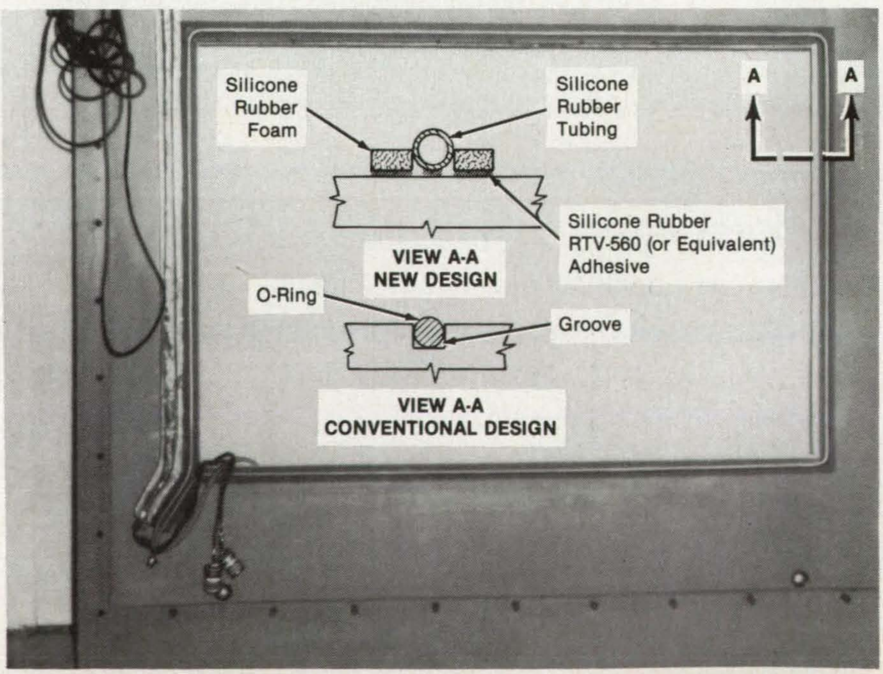
Inflatable tubing replaces gaskets or O-rings for sealing flat surfaces.

Lyndon B. Johnson Space Center, Houston, Texas

An effective, inexpensive pressure seal between two flat surfaces is formed from silicone rubber tubing. Resembling a refrigerator seal, the pressure seal is especially useful where the shape of the sealed region is irregular or subject to change. Unlike gaskets and O-rings, tubing seals require no machined grooves or custom-made parts and are not adversely affected by warpage of the sealed surfaces.

The seal path is first defined by gluing parallel strips of silicone foam to one of the two surfaces to be sealed. A continuous length of silicone rubber tubing ¼ in. (6 mm) in diameter is glued between the strips (see figure). One end of the tubing is plugged, and the other is attached to a pump or other source of pressure.

In operation, the other surface to be sealed is clamped against the tubing. The pressure in the tube is increased until the tube expands against both surfaces all around the perimeter. If not clamped, the tubing expands to 3/8 in. (9.5 mm) when inflated with air at 10 lb/in.^{2} (70 kPa) or con-



The **Inflatable Tubing Needs No Groove**, unlike an O-ring seal. The expense and time of machining a groove is therefore avoided. Since the tubing is continuous except at one point, leakage at splices and corners is nearly eliminated.

tracts to a flat strip 1/8 in. (3.2 mm) thick with an internal vacuum. This thickness variability ensures an effective seal over a wide range of gap sizes.

This work was done by Clayton C. Shepherd, Jr., of Rockwell International Corp. for **Johnson Space Center**. *No further documentation is available.*
MSC-20608

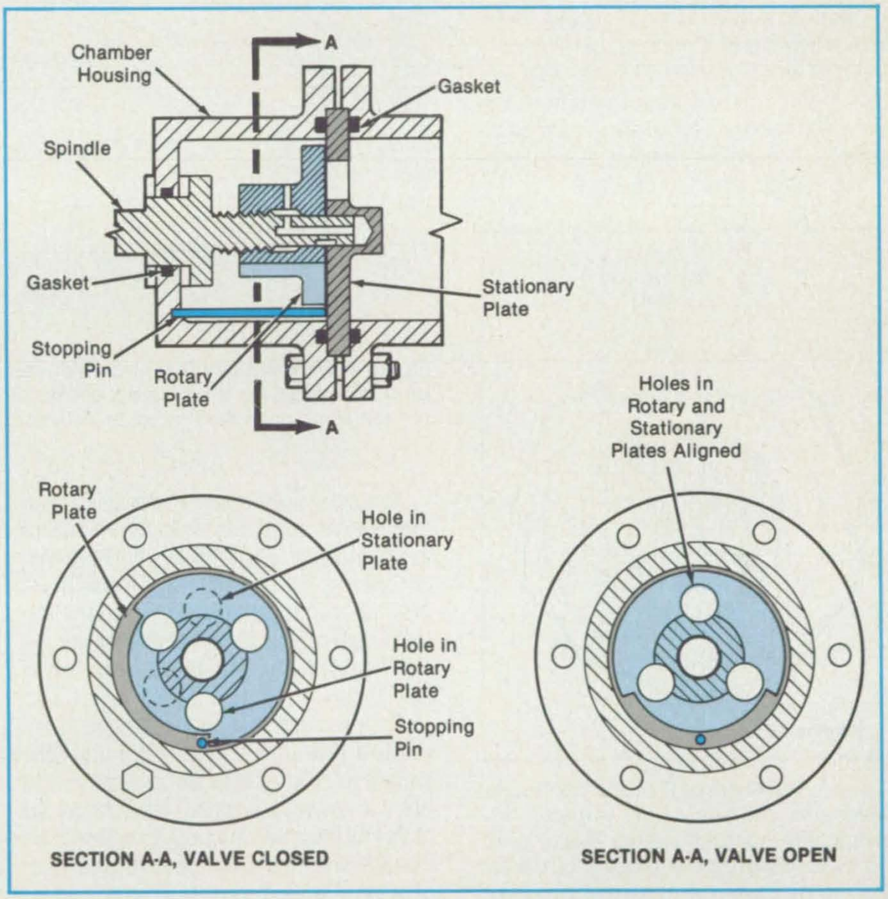
Low-Turbulence Valve

A valve promotes diffusion mixing of liquids rather than turbulence mixing.

Marshall Space Flight Center, Alabama

A valve opens and closes ports without introducing significant turbulence to the fluid passing through them. The valve was developed for an experiment involving mixing of solutions by diffusion. It allows the diffusion of contents between adjacent chambers with minimum turbulent mixing.

The valve mechanism forms a wall between the chambers, both of which are filled to capacity before the valve is operated. A central spindle through chamber 1 rotates one of the two valve plates (see figure).



Holes in Valve Plates Are Rotated clockwise into alignment to open the valve and counterclockwise out of alignment to close the valve. A stopping pin limits the overall rotation to 120° for opening and closing.

External threads on the spindle mate with internal threads on the rotary plate in a light interference fit so that the spindle and rotary plate move as a unit except when the rotary plate is restrained from turning. A pin on the stationary plate catches a notch on the rotary plate to stop the rotation when the valve is fully open or fully closed.

The tip of the spindle rests in a blind hole in the hub of the stationary plate; the rotary plate is thus aligned axially with the stationary one. The alignment minimizes friction during opening and closing and helps to ensure a good seal in the closed position.

The stationary plate sits in facing grooves in the mating chamber housings. Gaskets seal the plate near its circumference. Similarly, a gasket or O-ring seals the spindle at its support point in the housing.

A spring washer applies a biasing force against the spindle. In the closed position, this force presses the rotary plate firmly against the stationary plate, preventing leakage between the chambers. In the open position, the force preloads the spindle to prevent looseness and chattering from vibration.

The first step in opening the valve is to rotate the spindle clockwise. This pulls the rotary plate away from the stationary plate. Next, the spindle is turned counterclockwise. Separated from the stationary plate, the rotary plate is now free to turn with the spindle, and so it, too, rotates counterclockwise and pulls one of its notches away from the stopping pin. After about 60° of rotation, the three ports in the rotary plate are aligned with the three ports in the stationary plate. The solutions can now diffuse from one chamber to another.

The first step in closing the valve is to rotate the spindle counterclockwise about 60° until the notch on the rotary plate comes to rest on the stopping pin. The parts in the two plates no longer face each other. The rotary plate is now restrained against further rotation, and further counterclockwise rotation of the spindle forces the rotary plate axially against the stationary plate, thereby sealing the ports.

This work was done by Robert R. Belew of **Marshall Space Flight Center**. *For further information, Circle 28 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 17]. Refer to MFS-28058.

Keeping Floodlight Temperature Low

Safety in explosive atmospheres is enhanced.

Lyndon B. Johnson Space Center, Houston, Texas

A retainer for a floodlight is designed to undergo a relatively small temperature rise. The retainer reaches no more than 350 °F (177 °C) with a lamp operating at about 4,700 °F (2,600 °C). This satisfies the 352 °F (188 °C) requirement for operation in some explosive atmospheres. (This is a requirement for use in the Space Shuttle payload bay.) The retainer is made of a thermally conductive metal with a coating of a material having a low thermal absorptivity/emissivity ratio so that it can conduct heat away from the lamp and radiate it to the surroundings efficiently. It therefore remains at a relatively low steady-state temperature.

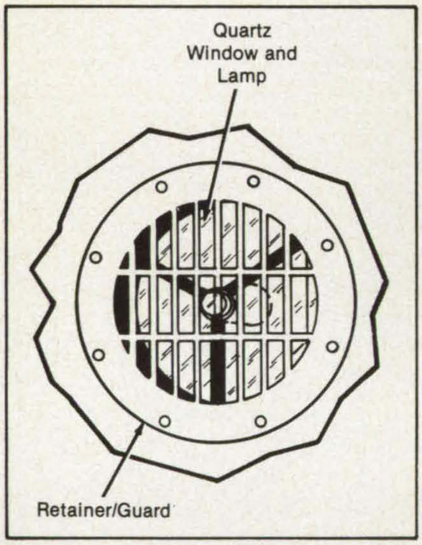


Figure 1. The **Retainer Protects the Quartz Cover** and the lamp from impacts. Although the lamp generates much heat, the conductivity and emissivity of the retainer keep its temperature relatively low.

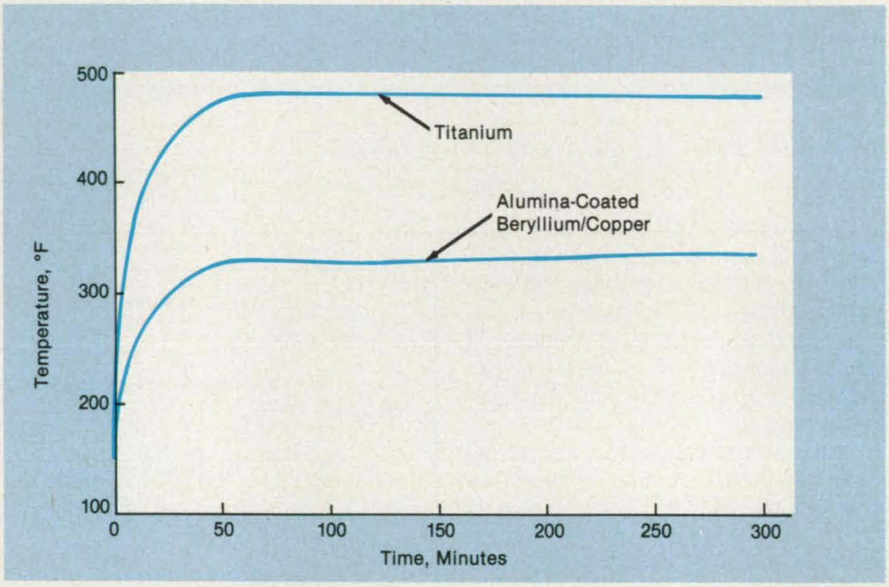


Figure 2. A **Worst-Case Test** was conducted by operating the lamp in a vacuum. The lower ratio of absorptivity to emissivity of the coated beryllium copper caused it to absorb less radiant energy and emit more, thereby reaching a lower steady-state temperature.

The light source is a metal halide arc lamp or a tungsten/halogen filament lamp, sealed in an aluminum housing with nitrogen at 7.5 lb/in.^{2} (52 kPa) pressure. A disk of transparent quartz covers the lamp aperture, and the retainer holds the disk in place and protects it from debris (see Figure 1).

The previous retainer was made of uncoated titanium. Chosen for its light weight and its resistance to impact, the titanium proved unacceptable because of its low thermal conductivity and its high absorptivity/emissivity ratio (3.3), which allowed the part temperature to rise to 500 °F (260 °C).

The new retainer is machined from a beryllium/copper alloy, chosen for its combination of strength and high thermal conductivity. The alloy is plasma-arc sprayed with alumina. The alumina coating has an absorptivity/emissivity ratio of only 0.34, which helps keep the retainer at a suitably low temperature (see Figure 2).

This work was done by John Kiss of ILC Technology, Inc., for **Johnson Space Center**. *No further documentation is available.*
MSC-20524

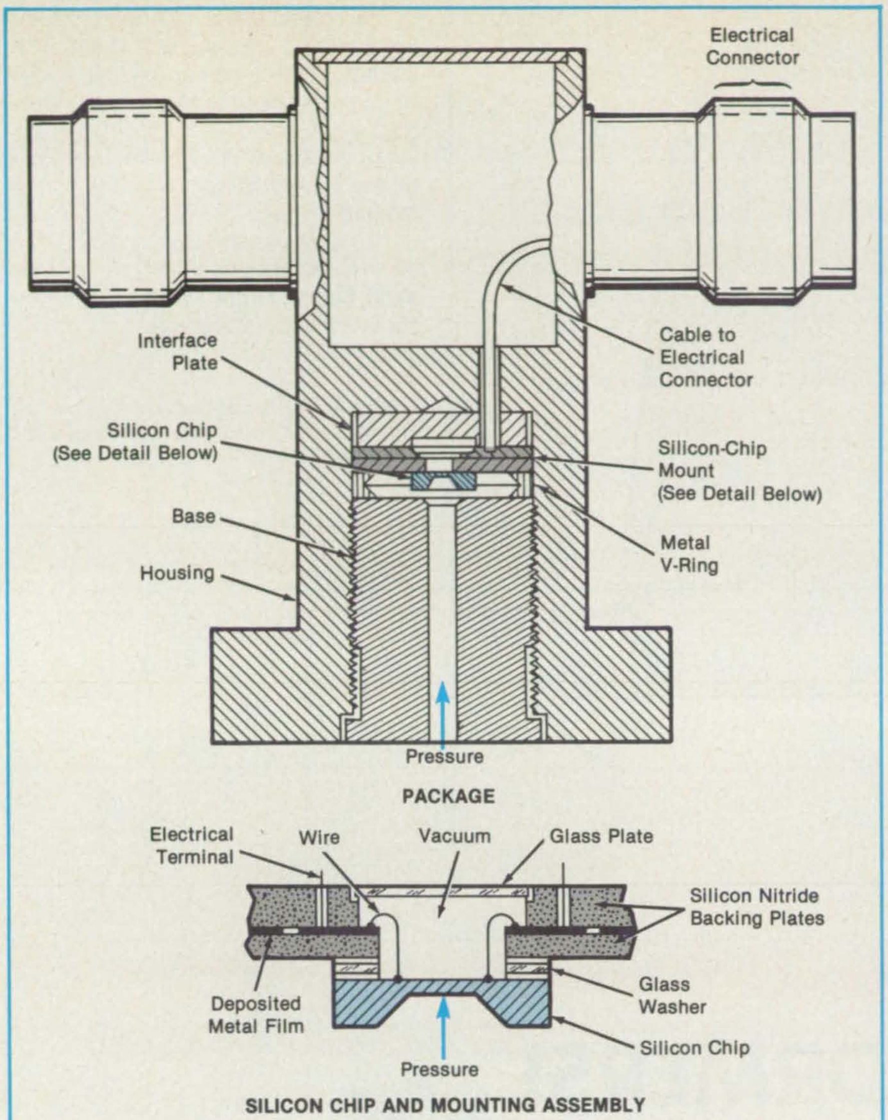
High-Pressure Transducer Package

An enclosure for a silicon device ensures accurate measurements of cryogenic liquids.

Marshall Space Flight Center, Alabama

A package for a semiconductor pressure sensor withstands pressures of 20 kpsi (138 MPa) and temperatures ranging from −423 to +259 °F (−253 to +126 °C). The package holds the silicon sensor in uniform compression around its periphery and thus helps to ensure accurate, stable, and repeatable pressure measurements.

The sensor is constituted of a thick diaphragm in a mounting assembly that includes a tempered-glass washer and silicon nitride backing plates (see figure). A glass plate seals a vacuum chamber on the top side of the silicon chip; the chamber serves as a pressure reference. The materials were chosen to match closely the thermal-expansion co-



The **Mounting Assembly is Housed in a Package** of stainless steel. The materials were selected for equality of thermal expansion and for pressure-sealing properties. Besides its high-pressure, low-temperature characteristics, the package can withstand vibration as severe as 400 times the standard gravitational acceleration at 0 to 2,000 Hz.

efficient of silicon and thereby minimize thermal stresses over the wide operating-temperature range.

The silicon nitride is hot-pressed to eliminate porosity and to prevent leakage and outgassing into the vacuum chamber. Conductors from the chip wires to the external leads are deposited onto one of the silicon nitride backing plates. Joints between the layers are hermetically sealed.

The mounting assembly is placed against an interface plate in the sensor package. The plate is made of Invar (or equivalent) nickel/iron alloy to match the thermal-expansion coefficients of the assembly materials. It is polished to a high degree of surface flatness, as are the backing plates and the silicon chip, to minimize the transmission of error-causing stress concentrations from the package to the chip. A metal V-ring between the lower backing plate and a stainless-steel package base distributes the compressive load uniformly around the structure. The high-pressure medium (which may be liquid oxygen or nitrogen or gaseous helium, nitrogen oxides, hydrogen, air, or water vapor) contacts the chip through a bore in the base.

The chip contains a thin-film resistor network on its high-pressure (lower) side. The network is trimmed by a laser to calibrate the sensor. To eliminate the effects of packaging stresses that may have been introduced despite precautions, the trimming is done after the chip has been installed in the package.

This work was done by D. Wamstad and M. Glenn of Honeywell, Inc., for **Marshall Space Flight Center**. *For further information, Circle 29 on the TSP Request Card.*

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

Honeywell, Inc.
Solid State Electronics Division
12001 State Hwy. 55
Plymouth, MN 55441-4799

Refer to MFS-28054, volume and number of this NASA Tech Briefs issue, and the page number.

Pressure-Assisted Seal for Castings

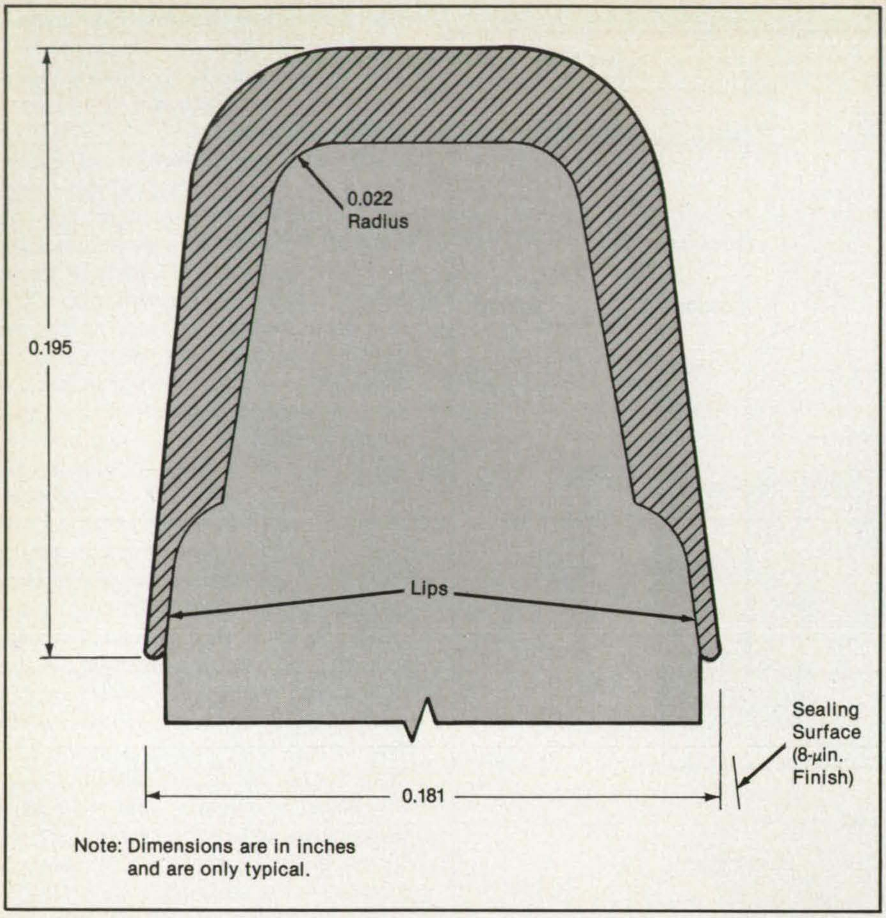
An adaptation of a standard gasket seals porous surfaces.

Marshall Space Flight Center, Alabama

A modification of a widely used pressure-assisted gasket ensures a tight seal even when one of the sealed surfaces is somewhat rough or porous. The basic gaskets, which have U-shaped cross sections, have been generally used for static sealing. They are accepted in aerospace technology because they maintain tight seals even when sealed flanges deflect significantly, as in lightweight aerospace structures.

U-seals are most effective when the sealed surfaces are smoothly finished. When they are used on such cast metals as aluminum, the roughness and porosity of the surfaces sometimes allow the gaskets to leak.

The basic gasket is modified by the ad-



dition of thin lips extending from the tips of the U (see figure). The lips provide a wider sealing area and extend the highly loaded region at the tip. The thin, flexible lip conforms more readily to substrate irregularities than does the body of the gasket. A coating of polytetrafluoroethylene on the tip and lip augments the conformance.

This work was done by Donald E. Stuck of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*
MFS-19375

A **Modified U-Cross-Section Gasket** has thin lips that increase the sealing area and conform to a slightly rough surface.

Circle Reader Action No. 453

Machinery

Hardware, Techniques, and Processes

Books & Reports

Computer Programs

Removing Welding Fumes

A duct can be placed quickly where it is needed.

Marshall Space Flight Center, Alabama

A portable exhaust duct for machining and welding shops removes oil mist, dust, smoke, and fumes. The duct was made especially for welding in a room with a low ceiling (see Figure 1). The room exhaust system could not remove pollution from the welding process; hazardous gases tended to accumulate overhead.

The portable duct is used with a shop exhaust system, the inlets of which are placed at various convenient locations in the shop floor (see Figure 2). The duct includes a 12-in. (30.5-cm) diameter flexible tube, about 14 ft (4.3 m) long, mounted on a swivel and a wheeled base. The base is rolled to the exhaust inlet near the

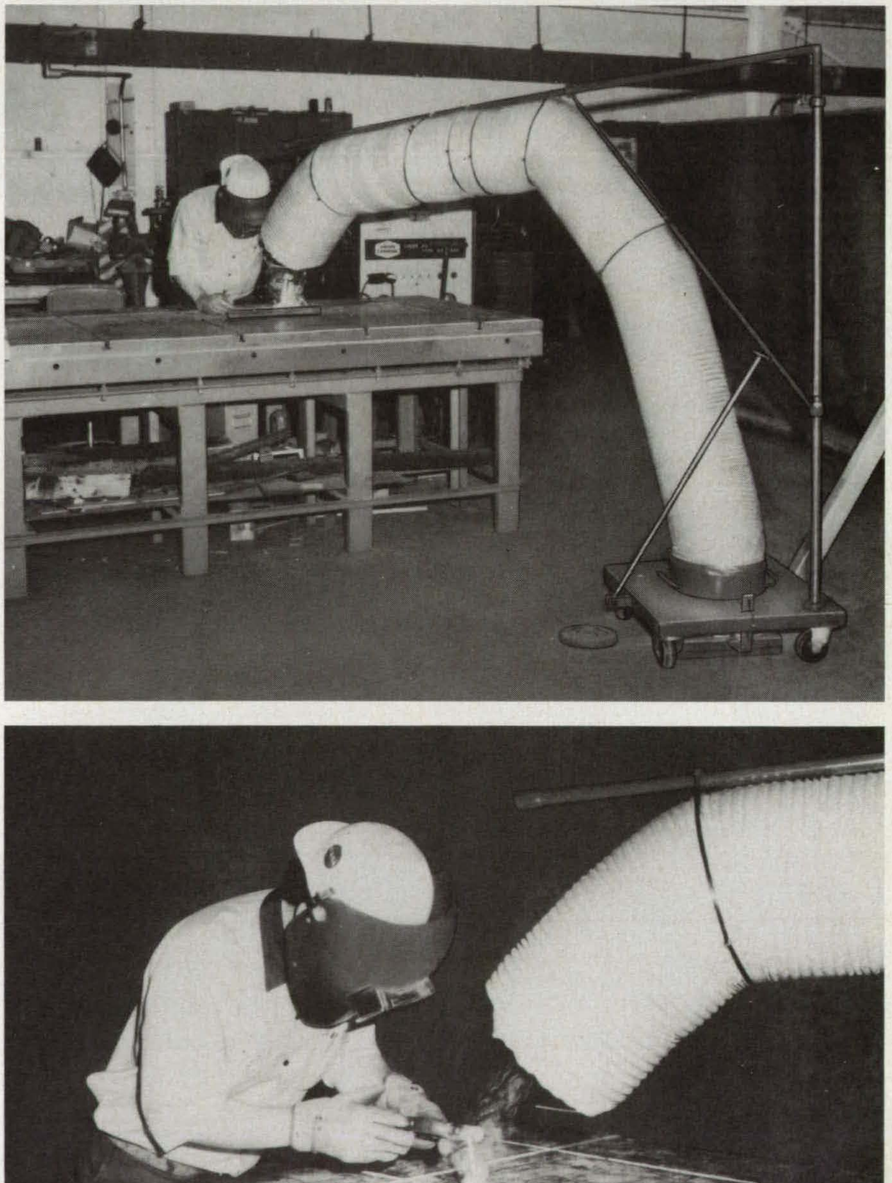


Figure 1. The **Exhaust Duct Scoops Up** welding fumes at one end and passes them to the exhaust system at the other.

welding station, and the swiveled end of the tube is positioned over the work. The suction in the exhaust system under the floor carries the fumes into the duct and the exhaust system.

The portable duct was built for about \$112 in labor and \$150 in material (1985 prices). A more-elaborate commercial system would cost almost 10 times as much.

This work was done by Lloyd J. Moore and Vandel L. Hall of **Marshall Space Flight Center.** *No further documentation is available.*
MFS-28106

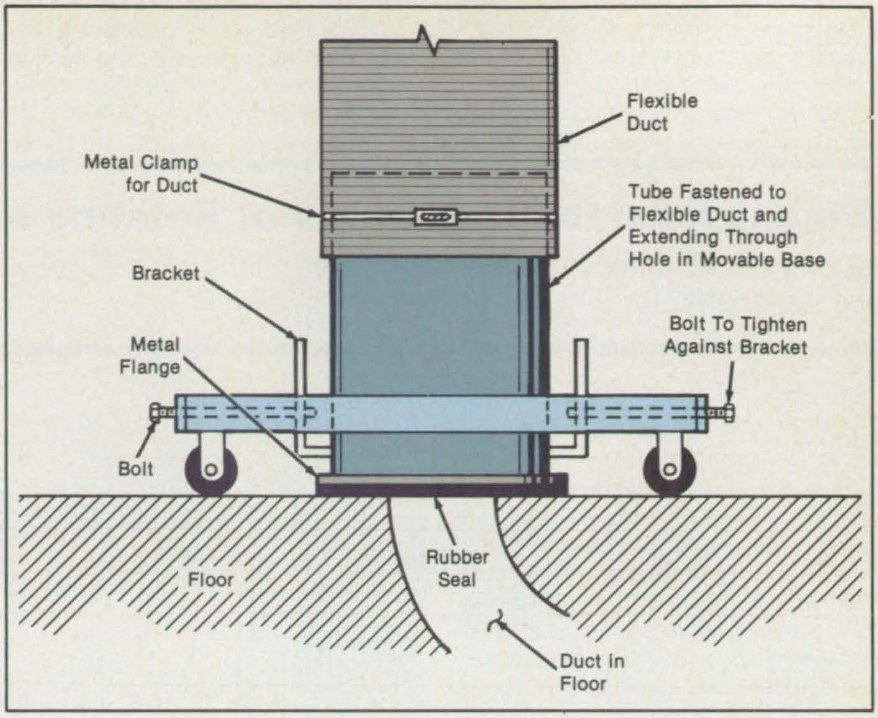


Figure 2. A **Flanged Connector** on the underside of the wheeled base links the flexible tube to the exhaust system under the floor.

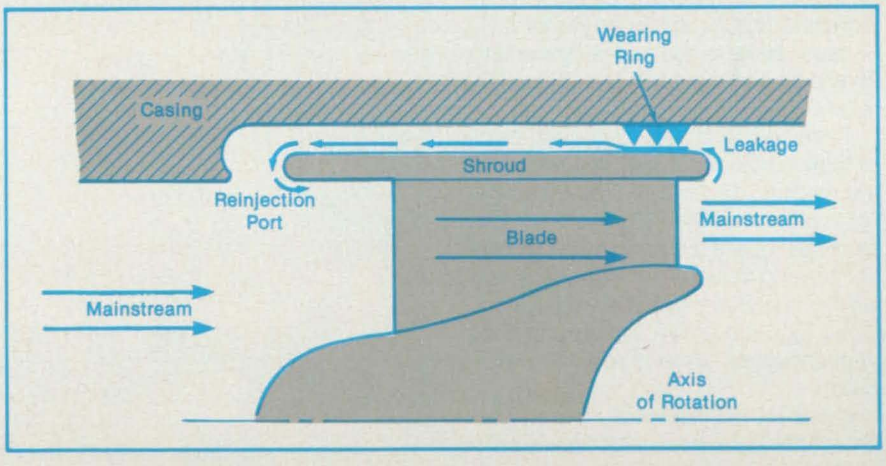
Calculating Leakage Around Turbopump Inducer Shrouds

An improved mathematical model aids designers of turbomachinery.

Marshall Space Flight Center, Alabama

A new mathematical model for the leakage flow around shrouded turbopump inducers yields more realistic analyses from which the designers can determine the best geometry for leakage-flow-reinjection ports. In addition, the designers can use the calculated velocity profile at the inducer leading edge to determine the blade-angle distribution of the inducer leading edge.

In a shrouded inducer, the axial leakage flow is created by the difference of static pressure across the wearing ring (see figure). By the combined effects of friction between the leaking fluid and the casing and between the leaking fluid and the shroud, the leakage flow is accelerated circumferentially to nearly half the speed of the outer surface of the rotating shroud. A reinjection port returns the leakage to the mainstream.



A **Portion of the Mainstream** leaks through the wearing ring and flows between the casing and the shroud. The leakage re-enters the mainstream at the inducer inlet.

Previous flow models assumed that the loss in pumping capacity due to the leakage around the shroud was uniformly distributed and that the flow-velocity profile at the inducer inlet was constant. The new model takes into account the local effects upon the overall flow caused by the leakage past the shroud and the spatial variations in the inlet velocity profile caused by this leakage.

The new model is based on a Navier-Stokes computer code that solves planar or axisymmetric elliptic partial differential equations through an iterative finite-difference procedure. The flow and turbulence equations are solved in the primitive variables (pressure, velocity, kinetic energy, and the like). The two-equation k-ε model and the advanced Reynolds stress model of turbulence are used to complete the set of governing equations. The Reynolds stress model also accounts for the anisotropy of swirling flows.

The new model shows that the tangential component of the leakage flow mixes only slowly with the mainstream. It also shows that the leading edge of the inducer tip experiences very large negative incidence and loses suction. The large negative-incidence angle increases the apparent blockage area.

The mixing of the leakage stream with the mainstream is affected by the degree of swirl and the relative flow rates of the two streams, according to the new model. At a given swirl level, a high flow rate in the leakage stream produces a wall jet that is carried far downstream essentially unchanged. Large levels of swirl (as much as three times the axial velocity) are needed to affect the axial velocity and change the spreading rate of the wall jet. Increasing the turbulent kinetic energy of either or both streams enhances mixing.

This work was done by Sen Yih Meng and Munir M. Sindir of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information, Circle 27 on the TSP Request Card.* *MFS-29106*

Stability/Instability Analysis of Rotating Machinery

A numerical index of stability can now be calculated for a nonlinear system.

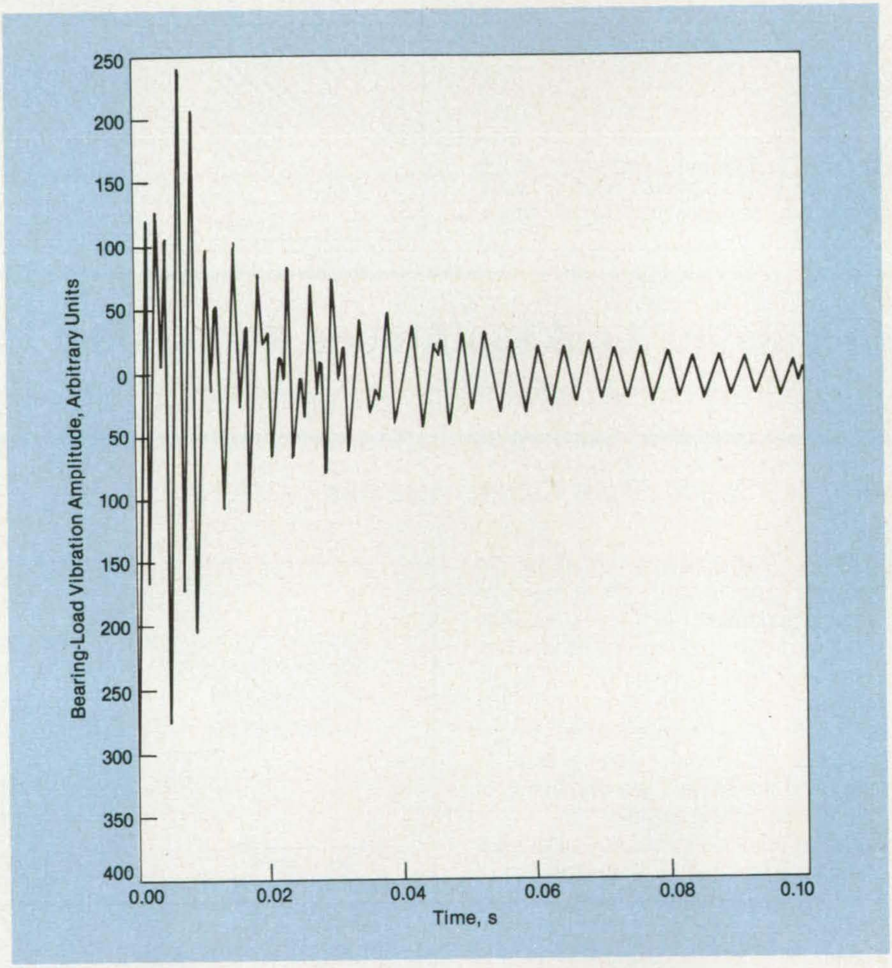
Marshall Space Flight Center, Alabama

A technique for determining rotor stability or instability from the analysis of measurements has been adapted for use with computer simulations of rotor motion. The technique involves the calculation of the log decrement (for stability) or increment (for instability) of the vibration amplitude. It is applicable to rotors mounted in loose bearings and to similar problems in which the load-versus-deflection characteristics are nonlinear. Developed for assessments of the vibrational characteristics of turbopump rotors, the technique is also usable with such mechanisms as high-speed ball bearings.

In the new technique, a stability analysis begins with a computer simulation of the transient response of the rotor, using the nonlinear equations of motion. To enable the assessment of stability, integrations should be carried out for 50 to 60 revolutions. In contrast, a conventional response analysis requires 250 to 300 revolutions.

Once the integration of the equations of motion has converged, the equations are modified by removing the terms that represent the rotor unbalances. This causes a transient decay in the calculated bearing loads (see figure). A fast Fourier transform of the decay is computed, and the active modes and peak frequencies of these modes are identified.

A discrete Fourier transform is computed at each peak frequency from a block of data initially consisting of half the number of points in the calculated transient decay. Because the frequency resolution of the fast Fourier transform depends on the sampling rate and the number of sample points, each peak frequency in the transform may not correspond to the correct frequency in the sampled signal. Therefore, the number of points in the transform is varied until the discrete amplitude reaches a peak. The optimized frequency is calculated from this number of data points. In this fashion, the frequency resolution can be improved over that available in a standard fast-Fourier-transform routine.



The **Vibration Amplitude** decays in this computer simulation of rotor motion, after the terms representing rotor unbalances are removed at zero time.

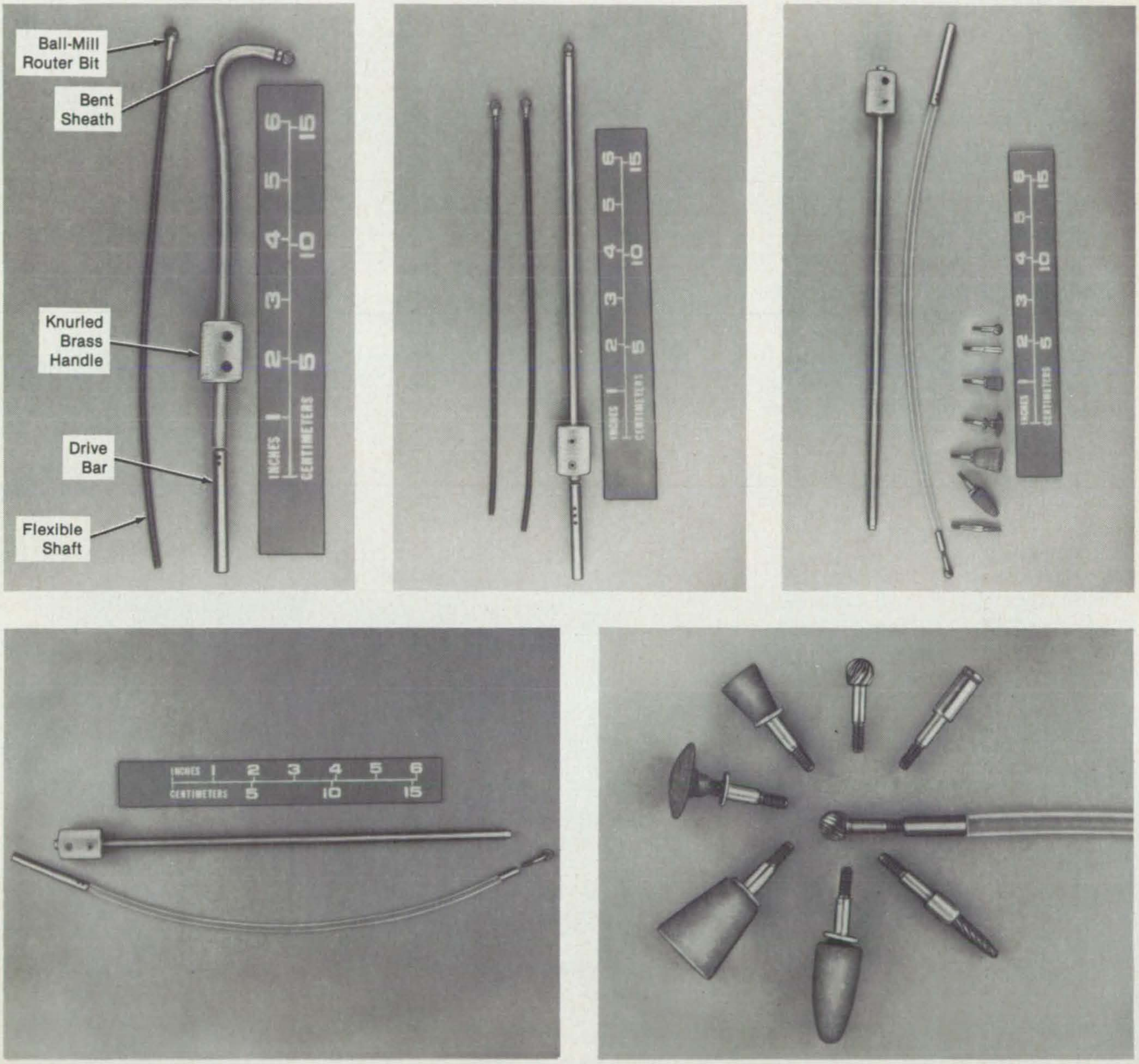
At each optimized frequency, the log decrement, or increment, is calculated from the amplitudes of the successive discrete Fourier transforms obtained as the block is moved along the transient-response record in the direction of increasing time. In effect, this calculation gives the transient decay, or growth, of the spectral content of the vibration at the optimized frequency. The log decrement, or increment, is taken to be proportional to the slope of a linear least-squares fit to a plot of the natural logarithm of amplitude versus time or the number of rotations. This number gives a direct indication of stability; for example, industrial experience has shown that, for an adequate safety margin of stability, a turpopump should have a log decrement of at least 0.05 at the first critical vibrational frequency.

This work was done by Richard W. Powers of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information, Circle 26 on the TSP Request Card.* *MFS-29168*

Bendable Routing Tool

Burrs can be removed in difficult-access cavities.

Marshall Space Flight Center, Alabama



A **Copper Sheath Gives Stiffness** to a flexible shaft but can itself be bent. Several types of routing bits can be attached to the shaft.

A tool extends a routing bit into internal cavities or passages so that burrs and similar defects can be removed. The tool can be bent so that it can be inserted through curving channels.

The tool (see figure) includes a copper sheath containing a flexible steel shaft like that in a tachometer cable. A steel drive bar, attached to one end of the shaft by a pair of setscrews, is inserted in the chuck of a hand-held manual or power drill to turn the shaft.

Any of a variety of routing bits can be attached to the opposite end of the shaft by screw threads or by brazing. The copper sheath can be bent as necessary to fit the access channel.

A polytetrafluoroethylene liner on the shaft reduces the friction between the shaft and the sheath so that the shaft turns more easily. At the bit end of the sheath, a bronze bushing resists sideways thrusts on the bit. At the other end, a brass handle is affixed with two setscrews.

This work was done by Walter Mayer of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*
MFS-29179

Piezoelectric Driver for Incremental Motion

A simple device offers potential advantages over small motors.

NASA's Jet Propulsion Laboratory, Pasadena, California

A vibrating device containing two piezoelectric ceramic slabs acts as a mechanical driver. The device, which is still experimental, may eventually substitute for small continuous or stepping electric motors of slow to moderate speeds.

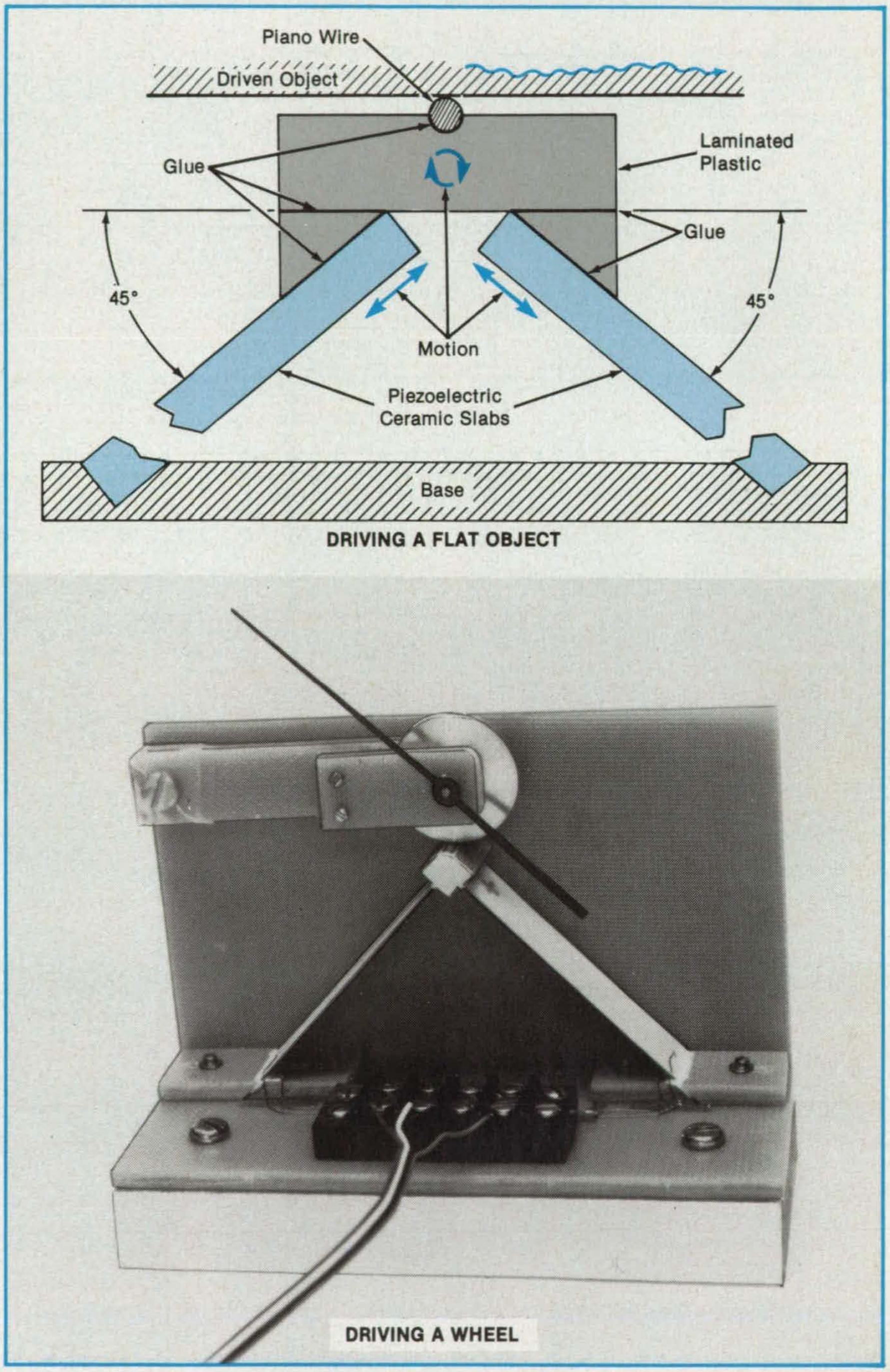
The piezoelectric driver is simple in construction, requires no precise dimensions, is inexpensive to make, and needs no lubrication. It is not damaged by stalling or overloads and is safe for use in explosive atmospheres; its motion is controllable in micron-size increments, and it holds its position when power is turned off.

The device has a variety of potential applications as a positioner or mover. It might be used to position instrument pointers, antennas, or solar panels; to focus lenses; or to operate tuners, recording instruments, or valves.

Each piezoelectric slab is excited electrically so that it vibrates elastically along its longitudinal axis. One end of each slab beam is fixed; the other is free to vibrate with small amplitude but with substantial force. The vibrating end contacts a driven element having a hard, smooth surface at an oblique angle. The vibrating end imparts motion to the driven element with a component tangential to the surface of the element.

Many variations of the basic piezoelectric drive mechanism are possible. In a demonstration device, each of two similar piezoelectric slabs is fixed at one end to a rigid base. The opposite (moving) ends are fastened together at an angle of 90° so that the assembly forms a rigid 45/90/45° triangle (see top of figure). The driven element rests on the 90° apex of the triangle.

The two piezoelectric slabs are driven at the same frequency but with a phase difference of about 90°. Consequently, the apex moves in small, nearly-circular closed loops. Because of its rapid motion, the apex makes contact with the hard, smooth surface of the driven element during only a small part of each loop. During each contact, the apex moves the driven element a small distance along the tangent to the contact surface. When the excitation is stopped, static friction at the point of contact holds the driven element in place. If the phase relation of the piezoelectric slabs is reversed, the direction of motion of the driven element will be reversed.



Two Piezoelectric Ceramic Slabs are tilted and joined together at an apex by an adhesive and a plastic slab, on which a wire forms a small contact area for the driven element. The phased vibration of the piezoelectric slabs pushes the driven element along the track.

In another demonstration device, shown at the bottom of the figure, the piezoelectric members impart motion to a wheel. In this case, the wheel is the driven element at the apex of a pair of piezoelectric wafers. The periphery of the wheel is given continual incremental motion by the vibration of the wafers and the loop movement of the apex.

Motive power for this device is not limited to the piezoelectric effect. Many

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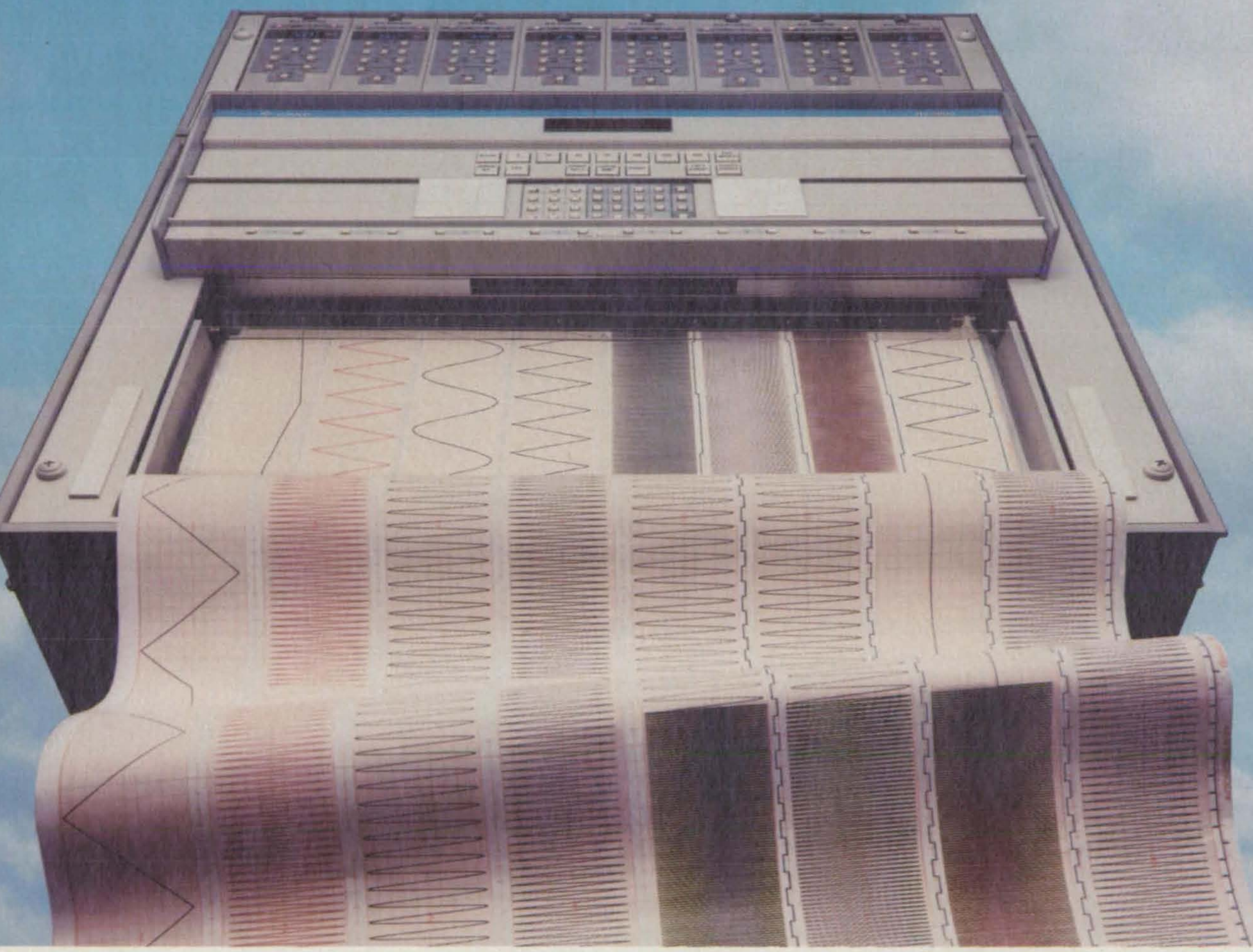

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other means of producing longitudinal vibration, for example a simple electromagnet, will serve equally well.

This work was done by Joseph R. Bruman of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 80 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 17]. Refer to NPO-16751.

Grasping Mechanism

This latching device captures and locks onto a handle without precise angular alignment.

Marshall Space Flight Center, Alabama

A grasping mechanism captures and locks onto a rodlike handle. The mechanism has unique features, including the following:

- A relatively large capture envelope [4 in. by 8 in. (10.2 cm by 20.3 cm)];
- A large force available to pull in the handle [200 lb (890 N), minimum];
- The ability to capture a handle without being precisely aligned with it (Capturing fingers may be cocked ±5° with respect to the handle.);
- Having captured the handle, the ability to lock the handle onto the supporting structure, thereby keeping the drive mechanism from having to carry handling loads; and
- The ability to release the latches to free the handle.

The mechanism (see figure) includes two faceplates and three rotatable fingers that mesh — the odd finger between the two members of the opposite finger pair. The power for the fingers is supplied by a motor powered via a harmonic drive that reduces the speed and increases the torque by a factor of 160.

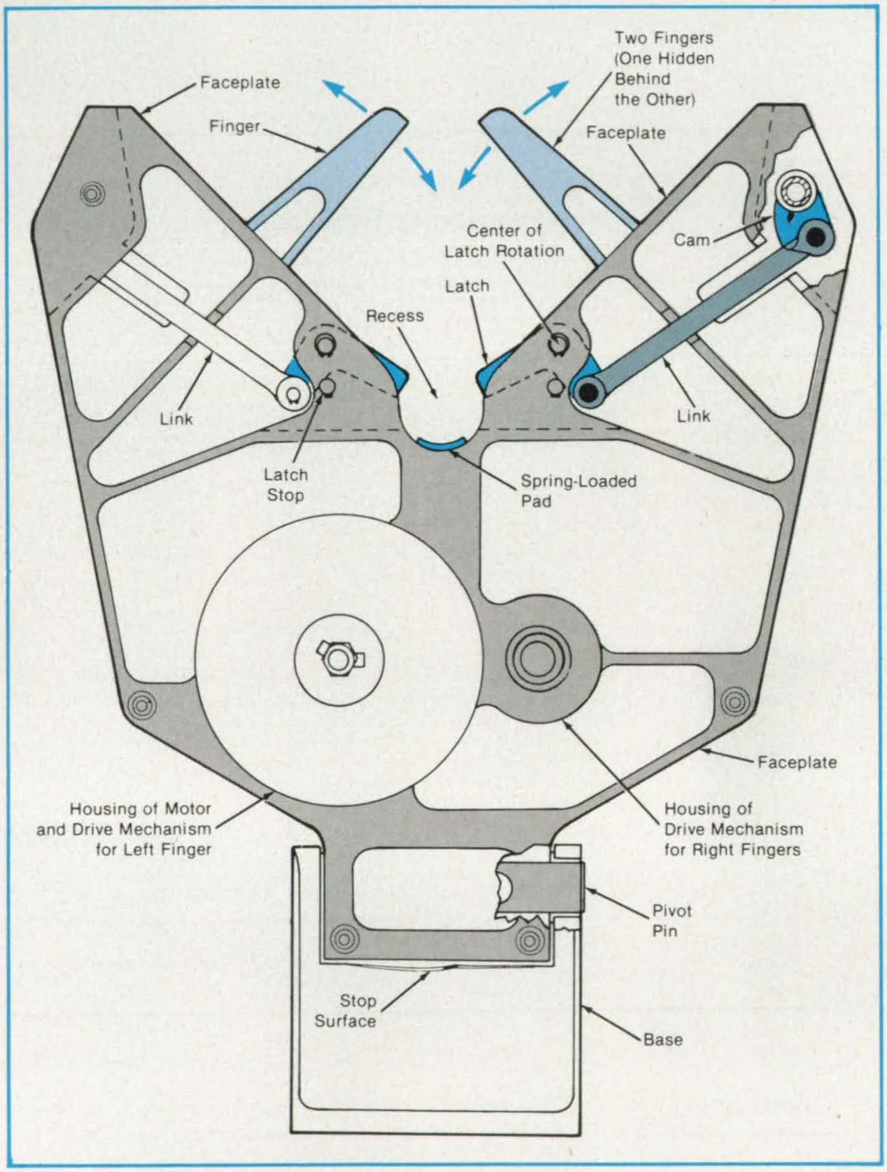
Incorporated into the two faceplates are latches, which hold the handle in the recess. The handle is pushed firmly against the latches by a spring-loaded pad. In the locking position, the latches are held against stops by torsion springs within the cams.

The faceplate/finger assembly is mounted on a base by a pivot pin. This allows the faceplate/finger assembly to cock ±5° until stop surfaces are reached. A leaf spring, which is attached to the pivot pin and retained in the base by pins, provides centering.

During the handle-capturing procedure, the captured and capturing systems approach each other until the handle is within part of the V-shaped space between the faceplates (the capture envelope). The fingers are drawn inward, trapping the handle and forcing it through the latches and into the recess. The ability of the effector to cock about the pivot allows the handle crossbar to enter fully the recess and engage all four latches, even if it was not originally parallel to the recess.

When the handle enters the recess, it depresses the spring-loaded pad and comes to a stop at the bottom of the recess. The motor current then rises, causing the motor to be cut off by a current-limiting switch. At this point, the fingers can be backed off without releasing the handle because the handle is now held against the latches by the spring-loaded pad. This backing off prevents the handle loads from being imparted to the drive mechanism.

When the telescope handle is to be released, the fingers are moved to the fully open position. The fingers actuate the cams, which retract the latches via links, freeing the handle. When the cams have moved through full travel, the motor current again rises, and the motor is cut off by the current-limiting switch.



The **Grasping Mechanism** captures and locks onto a rodlike handle without being precisely aligned with it initially.

This work was done by W. Neill Myers and John C. Forbes of **Marshall Space Flight Center**. *For further information, Circle 136 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 17]. Refer to MFS-28161.

Books and Reports

These reports, studies, and 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.

Heat Shields for Aerobrakes

The performances of three types of heat protectors are predicted.

Estimates of the expected performances of heat shields for a conical drag brake are presented in a paper. Drag brakes, or aerobrakes, are being considered as devices for slowing space vehicles when they return to Space Shuttle altitudes from higher satellite altitudes after supply missions. Aerobrakes add less weight than do retro-rockets for the same purpose and consume no fuel.

The paper provides general information on the sensitivity of performance to the thermal and physical properties of the materials that may be used in aerobrakes. The information will be useful to both designers of brakes and developers of materials for brake fabrication on aerospace structures.

Heat shields will protect the brakes from the heat created by air friction. Because of the great speed of the returning supply vehicles, the heat will be intense even in the tenuous atmosphere at Space Shuttle altitudes. Three types of heat shields are considered: rigid ceramic insulation, flexible ceramic blankets, and ceramic cloths.

The paper presents charts in parametric form so that they may be applied to a variety of mssions and vehicle configurations. The parameters include the braking-maneuver heat flux and total heat load, the heat-shield material and thickness, the heat-shield thermal mass and conductivity, the absorptivity of surfaces, the thermal mass of the support structure, and radiation transmission through thin heat shields. With the charts, the user can estimate the minimum required mass of heat-shield materials.

For the outer portion of the drag brake, the paper concludes that a flexible ceramic heat shield is preferable because it does not require as much supporting structure as does rigid insulation. However, the mass of the fabric will be significant, and its thickness must therefore be minimized. The mass is less for cloth, including the material required to insulate the cloth from the structure, than for a blanket. This is particularly true for large-radius brakes. However, a thick blanket provides the advantage of a low--temperature surface exposed to the spacecraft structure and minimizes radiation transmission and the flow of hot gas through the structure.

This work was done by W. C. Pitts of **Ames Research Center** *and M. S. Murbach of Informatics General Corp. To obtain a copy of the paper, "Thermal Design of AOTV Heat Shields for a Conical Drag Brake," Circle 153 the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center [see page 17]. Refer to ARC-11681.

Fabrication Technology

Hardware, Techniques, and Processes

Soldering Tool for Integrated Circuits

Many connections are soldered simultaneously in confined spaces.

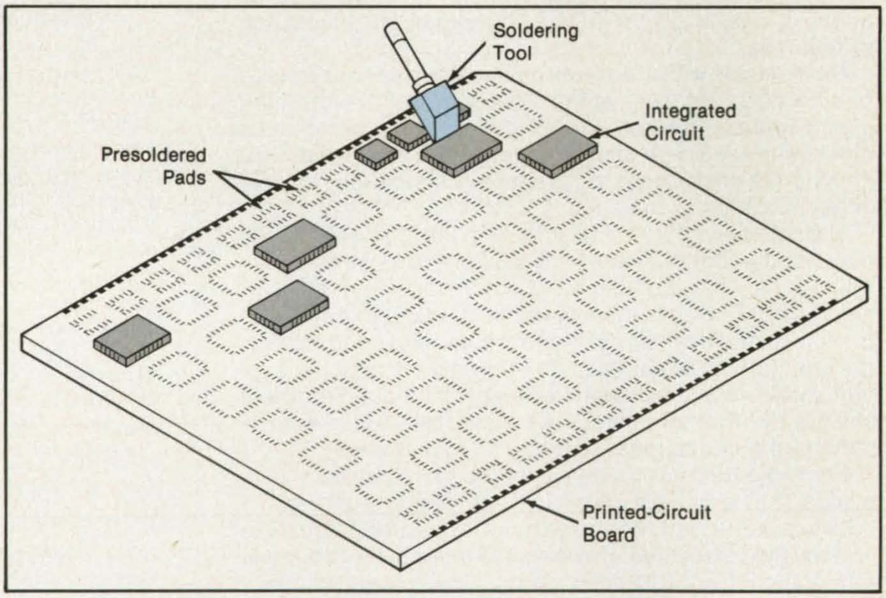
NASA's Jet Propulsion Laboratory, Pasadena, California

An improved soldering tool bonds integrated circuits onto printed-circuit boards. It is intended especially for use with so-called "leadless-carrier" integrated circuits. These circuits are not really leadless, but the leads emerge from the sides of the circuit packages and are folded underneath and thus require special care in soldering. Furthermore, it is difficult to solder the circuits in place with an ordinary soldering iron because the circuits are often closely spaced on printed-circuit boards, making the leads nearly inaccessible.

The tip of the new tool is a copper prism shaped to form a wedge that fits between adjacent integrated circuits (see figure). The wedge is thin enough to prevent the conduction of heat to the wrong chip and wide enough to enable the soldering of several connections at once. This is better than soldering connections one at a time — a process that can overheat the chip.

An integrated circuit is held down firmly with its presoldered leads in contact with the mating presoldered pads on a circuit board. The soldering tool is placed with its slanted surface in contact with several leads. The heated leads melt their solder coats and the solder on the pads. The tool is removed and the solder in the joints allowed to solidify before the holding force is removed.

This work was done by Ted H. Takahashi of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 40 on the TSP Request Card.*
NPO-16838



An **Integrated Circuit Is Soldered** onto a circuit board with the new tool.

Composite-Metal-Matrix Arc-Spray Process

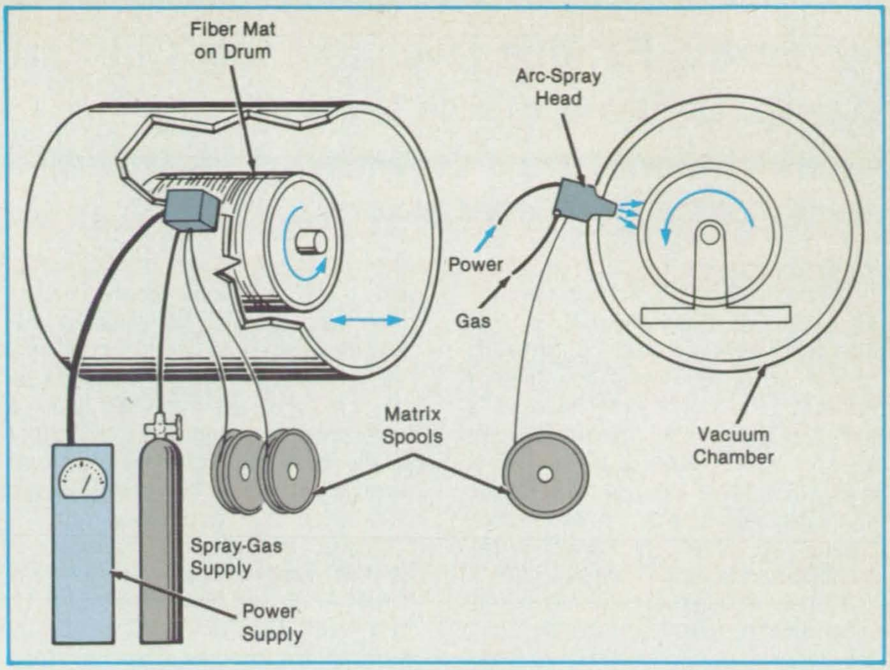
This automated system features low cost and fast production.

Lewis Research Center, Cleveland, Ohio

One of the major impediments to the full utilization of metal-matrix composites has been the labor-intensive nature of the process by which they are formed. High-quality, single-layer "monotape" composites are both expensive and difficult to reproduce accurately. "Monotapes" have the advantage of orientation control, and they can be joined and fabricated into various complex structures. This process involves cutting, stacking, aligning, and heat/pressure bonding of "monotapes" into structural components. Existing technology imposes severe limitations on "monotape" sizes and metal-matrix chemistry and properties. Current maximum "monotape" sizes are less than 50 in.^{2} (320 cm^2).

The Lewis Research Center has developed the arc-spray "monotape" process (see figure), a new fabrication process that solves the problems of reproducibility, cost, and size. The process can produce single sections of composite "monotape" 600 in.^{2} (3,900 cm^2) in area in four to six manhours. The "monotape" is reproducible and of a high quality. The process is carried out in a controlled gas environment with programmable matrix-deposition rates, resulting in a significant cost saving.

The cleanliness and properties of the "monotape" as processed and after final consolidation are vastly superior to those of the composite products of current powder metallurgy. Oxygen and nitrogen levels in the finished composite "monotape" are very low. As a result, such secondary bonding processes as hot isostatic pressing or hot pressing produce well-bonded structures with low oxygen levels. The process can be easily scaled up to meet any future production needs.



The **Arc-Spray "Monotape" Process** is automated, low in cost, and produces at a high rate. The process is ideal for the development of new metal-matrix composites.

This work was done by Leonard J. Westfall of **Lewis Research Center**. *For further information, Circle 77 on the TSP Request Card.*

This invention has been patented by NASA (U.S. Patent No. 4,518,625). Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Lewis Research Center [see page 17]. Refer to LEW-13828.

Increasing Fatigue Lives of Laser-Cut Parts

Cut edges are sanded to restore strength.

Marshall Space Flight Center, Alabama

A simple abrasion process removes the transverse striations (see Figure 1) that result from the laser cutting of Inconel* 718 (or equivalent) alloy, thereby increasing the fatigue strengths of parts that have been cut by laser beams. For stresses in the range of 80 to 130 ksi (550 to 900 MPa), the high cycle fatigue strengths are restored to levels comparable to those of conventionally machined parts (see Figure 2).

To help maintain consistency of material removal inside corners and radii, the abrasion is performed with a strip of sandpaper wrapped on a metal bar. To further ensure consistency, an effort is made to apply constant pressure while rubbing the laser-cut edge with forward strokes only.

Three different grades of silicon carbide sandpaper are used. The abrasion is begun with relatively coarse 180-grit paper. The operation is repeated with 320-grit paper and performed a third time with 600-grit paper. After completion, the edges are inspected under a microscope at a magnification of 30 to 50. The sanding operation is repeated as necessary until striations are no longer visible under the microscope.

*"Inconel" is a registered trademark of the INCO family of companies.

This work was done by Edward W. Glick and Michael H. Donovan of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*
MFS-29116

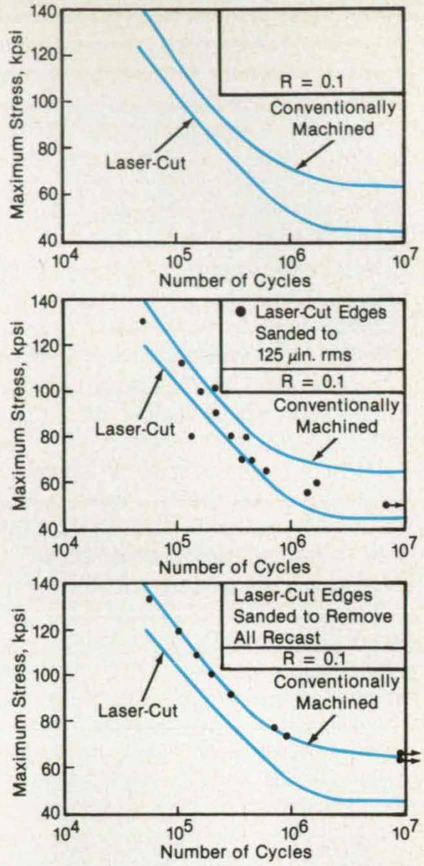


Figure 2. The **High Cycle Fatigue** of laser-cut Inconel* 718 is restored by sanding the edges of the cut.

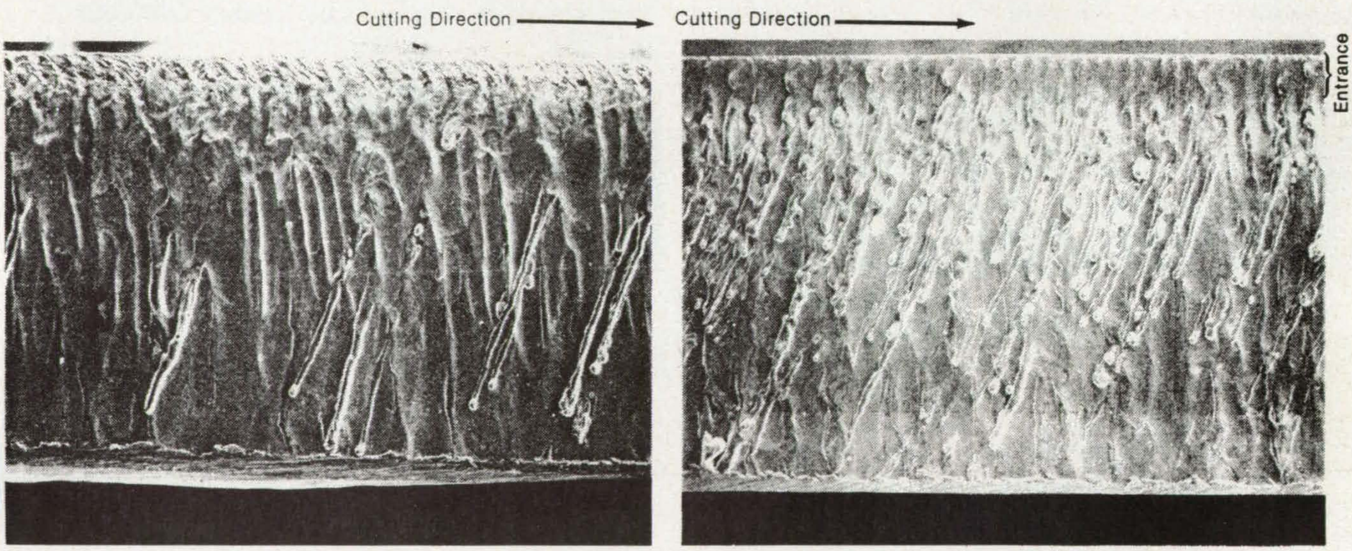


Figure 1. **Transverse Striations** form on the edges of a laser cut in mill-annealed Inconel* 718 alloy.

Making Linked, Wound-Filament Bands

Chains could be produced by the use of a rotating mandrel.

NASA's Jet Propulsion Laboratory, Pasadena, California

Chains of linked filament-wound bands could be made using a conceptual rotating mandrel (see Figure 1), eliminating the need to join separate bands by mechanical linkages. Short chains made in this way could have a variety of uses; for example, thermal isolators, each consisting of two linked bands of insulating material, could be used to support two separated insulating shields surrounding a container of liquid helium.

The first of two linked bands can be

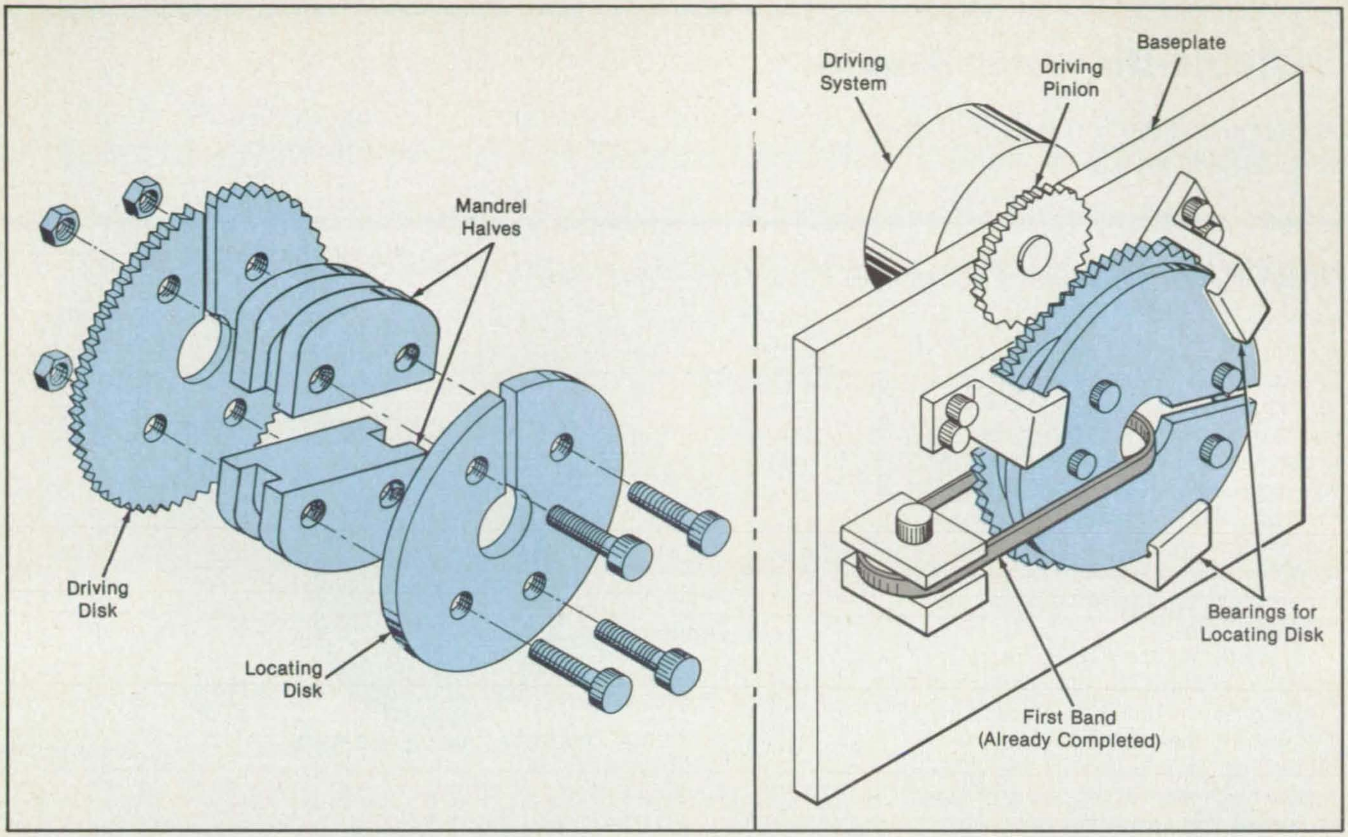


Figure 1. A **Mandrel and Its Locating and Driving Disks** are assembled around the first band. The mandrel and band are then mounted in their respective positions on the filament-winding machine.

made by using the rotating mandrel or by any existing method. The linking of the second band to the first is accomplished in the following seven steps:

1. The first band is fastened on the filament-winding machine in the position indicated in Figures 1 and 2. In this position, one end of the first band is at the center of rotation of the mandrel.
2. The mandrel is assembled around the first band, and all parts are mounted as shown in Figure 1.
3. The lead end of the filament is attached to the mandrel.
4. The mandrel is rotated, and the filament is wound until the new band attains the desired cross section.
5. The trailing end of the filament is bound to the newly formed band, and the filament is cut from the supply spool; then the newly wound band is removed on its mandrel.
6. The impregnating material in the filament is cured to form the solid band.
7. The mandrel is disassembled to remove the newly formed band.

If more linked bands are required, steps 1 through 7 are repeated with the new band becoming the "first" band mentioned in Step 1.

This work was done by Robert M. Bamford and James B. Stephens of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, Circle 82 on the TSP Request Card. NPO-16822*

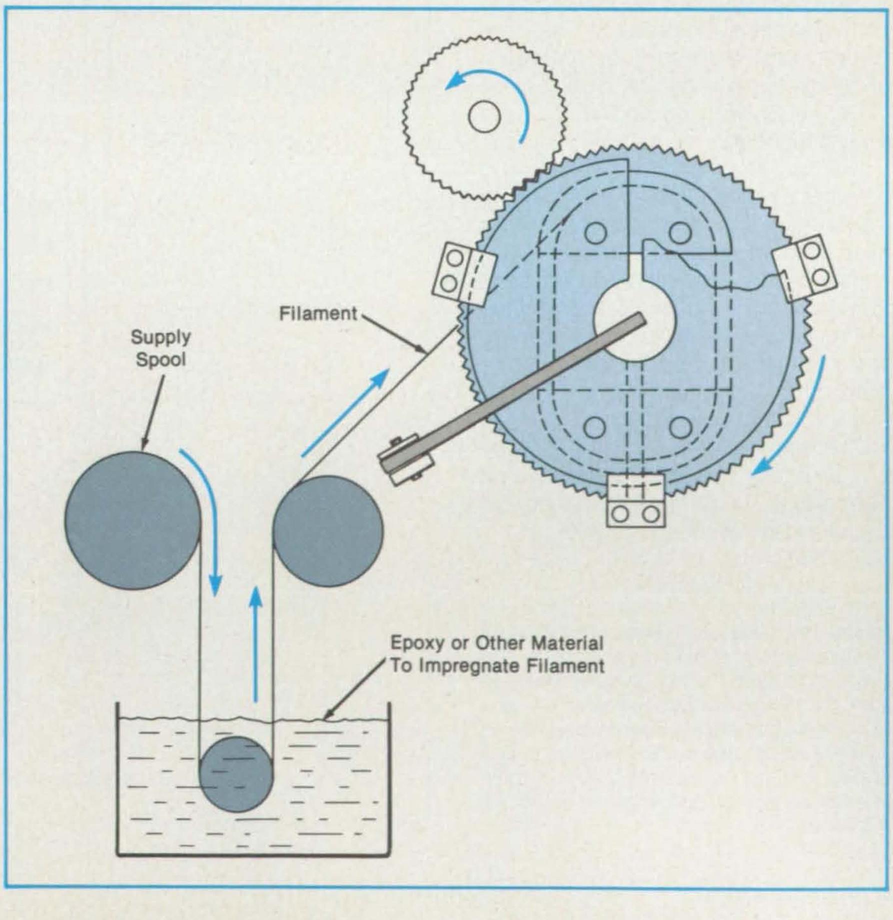


Figure 2. A **Second Band Is Linked** to the first by winding a filament around the first band on the rotating mandrel.

Variable-Diameter Nozzle

A proposed device would shape and seal filled shells.

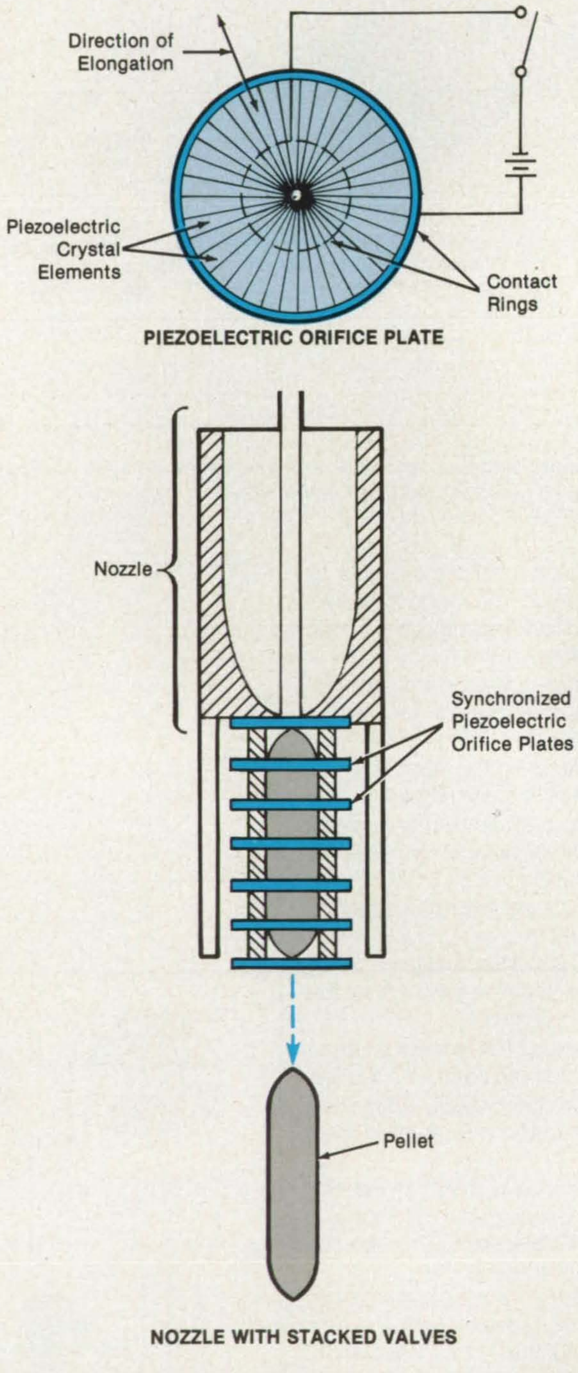
NASA's Jet Propulsion Laboratory, Pasadena, California

A conceptual variable-diameter nozzle would be used to produce uniform hollow pellets of controlled size and shape. The nozzle would fill the cores of the pellets with a gas or liquid and seal them before the shells harden so that the filler does not leak or become contaminated by the surroundings. The nozzle would handle such shell-material feedstocks as viscous or foaming plastics.

An electrically and mechanically controlled valve would be positioned at the nozzle orifice, through which both the filler and the shell material would flow in coaxial jets. In one version, the valve-closure mechanism would consist of radial piezoelectric crystal elements, which would contract and thereby enlarge a central orifice when a voltage is removed from concentric rings (see figure). The valve would be opened briefly so that a filled shell would be extruded under controlled temperature and pressure. The valve would then be reclosed by the application of voltage to the rings. The closing of the valve would seal the end of the shell around the filler.

Alternatively, the valve closure could be either a sliding plate on an orifice or an irislike set of interleaved plates. In either case, a piezoelectric transducer would enable the fast opening and closing and the precise control of the open-valve interval. A series of valves could be stacked, and their openings and closings could be synchronized to impart a tapered shape to the tip and tail of a pellet.

This work was done by Taylor G. Wang of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 58 on the TSP Request Card.*
NPO-15623



Radial Piezoelectric Elements arranged like overlapping spokes on a wheel would contract to open the hub and allow a filled shell to emerge through it. A stack of synchronized piezoelectric valves separated by spacers would shape the emerging pellet. Shells ranging in diameter from 2 millimeters to a few centimeters could be produced.

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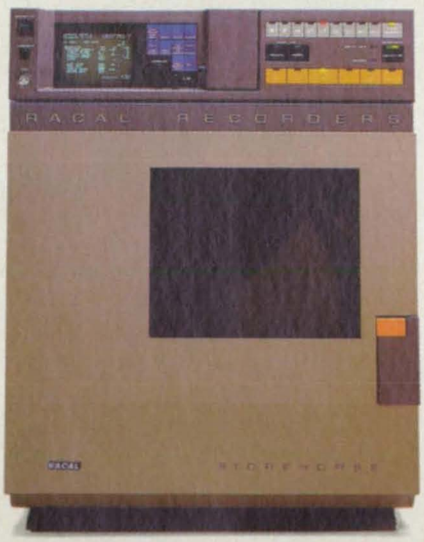

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Mathematics & Information Services

Books and Reports

These reports, studies, and 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.

Weibull Distribution From Interval Inspection Data

The most likely failure sequence is assumed.

A NASA technical memorandum discusses the application of the Weibull distribution to the statistics of the failures of turbopump blades. The Weibull distribution is a generalization of the well-known exponential random probability distribution and is useful in describing component-failure modes that include aging effects. The Weibull parameters are found from experimental data by the method of maximum likelihood.

The failure mode in question is shank cracking of the blades on the downstream pressure side and is assumed to follow the two-parameter Weibull probability per unit time

$$f(t) = (\beta/\eta^\beta)\, t^{\beta-1} \exp[-(t/\eta)^\beta]$$

where t is time, β is a dimensionless shape parameter, and η is the characteristic lifetime. The Weibull reliability or survivorship function — that is, the probability of surviving to time t — is then found from

$$R(t) = 1 - \int_0^t f(t')dt' = \exp[-(t/\eta)^\beta]$$

This equation shows that η is the time at which the probability of survival is 1/e. If $\beta < 1$, the failure rate decreases with the age of the component; this is often called the infant-mortality or burn-in failure mode. If $\beta > 1$, the failure rate increases with age, indicating a wear-out failure mechanism. If $\beta = 1$, the failure rate is random with a constant rate; i.e., the components neither burn in nor age.

Suppose that a turbopump rotor having M blades is subjected to N test runs. It is inspected at time t_{1i} before the *i*th run and again at time t_{2i} after the *i*th run. During the inspection after the *i*th run, F_i blades are found to have failed at some time during that run. The Weibull likelihood function, L, for these test results is the product of the Weibull probabilities of the failures during the intervals t_{1i} to t_{2i} and the probabilities of survival to t_{2i} and is given by

$$L = \prod_{i=1}^{N} \{\exp[-(t_{1i}/\eta)^\beta] - \exp[-(t_{2i}/\eta)^\beta]\}^{F_i} \{\exp[-(t_{2i}/\eta)^\beta]\}^{M-F_i}$$

To find the parameters β and η, it is assumed that the observed failure pattern is the most likely one. Using lnL (because it yields a simpler equation), this amounts to a search for the solutions to the equations

$$\frac{\partial \ln L}{\partial \eta} = 0 \text{ and } \frac{\partial \ln L}{\partial \beta} = 0$$

These equations can be solved iteratively by the Newton-Raphson method, using a programmable hand calculator.

Once found, β and η are useful in the calculation of several measures of the reliabilities of components and systems. For example, one can compute the reliability of R(t) of a single blade over a time t. The single-blade reliability can be used in a cumulative binomial distribution to find the probability $R_M(k,t)$ that not more than k of the M blades on a rotor will fail during t. Yet another useful measure is the conditional probability that a part will survive to time T after it has already survived to time T_0.

This work was done by Mario H. Rheinfurth of **Marshall Space Flight Center**. *Further information may be found in NASA TM-86515 [N85-32847/NSP], "Weibull Distribution Based on Maximum Likelihood With Interval Inspection Data."*

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. The report is also available on microfiche at no charge. To obtain a microfiche copy, Circle 108 on the TSP Request Card.
MFS-27130

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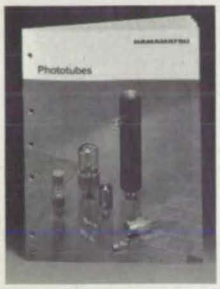
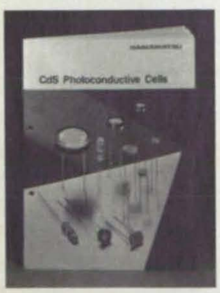
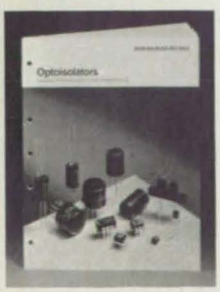


PHOTOTUBES — This 18-page catalog includes a selection guide, spectral response charts, dimensional outlines and specification charts for more than 40 head-on and side-on phototubes, UV detectors, vacuum phototubes, gas-filled and biplanar phototubes.

PHOTODIODES — Silicon, PIN Silicon, GaAsP, GaP, Avalanche This 44-page catalog provides spectral range, response time, temperature characteristics, linearity and specifications for UV to IR silicon, visible to IR silicon, GaAsP and GaP photodiodes.

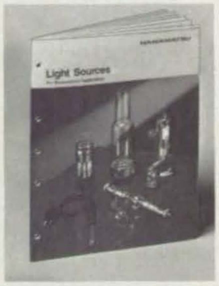


PHOTOCONDUCTIVE CELLS CdS, CdSe This 16-page catalog describes performance characteristics and specifications of various photoconductive cells used in exposure meters, auto dimmers, musical instruments, flame monitors, street light controls and other applications.



OPTOISOLATORS Single and multi-element LED-CdS optoisolators, LED phototransistors, Lamp CdS and opto-interrupters are described. Photos and diagrams illustrating physical characteristics and complete specifications are provided in this 18-page catalog.

Call or write to receive one or all ten catalogs.



LIGHT SOURCES — Deuterium, Xenon, Mercury-Xenon, Hollow Cathode, etc. This 24-page catalog provides information about the most complete line of light sources for scientific instruments. Specifications are provided which define the high stability and dependability. Super-quiet xenon lamps are among the special light sources described.

PHOTOMULTIPLIER TUBES FOR SCINTILLATION COUNTING AND HIGH ENERGY PHYSICS This 30-page catalog provides a quick reference of PMTs with special performance characteristics. Energy resolution, pulse linearity, response time and application information are included.

VIDICONS — Visible, IR, UV, X-Ray This 24-page catalog provides a cross-reference of vidicon types and typical applications in addition to dimensional outlines, application photos and complete specifications.

SPECIALTY IMAGING TUBES — This 25-page catalog contains a number of new types of photonic devices for capturing static and transit images. An ideal source of ideas for new types of instrumentation.

INFRARED DETECTORS — PbS, PbSe Cells; Ge, InAs, InSb Cells; Photon Drag Detector; Pyroelectric Detectors & More This 36-page catalog describes IR detectors with various elements and configurations. Extensive diagrams, characteristic graphs and glossary accompany performance specifications.

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Circle Reader Action No. 471

Life Sciences

Hardware, Techniques, and Processes

Hand-Strength Meter

A grip meter measures hand strength accurately and reproducibly.

Langley Research Center, Hampton, Virginia

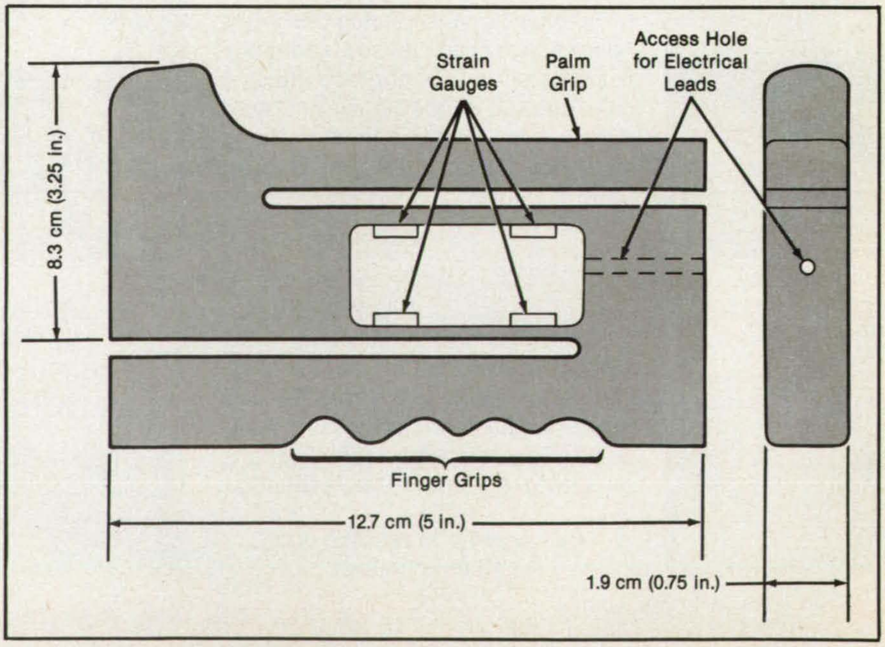
In rehabilitation efforts, it is necessary to evaluate the therapeutic methods by monitoring the patient's progress in response to these methods. In hand rehabilitation, hand strength is an important parameter to monitor, as are dexterity and flexibility. A special grip-strength meter has been designed for accurate, reproducible measurement of hand rehabilitation.

The hand-strength meter, shown in the figure, is machined from a one-piece aluminum block. The upper and lower parts of the block are contoured for the proper grip. These two parts are connected by two parallel measuring beams to which four strain gauges are cemented. The four strain gauges are wired to form a Wheatstone bridge. Two power leads to the bridge and two signal leads from the bridge are tunneled through a small access hole in the back of the meter to an external display unit that consists of a dc power supply, a three-digit light-emitting diode (LED), and signal-conditioning circuitry. Both the meter and the display unit are compact and lightweight [0.5 lb (0.2 kg) and 3 lb (1.4 kg), respectively].

When the meter is gripped, the compressive force exerted by the hand is transmitted to the measuring beams. The beams are therefore deflected or strained, and this mechanical strain is sensed by the strain gauges and converted into an electrical signal. After amplification and conditioning, the signal is displayed on the LED as a measure of the gripping strength of the hand.

Laboratory calibration indicates that the meter is extremely linear for a gripping force ranging from 0 to 1,001 N (225 lbf), with a precision of ±0.67 N (±0.15 lbf). The display unit can be adjusted easily to show direct digital readings in pounds of force.

This work was done by Ping Tcheng of **Langley Research Center** *and Joe Elliot of the U.S. Army Aerostructures Directorate. For further information, Circle 62 on the TSP Request Card.*
LAR-13507



The **Hand-Strength Meter** includes four strain gauges connected in a Wheatstone bridge to measure the deflection caused by a gripping hand.

MARTIN MARIETTA BALTIMORE AEROSPACE

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MARTIN MARIETTA

Circle Reader Action No. 440

Subject Index

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Circle Reader Action No. 455

Feedback

The Feedback column is designed to encourage a wide exchange of ideas among *NASA Tech Briefs* readers. To contribute a request for information or to respond to such a request, use the feedback cards in this issue, or write or call: Manager/Technology Transfer Division, P.O. Box 8757, Baltimore/Washington International Airport, MD 21240; (301) 859-5300. While we can print only a small number of letters, we will endeavor to select those that are of varied and wide interest.

GOOD IDEAS

The "Water Table" brief in October 1986, page 104 helped analyze turbulance causing rapid cavitation wear inside pump housing. Using "Water Table" and relatively inexpensive modeling aids, we were able to redesign the pump housing with greater working life and improved efficiency.

E. Thomas Malphus
New Products Mechanical Engineer
Pro-Max Machine
West San Diego, CA

In one Technical Support Package CMOS latch-up due to radiation was discussed. This helped us determine a problem with our cobalt radiation therapy readouts, which were giving us incorrect readings. The electronics have now been relocated.

Michale Olsen
Service Manager
AECL Medical
Elk Grove, IL

THE LAWS OF ROBOTICS

Tech Briefs articles have often been of value in our control system and robotics design projects, as well as in our robotics research. The discussions of basic concepts and clever applications, as well as the new and original ideas discussed in *Tech Briefs* have helped us over stumbling blocks several times. The conceptual "seeds" sown at our level will bear important future "fruit" for the Navy, as well as private industry. Thanks!

Dr. Kenneth A. Knowles
Director, Robotics Facility
U.S. Naval Academy Department of Weapons & Systems Engineering
Annapolis, MD

HIGH QUALITY

Your advertisers are getting more and more educational. It seems that they are of a higher quality and generally don't promise you the world. Your magazine seems to be attracting the more intelligent business ventures. Thanks.

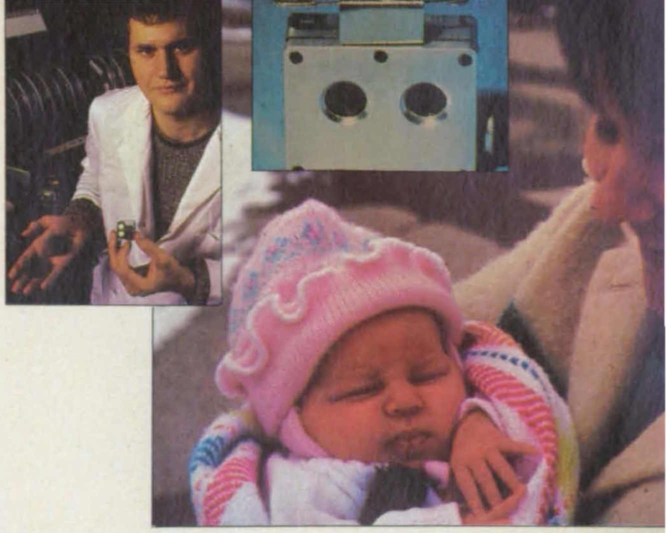
Thomas P. Lefebvre
Staff Manager
South Central Bell
Birmingham, AL

We have found a number of suggestions that, perhaps not directly applicable in our business, led to specific solutions that would otherwise been more difficult to solve. Further, we have received a number of calls from interested parties when a specific item described in *Tech Briefs* originated in our company, or was partly developed by us. Hopefully, some of these have led to productive use. Keep up the good work. I thoroughly enjoy this publication.

Ralph L. Stewart
Manager, Facilities Engineering
Martin Marietta Aerospace
Denver, CO

Mission Accomplished

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



Above: Dr. Bonnie Specker holds an infant wearing the solar dosimeter. Inset: The miniaturized dosimeter used in the study.

A recent study of vitamin D levels in children has shed new light on the nutritive benefits of sunshine.

Researchers from the University of Cincinnati's Medical Center investigated the relationship between sunlight exposure and vitamin D status in infants. Vitamin D_3, vital for the absorption of calcium and phosphate from the gastro-intestinal tract, is formed in the skin after stimulation by ultraviolet light.

To quantify sunshine exposure, the researchers utilized a "sunshine diary." For seven days prior to the drawing of blood, mothers recorded their child's time spent outdoors, clothing worn, and the weather conditions.

"The problem with the diary was that the mothers weren't very reliable in keeping accurate records," explained Neil Edwards, a bio-engineer involved with the study. "We needed a supplement to the diary. That's when I recalled reading in *NASA Tech Briefs* about a solar dosimeter."

The dosimeter, a miniature light meter spun off from NASA solar cell technology developed to power spacecraft, appeared in the Fall, 1980 *NASA Tech Briefs,* in an article by Richard Adams, Ian MacConochie, and Bordie Pool of NASA's Langley Research Center.

Designed to be worn during an individual's daily activities, the dosimeter measures the solar radiation to which the wearer is exposed. The device consists of two small silicon photovoltaic detectors that collect the radiant energy after passage through Schott Glaswerke glass filters that select the desired wave-band. Received energy is converted to electrical signals proportional to the absorbed radiation. E-cells record the electrical charge by plating silver ions onto an electrode. The time required to replate the silver indicates the total radiation absorbed.

"We received a license to produce about 120 dosimeters," said Edwards. "We used Langley's electronic circuits but changed the design, making it smaller for pinning onto the infants' clothes."

According to Edwards, "the dosimeter readings matched up really well with information in the diaries."

The study showed for the first time that vitamin D concentrations in the blood of infants correlated directly with the degree of sunlight exposure, and that a normal vitamin D intake (about 400 units daily) could be maintained by keeping a fully clothed child outdoors for two hours a week, regardless of the season. If the child was wearing only a diaper, required time dropped to a mere 30 minutes.

These findings are of particular relevance for exclusively breast-fed infants, according to Dr. Bonnie Specker, coordinator of the study. "A lot of people feel that because human milk is deficient in vitamin D, they have to supplement breast-fed children with the vitamin. Our work has shown that supplements aren't necessary if the child is getting sufficient sun exposure."

Since vitamin D requirements are the same for all age groups, Dr. Specker advises everyone, young and old, to "get outdoors as much as possible. Get out into that good sunshine." □

ABOUT THE NASA TECHNOLOGY UTILIZATION PROGRAM

Thumb Index

This document was prepared under the sponsorship of the National Aeronautics and Space Administration. NASA Tech Briefs is published ten times a year and is free to engineers in U.S. industry and to other domestic technology transfer agents. It is both a current-awareness medium and a problem-solving tool. Potential products. . .industrial processes. . .basic and applied research. . . shop and lab techniques. . .computer software. . .new sources of technical data. . .concepts. . .can be found here. The short section on New Product Ideas highlights a few of the potential new products contained in this issue. The remainder of the volume is organized by technical category to help you quickly review new developments in your areas of interest. Finally, a subject index makes each issue a convenient reference file.

Further information on innovations—Although some new technology announcements are complete in themselves, most are backed up by Technical Support Packages (TSP's). TSP's are available without charge and may be ordered by simply completing a TSP Request Card, found at the back of this volume. Further information on some innovations is available for a nominal fee from other sources, as indicated. In addition, Technology Utilization Officers at NASA Field Centers will often be able to lend necessary guidance and assistance.

Patent Licenses—Patents have been issued to NASA on some of the inventions described, and patent applications have been submitted on others. Each announcement indicates patent status and availability of patent licenses if applicable.

Other Technology Utilization Services—To assist engineers, industrial researchers, business executives, Government officials, and other potential users in applying space technology to their problems, NASA sponsors Industrial Applications Centers. Their services are described on pages 16-17. In addition, an extensive library of computer programs is available through COSMIC, the Technology Utilization Program's outlet for NASA-developed software. See special section on computer programs on page 46.

Applications Program—NASA conducts applications engineering projects to help solve public-sector problems in such areas as safety, health, transportation, and environmental protection. Two applications teams, staffed by professionals from a variety of disciplines, assist in this effort by working with Federal agencies and health organizations to identify critical problems amenable to solution by the application of existing NASA technology.

Reader Feedback—We hope you find the information in *NASA Tech Briefs* useful. A reader-feedback card has been included because we want your comments and suggestions on how we can further help you apply NASA innovations and technology to your needs. Please use it; or if you need more space, write to the Manager, Technology Transfer Division, P.O. Box 8757, Baltimore, Maryland 21240.

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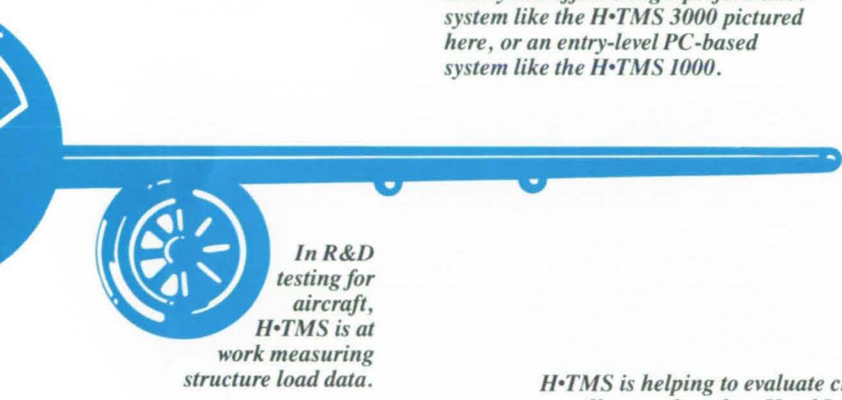
How test engineers are becoming heroes in data acquisition.

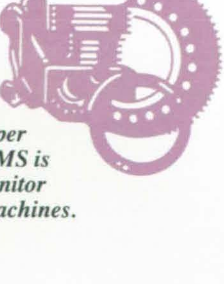
H•TMS is currently being used to test the hydraulics of cruise missile launch systems.

Honeywell offers a high-performance system like the H•TMS 3000 pictured here, or an entry-level PC-based system like the H•TMS 1000.



In R&D testing for aircraft, H•TMS is at work measuring structure load data.

H•TMS is helping to evaluate crash effects and analyze Head Injury Criteria for auto passenger safety.



In a variety of applications such as pulp/paper mills, H•TMS is used to monitor rotating machines.

H•TMS is monitoring turbines to detect alarm conditions and perform efficiency calculations.

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H•TMS is giving test engineers the unique ability to manage all phases of data acquisition within some of the world's largest and most innovative companies.

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Together, we can find the answers.

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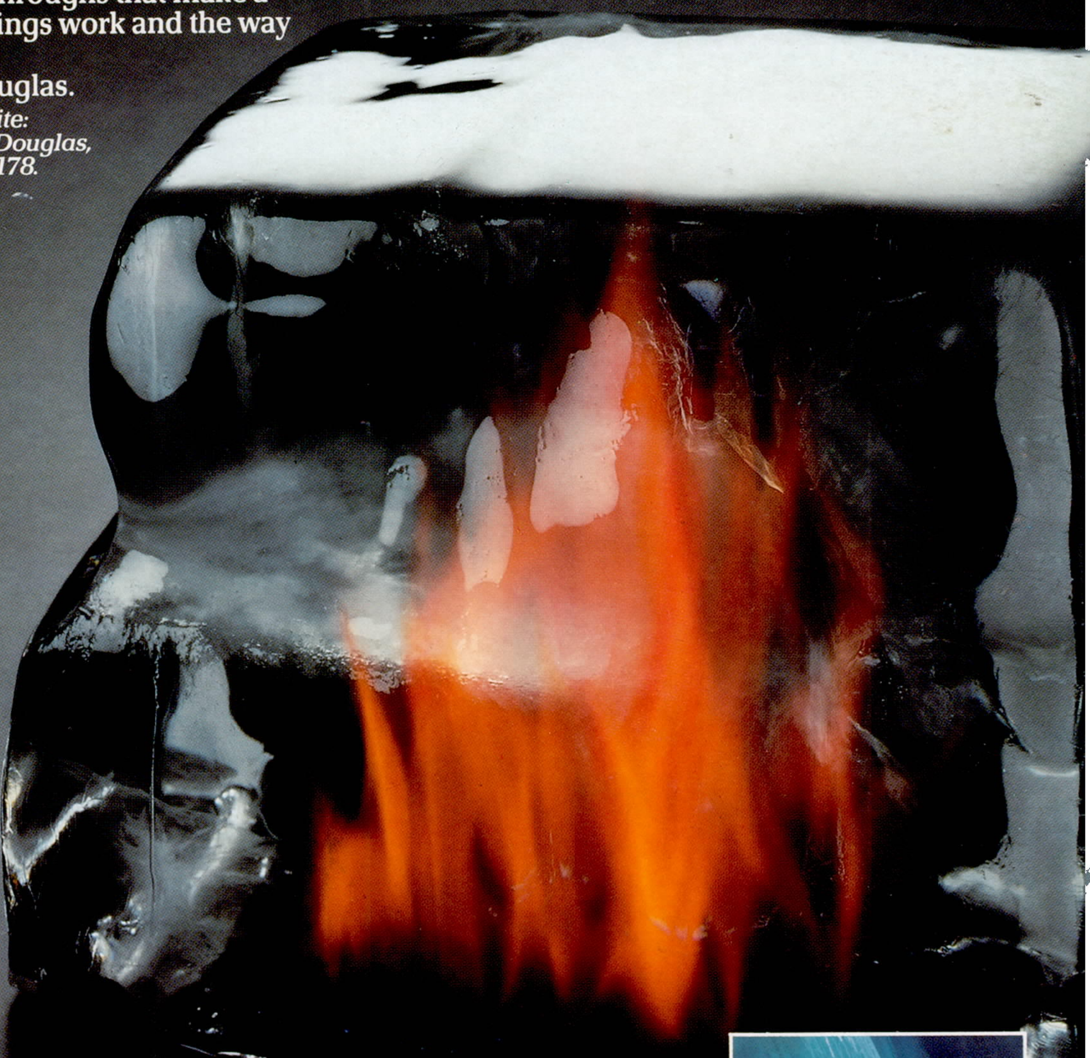

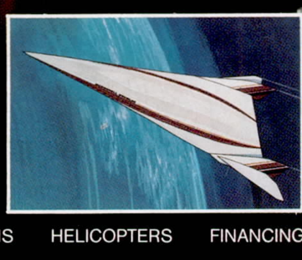

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