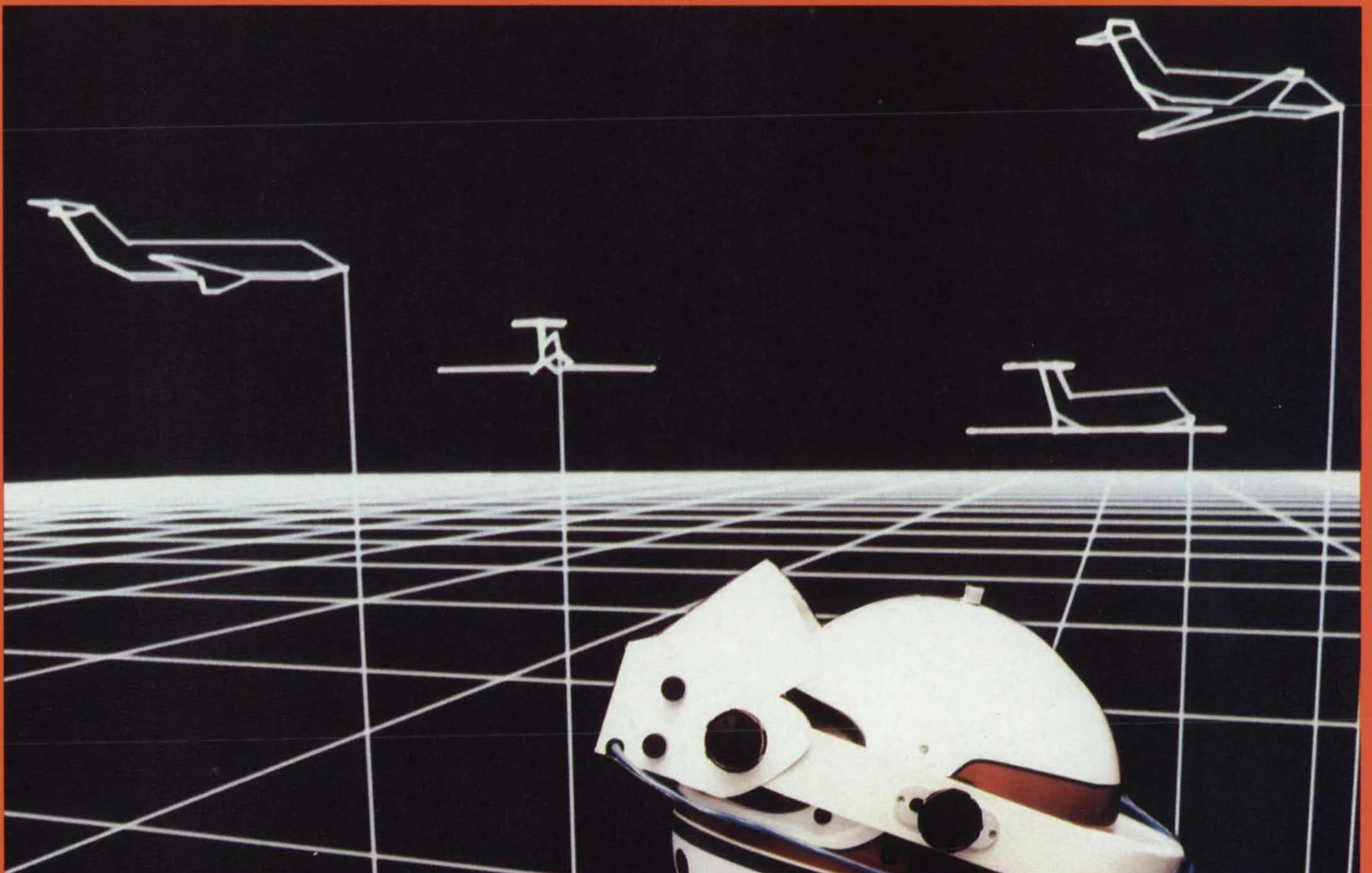
NASA Tech Briefs

Transferring Technology to
American Industry and Government

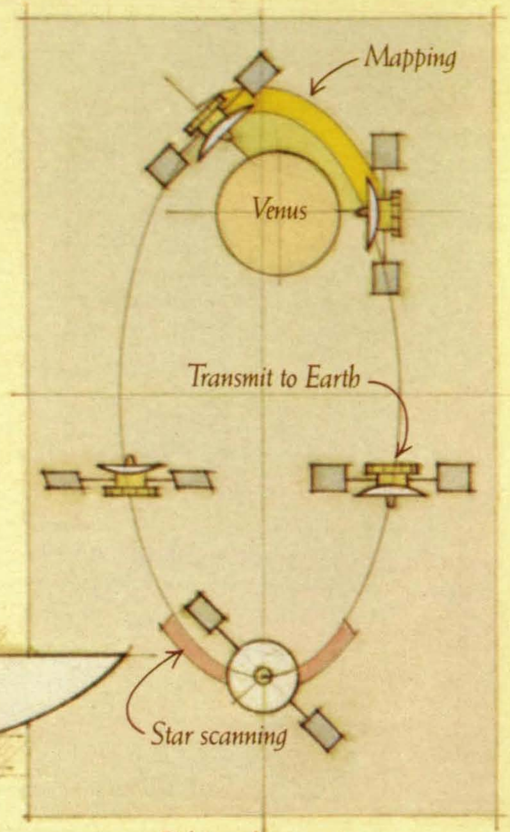
July/August 1988
Volume 12 Number 7



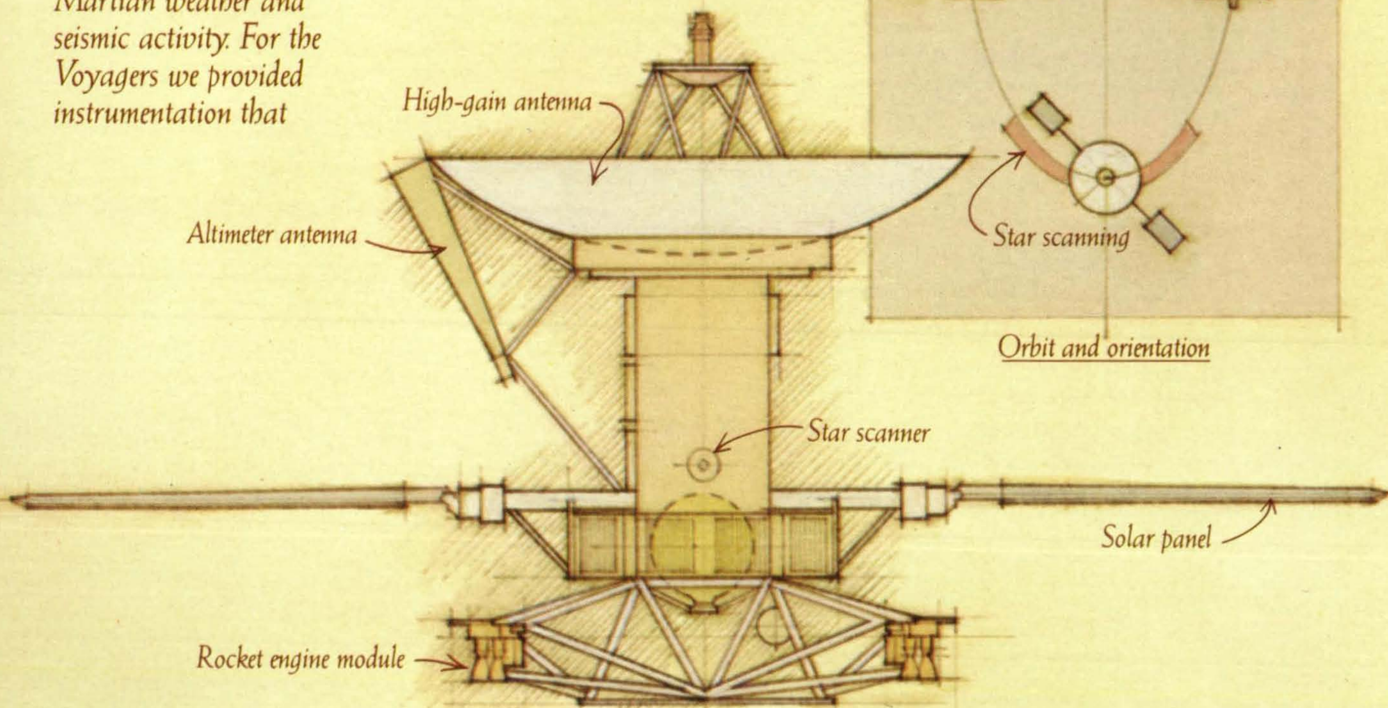
NASA's Virtual Workstation Shapes A VIVED Reality

In space: looking back to look forward.

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



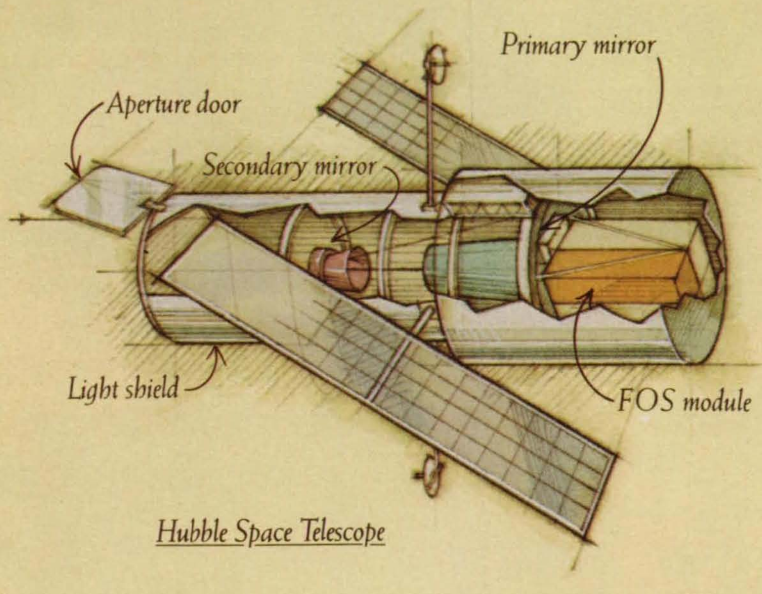
Orbit and orientation



Magellan Spacecraft

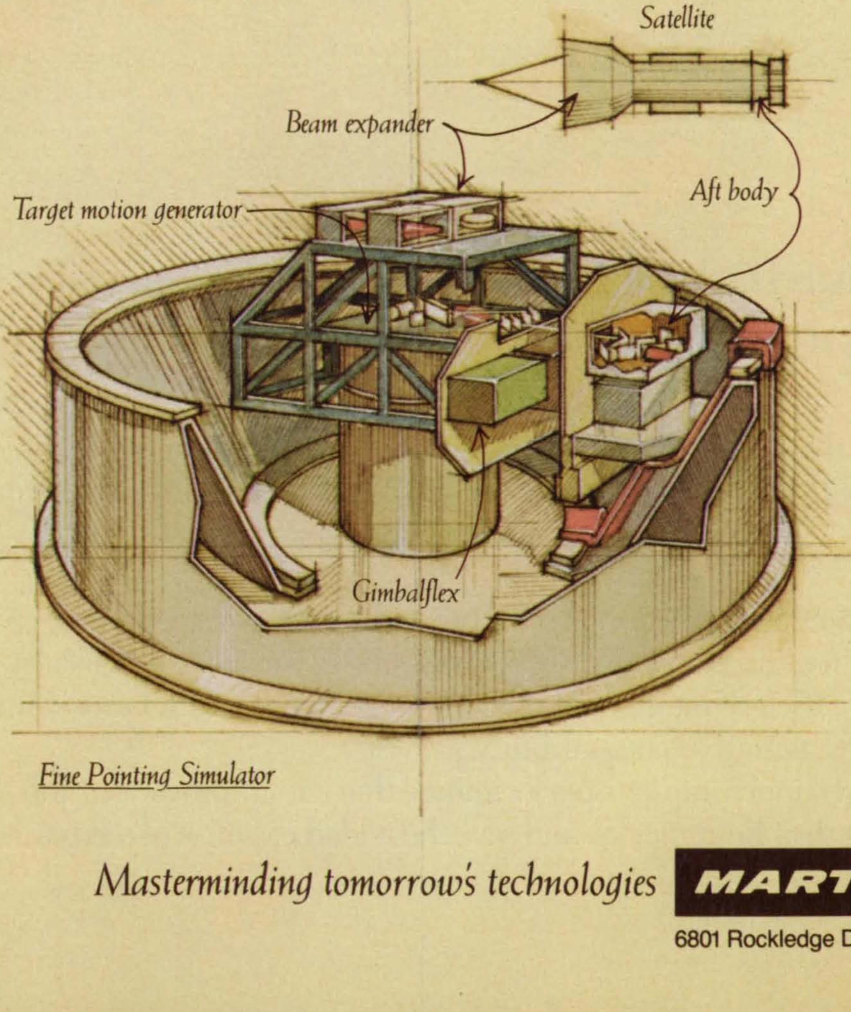
Mission: map Venus.

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



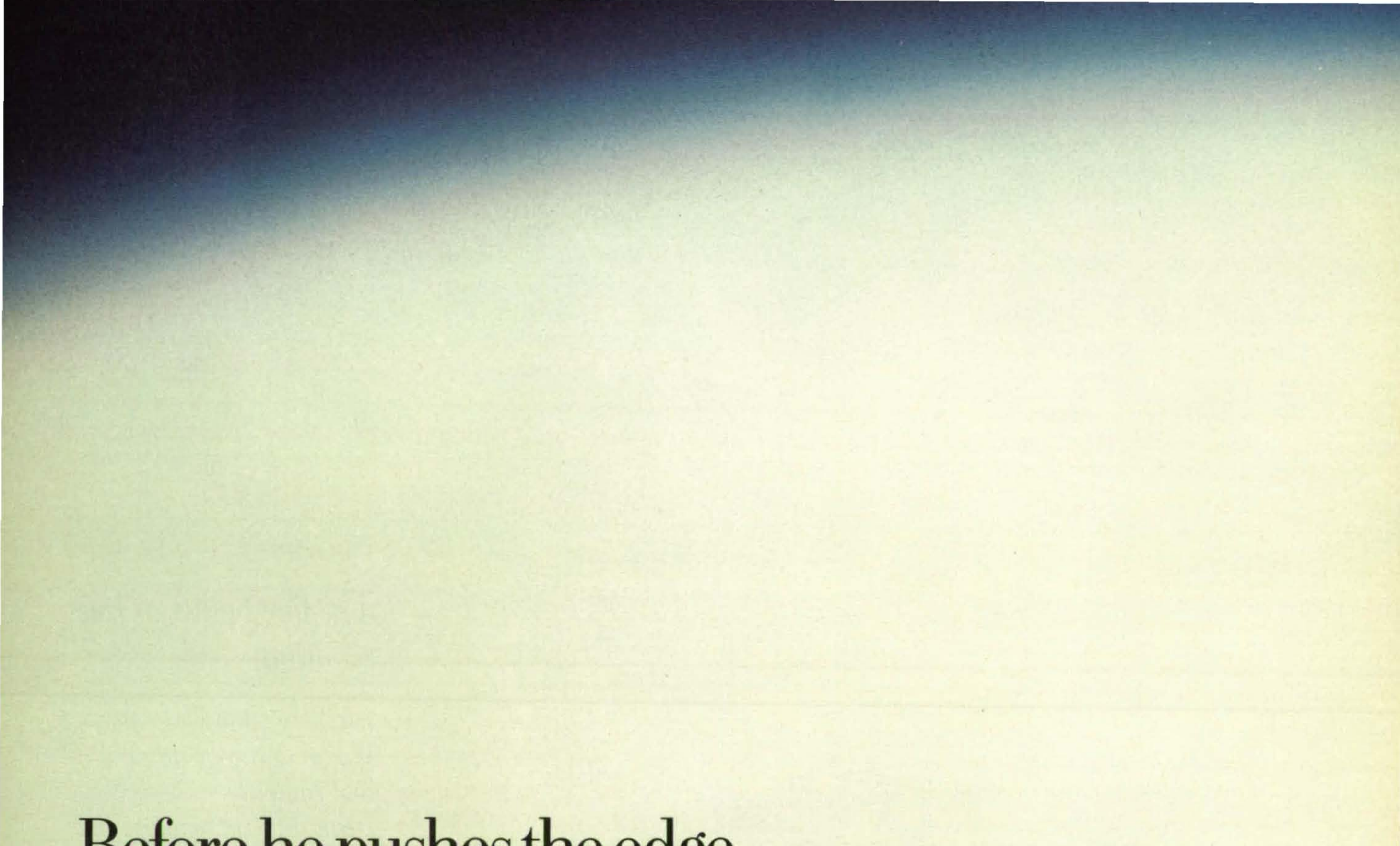
Viewing the infant universe.

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



The fine points of fine pointing.

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



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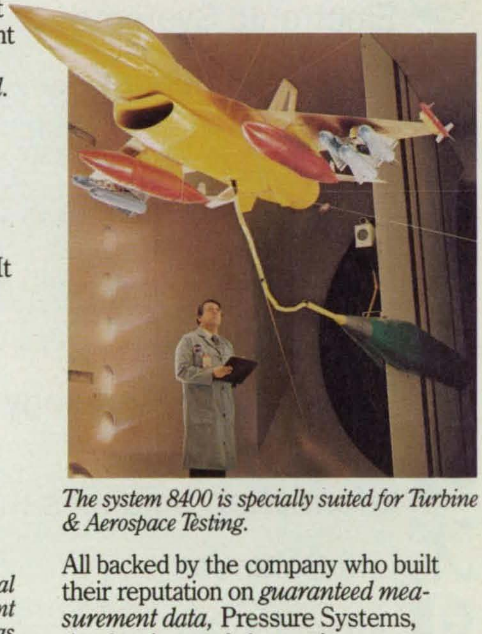

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National Aeronautics and
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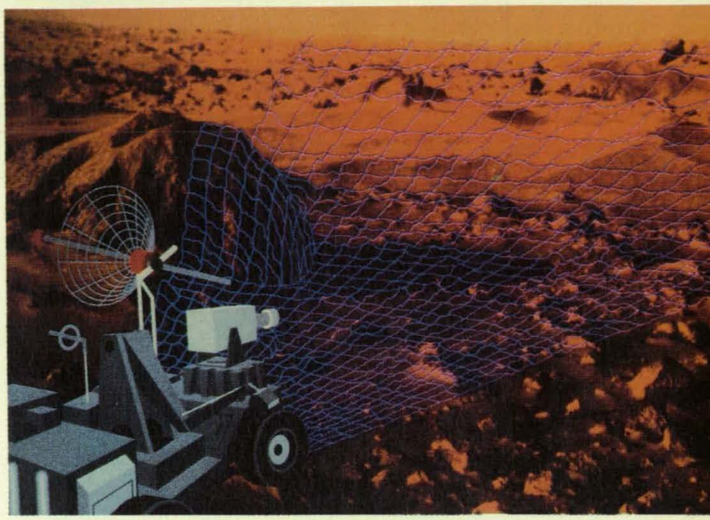
JULY/AUGUST 1988
Volume 12 Number 7

SPECIAL FEATURES



Computers may one day use image data captured by a Mars Rover to recreate the Martian surface on Earth, allowing humans to virtually explore Mars from the comfort of their homes. Turn to page 20. *(Photo courtesy NASA)*

TECHNICAL SECTION

DEPARTMENTS

Win a free stay at the United States Space Camp for you or your child. See page 14 for details. *(Photo courtesy U.S. Space Camp)*

On The Cover: Computer graphics imagery surrounds the wearer of a NASA-developed helmet called the Virtual Visual Environment Display (VIVED). VIVED combines three-dimensional graphics and sound to immerse the wearer in an "artificial reality." The simple graphics depicted on the cover only hint at VIVED's simulation capabilities; the device could potentially recreate entire cities or planets inside the helmet. See page 20. *(Photo courtesy NASA)*

ABP BPA

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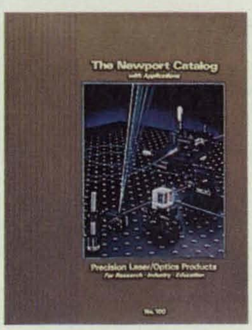

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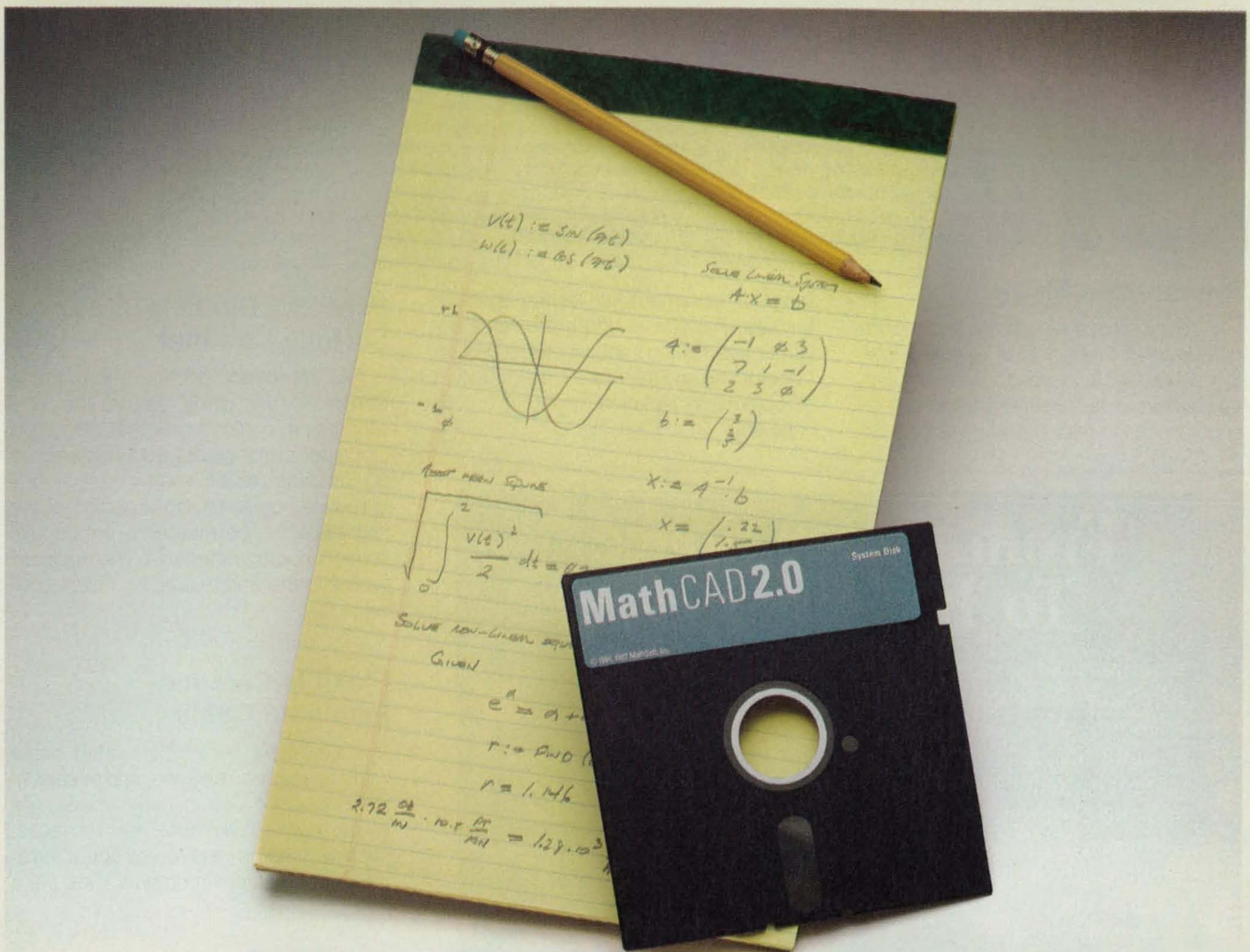
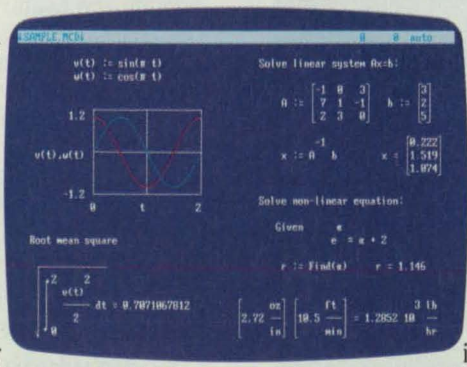


Your pad or ours?



If you perform calculations, the answer is obvious.

MathCAD 2.0.

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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 12). NASA's patent-licensing program to encourage commercial development is described on page 12.

Pressurized Sleeve

A fabric sleeve withstands a pressure difference of 8 lb/in.^{2} (55 kPa) while allowing the wearer fairly easy movement. Developed as a replacement for a space-suit sleeve, the new sleeve gives greater range of movement with lower restrictive torques. The sleeve offers the same advantanges in such applications as protective clothing and sleeves for manipulation of objects in isolation chambers. (See page 80).

Schottky Diode With Surface Channel

An improved configuration for a Schottky-barrier diode reduces the parasitic shunt capacitance that degrades diode performance at frequencies above 30 GHz. The parasitic shunt capacitance is reduced by removing a portion of the high-dielectric-permeability, conductive semiconductor material from a region adjacent to the anode contact finger. (See page 22).

Flexible Ceramic-Insulated Cable

A proposed ceramic-insulated cable withstands heat, radiation, and oxidation. Developed for use in outer space, the cable is also suitable for furnaces, nuclear reactors, and robots operating in hot radioactive environments. (See page 30).

Graphite/Epoxy Deicing Heater

A graphite/epoxy composite heater prevents and reverses the formation of ice on advanced composite surfaces of aircraft. The heater includes a graphite-fiber/epoxy composite as the heating element. This heater can be thin and highly electrically and thermally conductive and can conform to irregular surfaces. (See page 48).

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

HOW YOU CAN BENEFIT FROM NASA's TECHNOLOGY UTILIZATION SERVICES

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

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

How You Can Utilize **NASA's Industrial Applications Centers**—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 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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Indianapolis, IN 46204
Dr. F. Timothy Janis, Director
(317) 262-5036

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If you represent a public sector organization with a particular need, you can contact NASA's Application Team for technology matching and problem solving assistance. Staffed by professional engineers from a variety of disciplines, the Application Team works with public sector organizations to identify and solve critical problems with existing NASA technology. **Technology Application Team, Research Triangle Institute, P.O. Box 12194, Research Triangle Park, NC 27709.** ***Doris Rouse, Director,*** **(919) 541-6980**

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

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

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If You Have a Question... **NASA Scientific & Technical Information Facility** can answer questions about NASA's Technology Utilization Network and its services and documents. The STI staff supplies documents and provides referrals. Call, write or use the feedback card in this issue to contact: **NASA Scientific and Technical Information Facility,** Technology Utilization Office, P.O. Box 8757, Baltimore, MD 21240-0757. *Walter M. Heiland, Manager,* (301) 859-5300, Ext. 242, 243

Editorial Notebook

A Contest We're All Guaranteed To Win

A few months ago I read that several Congressmen suggested NASA contractors hire advertising agencies to help generate support for NASA because they weren't hearing much from their constituents and felt they didn't care. It's no secret that NASA's budget in constant dollars is about half what it was during the Apollo era. Nor is it a secret to anyone who is remotely familiar with *NASA Tech Briefs* that the benefits spun off through NASA's Technology Utilization Program have improved the quality of American life in myriad ways.

I wondered what we at Associated Business Publications could do to help spread the word. I've long been a believer that a few determined people can make a difference, so I wrote to every Representative, Senator, and Presidential aspirant asking them to state whether they were for or against maintaining a strong national space program.

Our politicians certainly reflect the general inertia of their constituents. The response rate was only eight percent, which means the odds are better than ten to one that neither of your Senators nor your Representative responded to the survey. None of mine did. (If you'd like a list of those who did respond, write to us and we'll send you the list.)

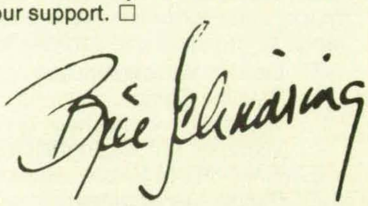
In total, I received 47 responses, all in favor of a strong space program. That leaves another 500 government decision-makers who did not respond. Which is why we need your help. From the thousands of feedback cards we read every month, we know that there are few Americans more aware of the benefits we have all obtained through the activity of NASA and its contractors than the readers of NTB. These feedback cards also attest that you're eloquent letter writers.

Therefore, we thought this would be an apt time to announce a writing contest in which everybody wins. In honor of Independence Day, and in the interest of continuing a long line of future Independence Days, we hereby announce a contest for the best letters in support of NASA and U.S. space exploration written to government leaders.

Here's how it works: Write a letter to the politician(s) of your choice, outlining your reasons for asking him or her to support NASA and the exploration of The Last Frontier. Then send us a copy of your letter(s). All letters received by August 31, 1988 will be judged by NTB's editorial board, and the winning letters will be published in the October issue. All letter writers will be listed on our *NASA Tech Briefs* Honor Roll, published in the same issue. We plan to send copies of each letter submitted to every Congressman on the Hill.

The grand prize winner will receive a tuition-free stay at the United States Space Camp. Second prize is a complete set of the NTB:BASE software library. Five runners-up will receive one free NTB:BASE category. Every reader who makes the honorable effort of writing a letter will get a certificate of honorable mention.

Gentlepeople, we are all responsible for what will or will not happen to our space program. We cannot afford to wait for the other guy to do it for us. So please, start those cards and letters flowing to the politicians. Send the original to the politician, and a copy to my attention at *NASA Tech Briefs.* Not only is this a contest wherein everyone who enters will get a prize, this is a contest in which every American will prove ultimately to be a winner. Thanks for your support. □



On the following page we've published excerpts from a recent speech by NASA Administrator Dr. James C. Fletcher and from an editorial by National Space Society President Ben Bova. Dr. Fletcher's warning on the consequences of cutting NASA's budget should sound the alarm for anyone interested in the preservation of our civil space program. And we hope Mr. Bova's words spur you to write your letter. . . today.

About The Contest

Deadline: August 31, 1988

Rules:

Write a letter to the politician of your choice, outlining your reasons for asking him or her to support NASA and the civil space program. Then send a copy of the letter, with your phone number, to the attention of Bill Schnirring at the following address:

NASA Tech Briefs
Letter Writing Contest
41 East 42nd Street, Suite 921
New York, N.Y. 10017

Prizes:

First prize is a tuition-free stay at the U.S. Space Camp, an educational camp that simulates an astronaut's training program. The winner will have the choice of attending the three day adult camp in Huntsville, AL or sending a child to a week-long camp in either Huntsville or in the Space Coast area of Florida. Second

U.S. Space Program At The Crossroads

Dr. James C. Fletcher
Administrator
National Aeronautics and
Space Administration

This may come as a surprise to you, but the nation's civil space program is facing extinction this year.

While I remain optimistic about the launch of the Space Shuttle this summer, I believe Americans must know that the long-term future of the space program hangs in the balance this year. The program's future rides on the outcome of current budget deliberations in Congress. And the outlook is grim.

The budget resolution approved by the House gives NASA a budget for fiscal year 1989 that falls way short of what the Administration has proposed. Should final Congressional action set the NASA budget at that level, the civil space program will be stopped in its tracks.

The budget levels being discussed on Capitol Hill would spell death to the Space Station, the key to our future in space. The Space Station will give the country a permanent presence in space and be the focus of our activities there through the 1990's and beyond. If we stop development, and we will have to if the budget is cut, the United States' civil space program will fall into disarray, and with it the prestige and leadership we worked so hard to gain. Major commitments to our Space Station international partners will have to abrogated. Advanced astronomy observatories designed to be serviced from the station will never get off the ground. And scientific research that could lead to new products and processes here on Earth will never take place.

In addition, the Space Shuttle will be able to operate at only a reduced flight rate in the years ahead. This would mean that the scientific and critical national security payloads waiting to be launched will fall even further behind at a time when the Soviet Union, Japan and our European allies are moving steadily ahead.

In his new National Space Policy, the President cited leadership in space as the country's basic goal. He backed that policy with a budget request for NASA that would ensure the space program recovers and begins to move out on the road to leadership in the decades ahead. That budget is not extravagant; it contains no whistles and bells. It merely allows NASA to do its job for now.

The NASA budget—less than one percent of the entire federal budget—is probably the best investment we can make as a nation. If we fail to make that investment, the fire and spirit will be gone from NASA and the space program will come to a grinding halt. If the United States, the richest nation on Earth, cannot afford a fraction of one percent of its budget for its future, then clearly it cannot afford to be a world competitor in space or on Earth.

I don't believe the American people want our country to fall into that position. But unless the people speak out, I'm afraid we stand to lose by default what we've so carefully and effectively built. □

Space Gets Lost In Presidential Shuffle

Ben Bova, President
The National Space Society

So far in the 1988 Presidential campaign, space has been a non-issue. There is little evidence that any of the candidates believes space is vital to the nation's present and future economic strength in the global marketplace, little evidence that they understand how we must strive to allow private enterprise to move unfettered into this new frontier, little evidence that they see the human race expanding into the solar system.

This is because politicians perceive that space is not an important issue to the voters. They perceive correctly. While most Americans are in favor of a strong space program, their support is at best lukewarm. They would gladly swap the space program for better law enforcement or garbage collection.

To the politicians and voters space is an expense, a drain on the treasury, a program that must be trimmed back in the largely delusional effort to control the national debt. None of them understands that space is the biggest, richest resource this nation has, more important economically than all of the coal, iron and other natural resources we possess. The technologies derived from space are already the backbone of our economy. Millions of jobs have been created by space-derived technologies and trillions of dollars have poured into the economy as a result.

We must seek out the key people in each candidate's organization and convince them of the importance of space. For we are not only electing a President this November. We are electing a third of the Senate and the entire House of Representatives. At the local and state level you can—you must— establish contact with the key people. Do that, and you will have accomplished the first step on the road to human settlement of the solar system. □

prize is a complete set of NTB:BASE, NASA Tech Briefs' PC-compatible database covering 25 years of NASA technology. Five runners-up will each receive one NTB:BASE category. All entrants will receive a certificate of recognition and will have their names published in the October issue. Winners will be announced in the same issue.

Where To Write:

To United States Senators:
United States Senate
Washington, D.C. 20510

To members of the House of Representatives:
United States House of Representatives
Washington, D.C. 20510

Presidential candidates can be reached at the following addresses:

Vice President George Bush
212 Capitol Bldg.
Washington, D.C. 20510

Governor Michael Dukakis
105 Chauncey Street
Boston, MA 02111

Reverend Jesse Jackson
30 West Washington Street
Suite 300
Chicago, IL 60602

When addressing a Congressman, the title "Honorable" should precede the name, as in the Honorable John Smith. For the letter's salutation, "Mr." or "Ms." is acceptable.

Remember: Send the original letter to the politician of your choice, and a copy to Bill Schnirring at NASA Tech Briefs.

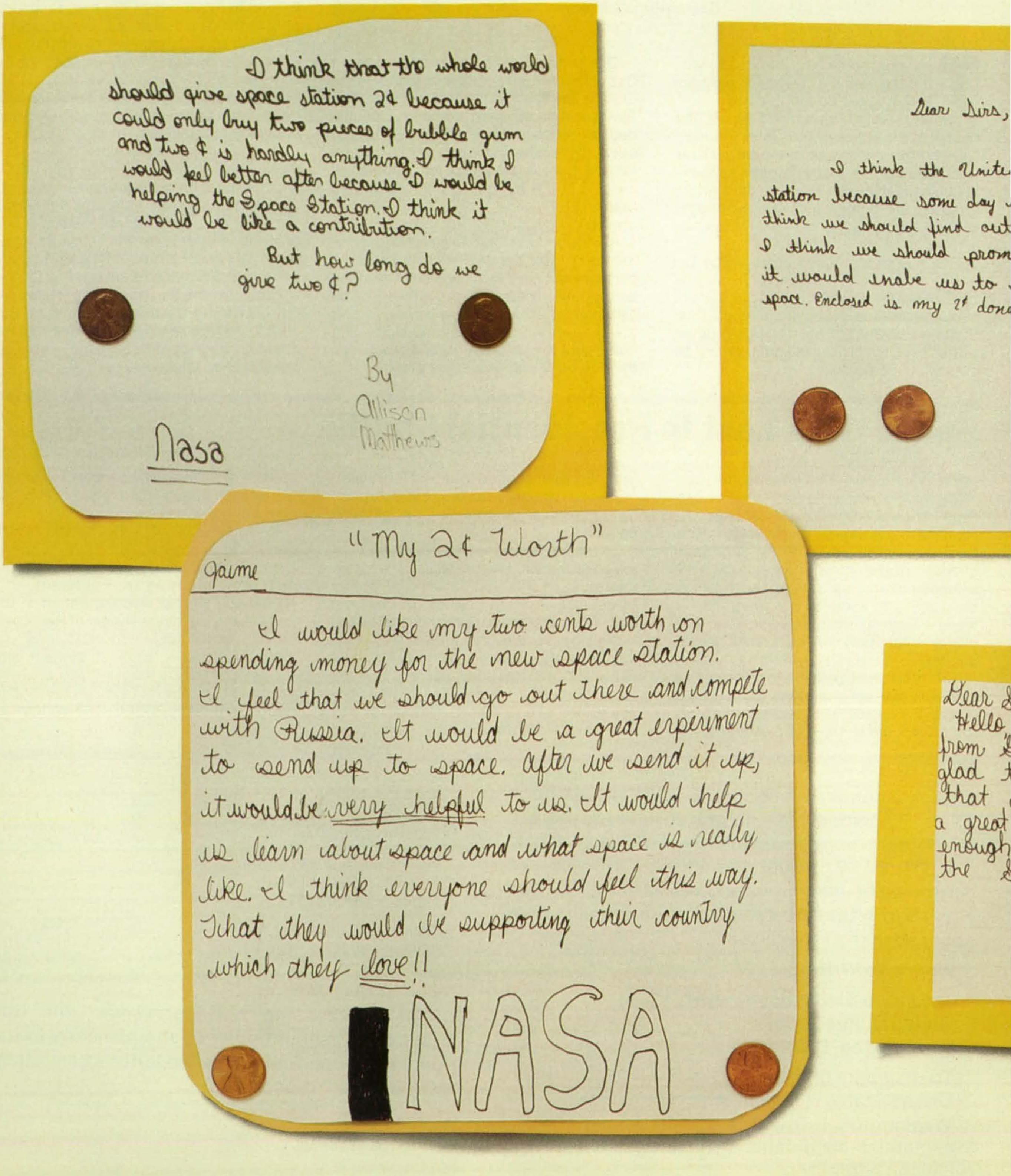
WHO'D SPEND TWO CENTS ON GUM WHE

Not these kids.

They've learned a manned Space Station will cost each one of us just two cents a day. And they know the payback in human benefits will be enormous.

With the special power of the young to imagine what could be, children are among the first to see the value of the Space Station. So when we ran a message in the newspaper supporting it, they wrote us with their two cents' worth—not only in words, but in cash.

We're sharing some of their thoughts here as a



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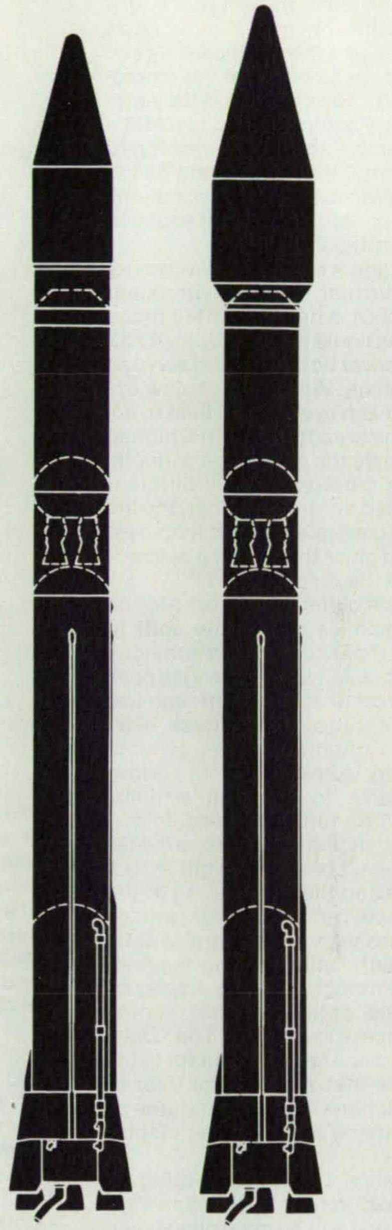

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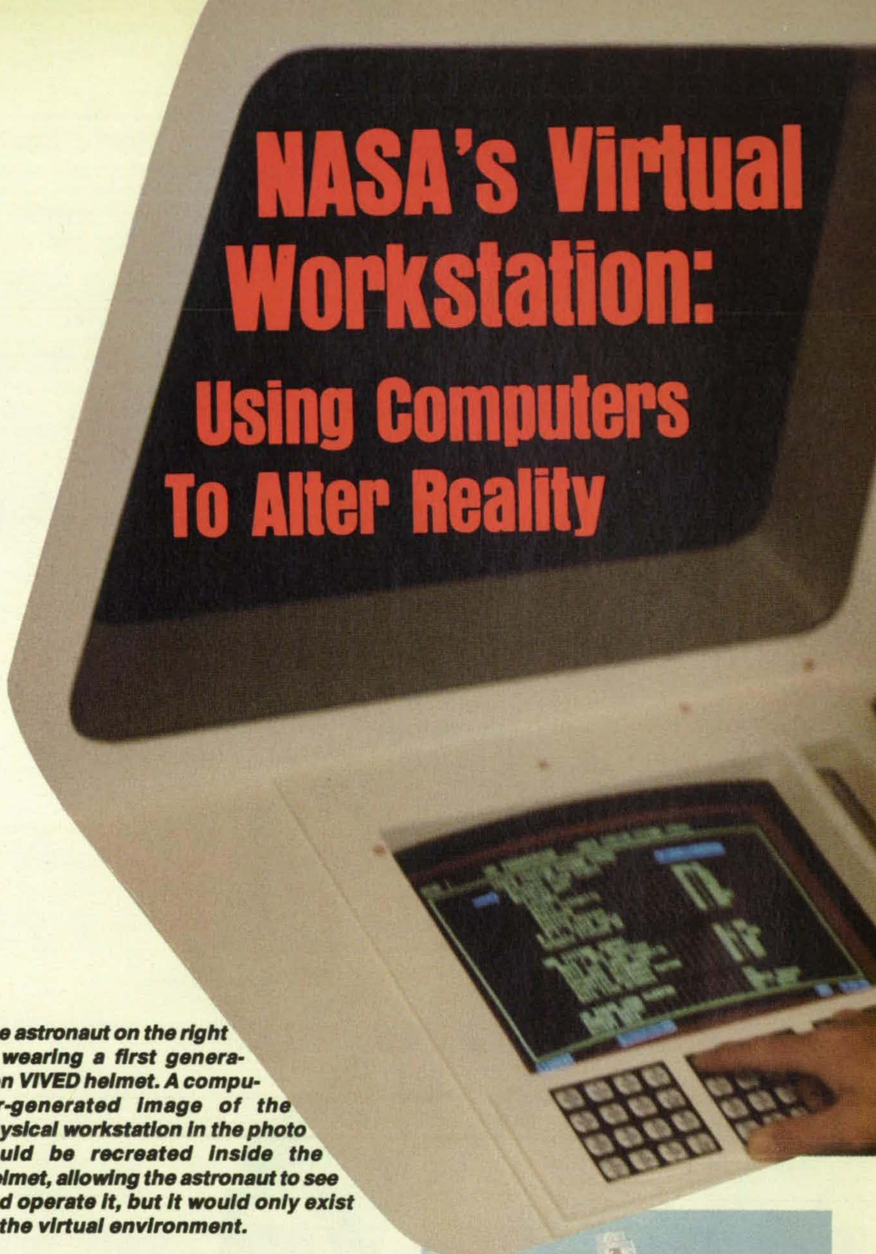
NASA's Virtual Workstation: Using Computers To Alter Reality



The astronaut on the right is wearing a first generation VIVED helmet. A computer-generated image of the physical workstation in the photo could be recreated inside the helmet, allowing the astronaut to see and operate it, but it would only exist in the virtual environment.

Imagine having the power to instantly change your environment; to be transported at will to the surface of the moon or a distant star, and yet never physically leave the comfort of your living room. Though it sounds like science fiction, environment-hopping is not only possible but may one day be as commonplace as a drive in the family car.

NASA is at the forefront of this emerging technology. Researchers in the Aerospace Human Factors Division at NASA's Ames Research Center have developed an experimental display system called the Virtual Workstation that combines three-dimensional graphics and sound to create an "artificial reality."

The invention's key hardware component is the Virtual Visual Environment Display (VIVED), a head-mounted monitor containing liquid crystal display (LCD) panels that cover both eyes and serve as viewing screens. Wide field-of-view optics expand each eye's visual field to approximate the breadth of normal human vision. To create the perception of depth, each screen receives slightly different imagery. When viewed together, the images fuse to generate a stereoscopic experience that gives the wearer a sense of being inside the display.

Other depth clues come from motion parallax, which describes the shift in background that occurs when someone looking at a point in space changes position. This effect is achieved through use of electronic sensors that track head position and orientation. The sensors match imagery to head movement, allowing the wearer to scan an artificial panorama as he turns his head. In one current program, the wearer experiences a walk in space. Looking straight ahead, he sees a Space Station floating in the distance, while over his shoulder a satellite drifts into view. Looking down, he views the Earth "miles" below his feet.

The user interacts with the display by wearing a fiber optic glove that records hand and finger movements. The "DataGlove" provides a hand-like cursor in the virtual space that permits the user to issue instructions to the computer by pointing at menu items on the display screen.

In cooperation with Ames, NASA's Jet Propulsion Laboratory (JPL) is building a robotic arm that will be controlled using a DataGlove. NASA hopes that one day a robot will be able to repair orbiting satellites by mimicking the hand movements of an astronaut inside the Space Station.

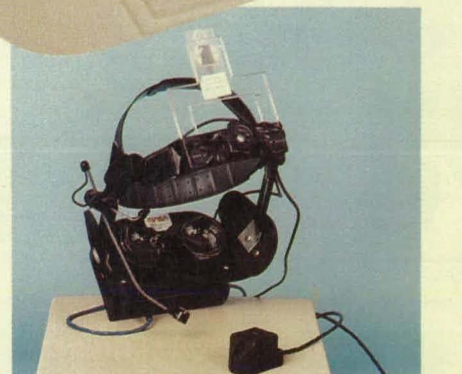
Thrifty Technology

Manned systems engineer Dr. Michael McGreevy developed the Virtual Workstation concept in 1984 while exploring ways to use simulation to improve the spatial relationship between humans and computers. "In the past," said Dr. McGreevy, "people had thought of simulators solely in terms of aircraft simulation for pilot training. Our research team wanted to create a personal simulator for such applications as high fidelity telepresence, the projection of human capability to remote locations like Mars or a moon base."

Working with a shoestring budget, the Ames group crafted a helmet-mounted prototype within a year. "We used mostly off-the-shelf components," explained Informatics support contractor James Humphries, who designed VIVED's video processors and helmet packaging. "For instance, the LCDs were pulled from commercial pocket televisions and modified to present video imagery to the optics. This enabled us to produce a low-cost device while at the same time advancing the state of wide field-of-view displays."

The workstation's first customers are likely to be design engineers. By merging VIVED displays with computer aided design software such as NASA's PLAID, which models Space Station modules, an engineer could walk through a computer design prior to building mock-ups, thereby saving both time and money in the refinement of designs.

Scientists in Ames' Numerical Aerodynamic Simulation (NAS) Program plan to use the NASA workstation to create virtual wind tunnels for computational fluid dynamics (CFD) research. "The problem with present wind tunnel simulations is that you're stuck looking at a two-dimensional screen," said McGreevy.



Above: The second generation viewer eliminates the helmet and features higher resolution LCDs. Also shown are the commercial head tracker and the first generation DataGlove, which allows the wearer to interact with the VIVED display.

"But by combining CFD graphics with the virtual environment, a scientist could walk out onto the wing of a hypersonic aircraft without getting blown away and study the effects of airflow on a design configuration. Wearing a DataGlove, he could reach out and touch the simulated wing, or give a command to change its scale."

A Nation Of Space Explorers

McGreevy is working with JPL scientists to develop the concept of virtual planetary exploration. "Planetary environments could be recreated on Earth by integrating photography from space missions into a computer graphics database," explained the Ames engineer. "This would democratize space exploration. Large groups of people on Earth could virtually explore Mars through image data captured by a rover traveling the Martian surface."

Live television images transmitted from space to personal simulators on Earth would allow entire nations to participate in manned space missions. "They could stand next to an astronaut on the Space Station's observation deck and see exactly what he's seeing," stated McGreevy. At the same time, the astronaut could strap on VIVED and enjoy a virtual visit with earthbound family and friends.

McGreevy said his invention could revolutionize education by creating a "global classroom." "Instead of lecturing to students about a foreign land, you would give them a virtual database and let them fly over and discover it for themselves. My guess is that their natural curiosity will cause them to always wonder what's over the next hill or in the next town. They'd no longer be just students but explorers."

Space Age Television

One potential spinoff of VIVED technology is three-dimensional television that would surround the viewer with imagery. "TV has gotten very jaded," commented McGreevy. "Who wants to watch a half-hour of other people's families acting strange? But if you could be transported to another country or period in history for those thirty minutes, well, it could really excite the television market. You're looking at a multi-billion dollar market for programming alone."

Television programs and stereo videotapes can already be shown on the VIVED screen, but without the head tracking feature. "To add tracking to wide field-of-view TV, you'd probably have to be off-line," said McGreevy. "It would be difficult to have the image change independently for each viewer."

The Next Step

McGreevy describes the Virtual Workstation as a "constantly evolving technology." The current monochromatic screens of 320 x 240 picture element dots, or pixels, will be replaced by 512 x 512 color screens by year's end. Ames researchers are also developing voice interaction and enhanced 3D sound capabilities, and plan to create a wireless display system to be tested aboard the Space Shuttle.

The next step, according to McGreevy, is to put the workstation into the hands of graduate students. "I want to turn this device loose and give it to students in the best engineering schools and research labs across the country," he said. "That will incite an explosion of the technology."

McGreevy predicts that within a decade personal simulators will be manufactured on a production line, in a form resembling ordinary eyeglasses. "They'll be made from a sandwich of transparent plastic lenses and LCD panels a fraction of an inch thick, yet will feature much higher resolution than possible today," he said. "And everyone will have one."

"In the next century," he added, "this invention could turn today's televisions and computer terminals into museum pieces." □

Electronic Components & Circuits

Hardware Techniques, and Processes

Schottky Diode With Surface Channel

Straightforward design changes improve performance and simplify fabrication.

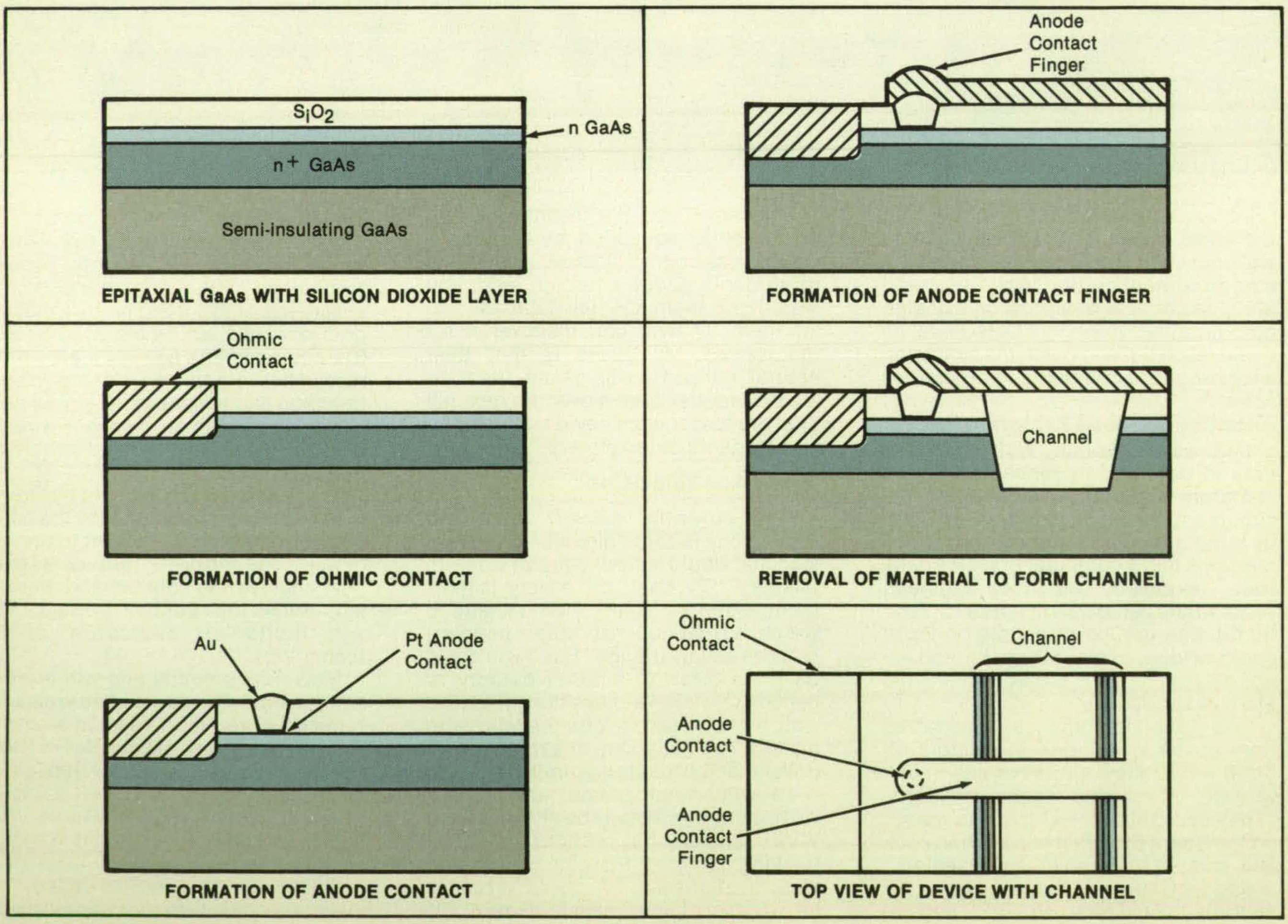
Goddard Space Flight Center, Greenbelt, Maryland

An improved configuration for a Schottky-barrier diode reduces the parasitic shunt capacitance. Schottky-barrier devices are used as microwave mixer and varactor diodes, and shunt capacitance degrades performance at the typical operating frequencies above 30 GHz.

The new configuration avoids the need for the special skill and equipment required to make contact-whisker Schottky-barrier diodes, which have low shunt capacitance. As in previous whiskerless designs, the contact whisker is replaced by an integrally-fabricated anode contact finger. However, the new configuration eliminates some of the difficulties encountered in the fabrication of prior, more-complicated whiskerless Schottky diodes of low shunt capacitance.

The parasitic shunt capacitance is reduced by removing a portion of the high-dielectric-permeability and conductive semiconductor material from a region adjacent to the anode contact finger. If not removed, this material would support conduction and displacement currents between the anode contact finger and the metal/semiconductor junction, thereby giving rise to a relatively high shunt capacitance.

The fabrication process and the configuration of the diode are shown in the figure. The first step is the prefabrication of an



The **Anode Contact Finger** forms a bridge over the channel from which material has been removed to reduce the parasitic shunt capacitance. The device is made by standard processing techniques that readily accommodate changes of design.

epitaxial wafer that consists of a semi-insulating GaAs substrate layer, an intermediate buffer layer of n^+ GaAs, and an upper layer of n GaAs. An insulating layer, preferably of SiO_2, is deposited on the upper n GaAs layer.

Space for an ohmic contact pad is formed by the use of a photoresist pattern and etching through the SiO_2 and, in some cases, the GaAs layers. The ohmic-contact metal is deposited by electroplating a sequence of tin, tin/nickel, and gold over the contact-pad area. The contact is alloyed, then overlaid with gold.

The anode region is defined by a photoresist pattern, and the anode window is etched through the SiO_2 layer. The photoresist is then removed, and a thin layer of platinum followed by a thicker layer of gold are plated into the anode window and onto the n GaAs to form the anode. A thin layer of chromium and another of gold are then sputtered onto the entire upper surface.

A photoresist is applied and patterned to define the anode contact pad and anode contact finger. A thick layer of gold for the pad and finger is then deposited. The photoresist is removed, and the thinner layers of gold and chromium are etched away, thus forming the anode contact pad and finger.

A photoresist is then applied and patterned to define the region from which the material will be removed to reduce the shunt capacitance. After the etching of the SiO_2 in this region, the photoresist is removed and the region is etched further, forming a channel that extends under the anode contact finger and into the semi-insulating GaAs layer.

This process allows for easy variation of the length, width, and thickness of the anode contact finger, thus enabling the design of the finger for optimum inductance. The size of the anode contact pad can also be varied easily for optimum coupling of power into the device. The depth and width of the channel can be adjusted to minimize shunt capacitance. Thus, design changes can be executed through routine processing variations to make devices that have parasitic series resistances and shunt capacitances approaching theoretical limits.

This work was done by William Bishop, Robert J. Mattauch, Kathleen McKinney, and Diane Garfield of the University of Virginia for **Goddard Space Flight Center**. *For further information, Circle 11 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Goddard Space Flight Center [see page 12]. Refer to GSC-13063.

RF Testing of Microwave Integrated Circuits

Fixtures and techniques are undergoing development.

Lewis Research Center, Cleveland, Ohio

Four test fixtures and two advanced techniques have been developed in a continuing effort to improve the radio-frequency (RF) characterization of monolithic microwave integrated circuits (MMIC's) in the K and K_a bands (18 to 26.5 and 26.5 to 40 GHz, respectively). RF characterization requires small-signal input/output scattering-parameter measurements by automatic vector network analyzers; these measurements are difficult at and above the K band because the increased effects of parasitics at these frequencies introduce inaccuracy and nonrepeatability, the mounting of MMIC's in conventional fixtures is time consuming, and it is difficult or impossible to couple test equipment to MMIC's in a nondestructive manner.

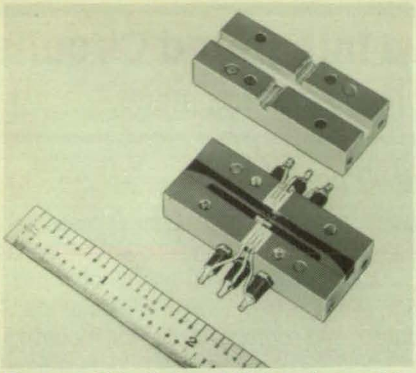


Figure 1. This **K_a-Band Fixture** is used to test MMIC submodules of a 30-GHz receiver. A 3-bit switched-line phase shifter is bonded to the fixture.

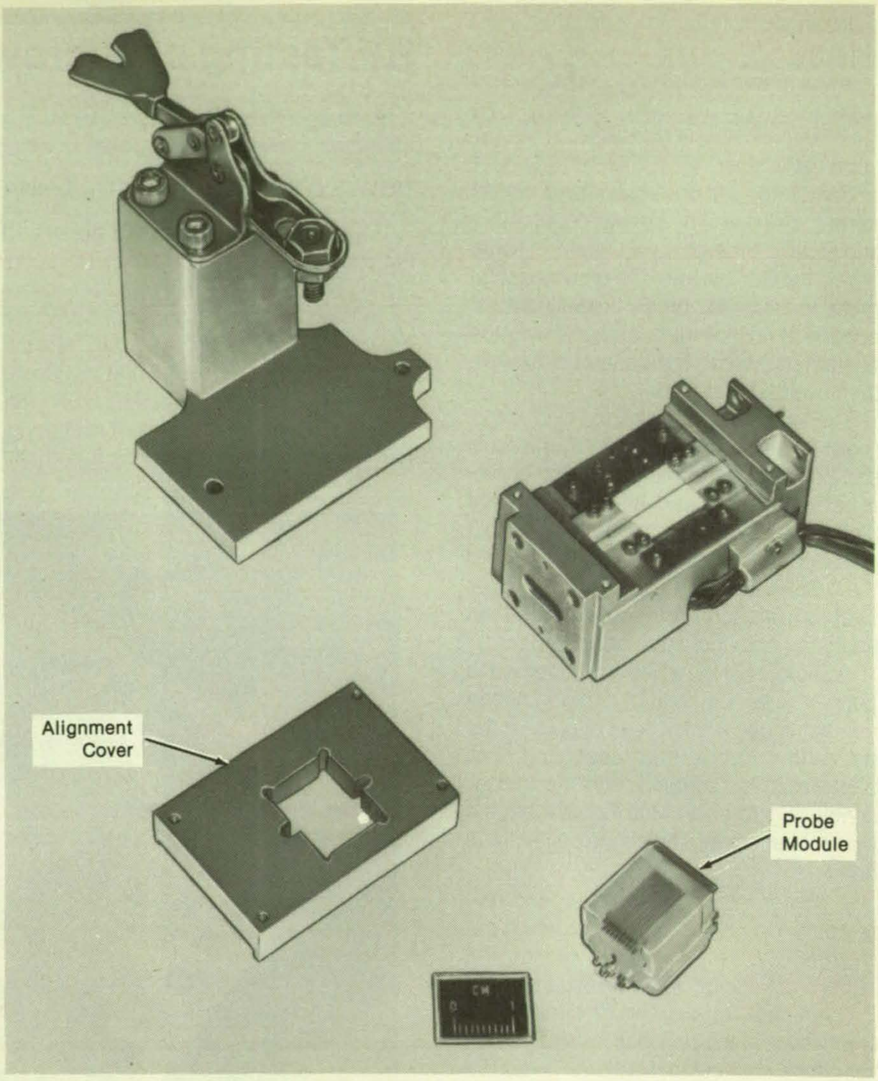


Figure 2. This **K-Band Fixture** is used to test packaged components of a 20-GHz MMIC transmitter. The alignment cover guides the probe module onto the MMIC.

The finline/waveguide test fixture shown in Figure 1 was developed to test submodules of a 30-GHz monolithic receiver. The fixture provides accurate and repeatable data. However, ribbon and wire bonds are needed to secure each MMIC, and skill is required to solder the MMIC to a carrier block in the fixture; consequently, testing is difficult, and it is almost impossible to reuse the MMIC after testing.

A "universal" commercially-manufactured coaxial test fixture was modified to enable the characterization of various microwave solid-state devices in the frequency range of 26.5 to 40 GHz. The coaxial-to-microstrip transition and its housing were replaced by a waveguide-to-microstrip transition and a suitable housing, which is compatible with the existing fixture while minimizing transition losses and eliminating resonant modes. Preliminary tests indicate problems with waveguide modes and nonreproducibility of characteristics.

The probe/waveguide fixture of Figure 2 is compact, simple, and designed for the nondestructive testing of a large number of MMIC's. All four scattering parameters have been measured on this fixture. Although the measurements were less repeatable than they were on other fixtures, they are expected to improve considerably with the addition of a precise probe-alignment cover.

Another nondestructive-testing fixture includes a cosine-tapered ridge, to match the impedance of the waveguide to that of the microstrip. Although contact is achieved through a critical pressure fit between the ridge and the chip carrier, this fixture promises high repeatability due to the elimination of ribbon bonds and of the need for a spring mechanism.

One of the emerging techniques for characterization is microwave-wafer probing. A wafer probe is essentially an adapter from coaxial cable to bonding pads and performs about as well as a normal SMA connector. However, accuracy can be enhanced significantly through the use of chip-level impedance standards. A "de-embedding" procedure requires the use of short, open, and load standards for one-port characterization and an additional through connection and isolation standards for two-port characterization.

The second emerging technique is electro-optical sampling. Short-pulse lasers and ultra-high-speed photoconductors are used to generate wideband electronic pulses to provide direct electronic sampling on GaAs devices or integrated circuits. The technique provides characterization without bonding of the device or circuit under test and can yield measurements at frequencies from 2 to 100 GHz.

This work was done by R. R. Romanofsky, G. E. Ponchak, K. A. Shalkhauser, and K. B. Bhasin of **Lewis Research Center**. *Further information may be found in NASA TM-88948 [N87-22065/NSP], "RF Characterization of Monolithic Microwave and mm-Wave IC's."*

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-14639*

Image-Method Gain Measurement With Mismatch

A new formula accounts for multiple reflections.

Lewis Research Center, Cleveland, Ohio

An equation has been derived for measurement of the absolute gain of a microwave antenna by the image method where the antenna is mismatched with its waveguide. While the image method (see figure) is simple to use, up to now its ac-

curacy has depended on the assumption of a perfect match.

The perfect-match formula for absolute-gain measurements is

$$|\Gamma|^{-1} = 8\pi R/G\lambda$$

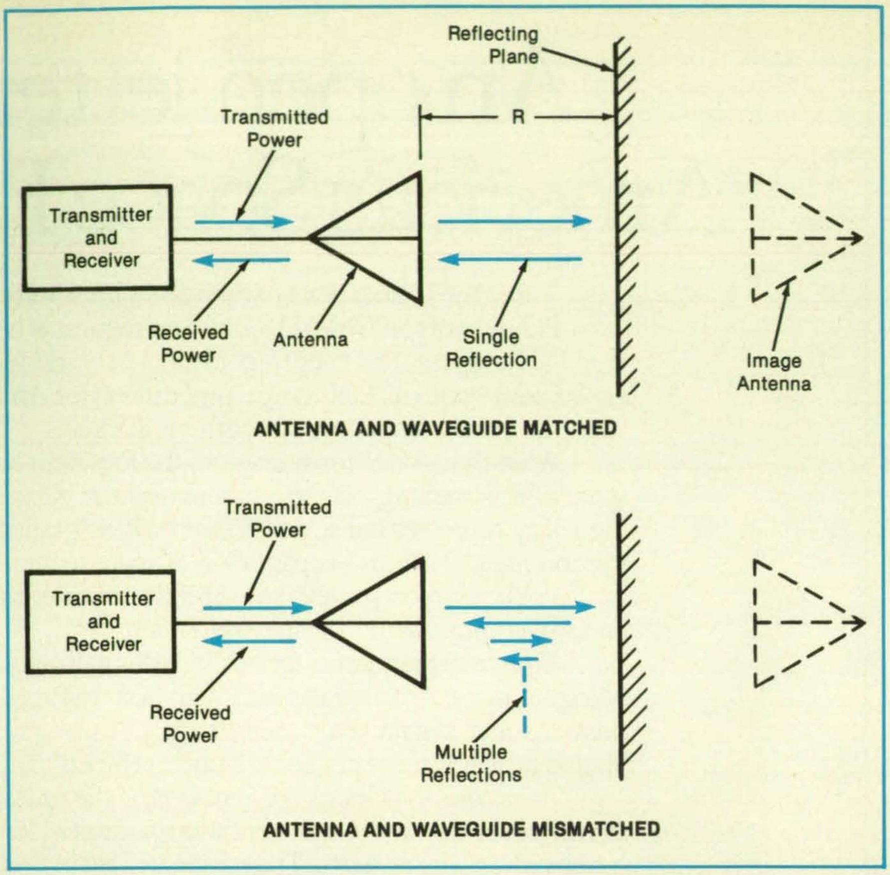
where Γ^2 is the ratio of received power to transmitted power, R is the distance from the antenna to the reflecting plane as shown in the figure, λ is the wavelength, and G is the gain. To obtain G, it is first necessary to measure the received and transmitted powers at various distances R to obtain a plot of $1/|\Gamma|$ versus R. The slope of the mean straight line interpolated through this plot is $8\pi/G\lambda$, from which G is then easily calculated.

If the antenna and waveguide are mismatched, then some of the received power is reflected from the waveguide/antenna junction and sent out again along with the transmitted power. A portion of this reflected power is returned to the antenna in a series of reflections of ever-decreasing power. When the effects of the multiple reflections are included, the gain-measurement formula becomes

$$|\Gamma - \Gamma_o|^{-1} = 8\pi R/G\lambda(1 - |\Gamma_o|^2)$$

where Γ_o is the reflection coefficient of the waveguide/antenna junction and it is assumed that the imaging plane is a perfect reflector.

The formula was tested by applying the image method to two antennas having previously known gains of 15.0 dB at 22 GHz and 23.9 dB at 20 GHz, respectively. Using the formula, the image-method gains were 14.65 dB and 23.98 dB, respectively.



In the **Image Method** an antenna is placed facing its image in a reflecting plane. The power transmitted by the antenna and the portion of the transmitted power received by the antenna after reflection from the plane are measured at various distances *R*.

This work was done by Richard Q. Lee and Maurice F. Baddour of **Lewis Research Center**. *Further information may be found in NASA TM-88924 [87-16968/NSP], "Absolute Gain Measurement by the Image Method Under Mismatched Condition."*

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-14555

Hot-Film Anemometer for Boundary-Flow Transitions

A temperature-compensated instrument yields data at subsonic and supersonic speeds.

Ames Research Center, Moffett Field, California

An improved temperature-compensated hot-film anemometer detects aircraft boundary-layer transitions at transonic speeds over a range of altitudes and speeds. In previous experiments, the sensitivity of a hot-film anemometer varied with changes in the speed and altitude of the aircraft. During extremes of high speed at low altitude or low speed at high altitude, the anemometer output saturated, resulting in the loss of data on the flow transition. The new anemometer corrects for this effect by measuring the local total temperature (the ambient temperature at a stagnation point) and heating the hot-film gauge to a fixed differential of 90 °C above the total temperature. The configuration of the circuit and electrical shielding of the new instrument also improve the quality of the measured data by increasing the ability of the anemometer amplifier to reject noise.

The basic instrument employed a hot-film gauge with a bridge circuit to maintain a constant film temperature. The new instrument (see figure) adds an external temperature-compensating resistor to maintain the film at the constant temperature differential rather than at constant temperature. As the airflow varies, so does the amount of heat carried away from the film. Thus, the amplifier output gives an indication of the flow past the hot film. When a transition of the boundary layer is encountered, the amplitude and frequency of the dynamic voltage output rise sharply. The steady-state voltage changes correspondingly.

The hot-film gauge and the temperature-control resistor are mounted on the surface of the aircraft. Both components are wired through the same cable to the electronic circuitry inside an instrumentation fin on the aircraft. The common side of each is connected to the cable shield, which is grounded inside the electronic housing to increase the rejection of noise by the amplifier.

Several maneuvers were flown to demonstrate the characteristics of the temperature-compensated anemometer. Constant-mach-number and constant-dynamic-pressure ascents and descents were flown. Altitudes ranged from 5,000 to 40,000 ft (1.5 to 12 km), mach numbers from 0.7 to 1.8, and dynamic pressures from 300 to 600 lb/ft^2 (2 to 4 MPa). The sensors survived rapidly passing shock waves as well as high dynamic pressures.

This work was done by Harry R. Chiles and J. Blair Johnson of **Ames Research Center**. *Further information may be found in NASA TM-86732 [N85-33121/NSP], "Development of a Temperature-Compensat-*

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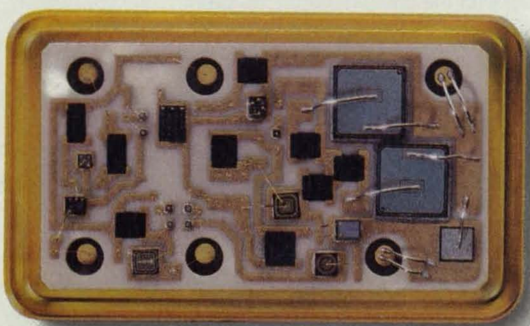
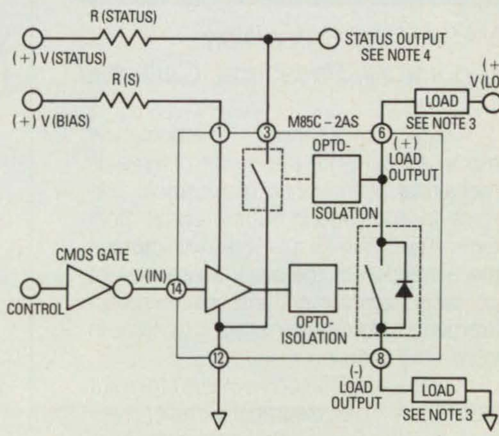


PART #M85C-2AS

ELECTRICAL CHARACTERISTICS (–55°C to +105°C unless otherwise noted)				
	Min	Max	Units	
Bias Voltage (V_{BIAS})	3.8	32	V_{DC}	See Note 1
Bias Current (I_{BIAS})		15	mA	$V_{BIAS} = 5V_{DC}$
Control Voltage (V_{IN})	0	18	V_{DC}	
Control Current (I_{IN})		250	μA	$V_{IN} = 5V_{DC}$
Turn-Off Voltage	3.2		V_{DC}	–55°C to +25°C
$V_{IN(OFF)}$	2.8		V_{DC}	+25°C to +105°C
Turn-On Voltage		0.5	V_{DC}	–55°C to +25°C
$V_{IN(ON)}$		0.3	V_{DC}	+25°C to +105°C
Continuous Load Current		2.0	A	–55°C to +25°C
I_{LOAD}		400	mA	+105°C
Output Trip Current (I_{TRIP})	8 (TYP.)		A	+25°C, 100 ms
Continuous Load Voltage (V_{LOAD})		60	V_{DC}	
Output Leakage Current (I_{LEAK})		2	mA	
On-Resistance (R_{ON})		0.28	Ohms	
Turn-On Time (T_{ON})		3.0	ms	
Turn-Off Time (T_{OFF})		1.0	ms	
Status Voltage (V_{STATUS})	1	18	V_{DC}	
Status Current (I_{STATUS})		0.6	mA	See Note 2

Notes:
1. Series resistor is required for bias voltages above $6V_{DC}$. $RS = (V_{BIAS} - 5\,V_{DC})/15$ mA
2. A pull up resistor is required for the status output. $R_{STATUS} = V_{STATUS}/600$ μA
3. Output will drive loads connected to either terminal (sink or source).
4. Status output is low when the load output is off.



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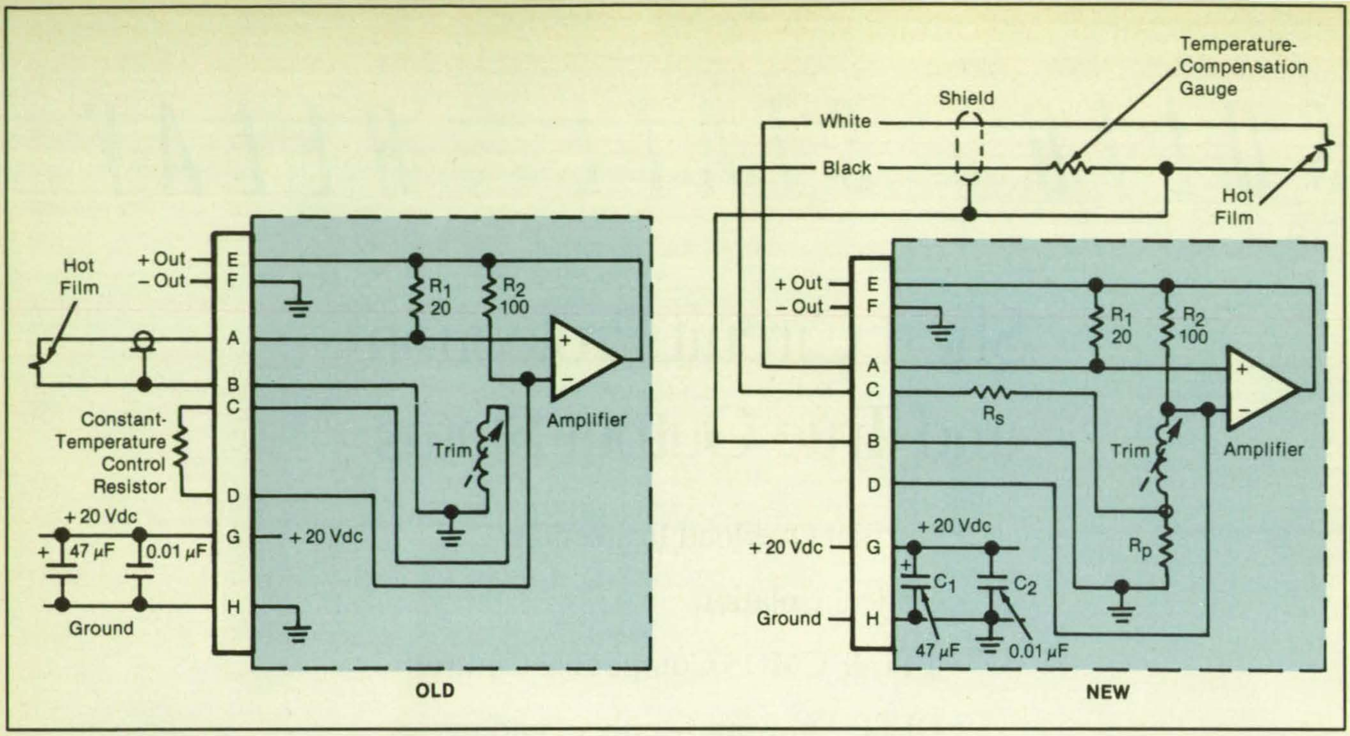

Old and New Anemometers are compared. Modifications in the new version include the addition of the temperature-compensation resistor and resistors R_s and R_p in series and parallel with the compensation device.

ed Hot-Film Anemometer System for Boundary-Layer Transition Detection on High-Performance Aircraft."

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Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center [see page 12]. Refer to ARC-11811.

Formula Gives Better Contact-Resistance Values

Lateral currents in the contact strips are taken into account.

NASA's Jet Propulsion Laboratory, Pasadena, California

A quasi-two-dimensional, mathematical model accounts for the effects of three-dimensional distributions of electrical currents in and around square ohmic contacts. The "Thin-Film" model will improve the extraction of the areal resistivities of contacts from current and voltage measurements of four-terminal test structures in integrated circuits.

In a four-terminal contact-test structure (see Figure 1), an electrical current I is applied through taps on the upper and lower conducting strips, while the voltage V_K across the contact is measured via side taps connected to the conducting strips. Because some of the current flows laterally in the strips around the narrower square contact, the measured contact resistance $R_K = V_K/I$ is larger than the true contact resistance $R_I = \varrho/L^2$ (where ϱ is the areal contact resistivity and L is the width of the square).

In the Thin-Film model, the upper con-

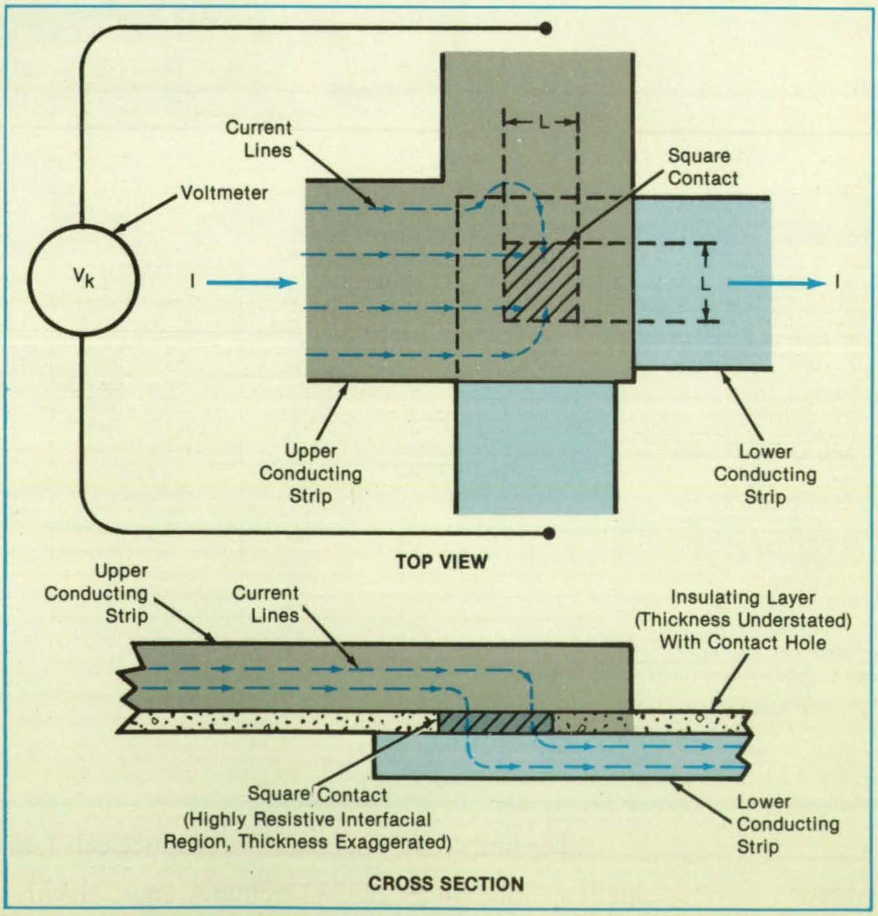

Figure 1. **Four-Terminal Test Structures** like this one are added to integrated circuits to enable the measurement of interfacial resistivities of contacts between thin conducting layers.

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AMC-230

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ducting strip (e.g., metal) is treated as an equipotential surface. The lower conducting strip (e.g., doped semiconductor) is treated as two-dimensional. An equipotential core smaller than the contact is considered to be embedded in the lower conducting strip, connected to the upper strip through a lumped resistance of R_I (see Figure 2). The last two features model horizontal current flow under and vertical current flow in the actual contact; i.e., a thin but highly resistive layer between the conducting strips (Figure 1).*

The current is introduced to the lower conductor at the left, far from the contact (Figure 2). While the current through the back edge of the contact is neglected, the currents through the front and side edges are analyzed by dividing the structure into three regions. No current is allowed to flow between regions. Current is considered to be injected into those regions through long feeding strips and, therefore, to be distributed according to the width of each strip.

The resulting potential distribution in the side region with the voltage tap is found by conformal mapping. The potential at the end of this tap, referred to the core zone, is $V_S = R_S I$, where R_S is given as a function of contact size L, width and sheet resistance of the lower strip, and the areal resistivity ϱ itself.* From Figure 2 follows

$$R_K = R_S + R_I$$

and, hence,

$$\varrho = L^2(R_K - R_S)$$

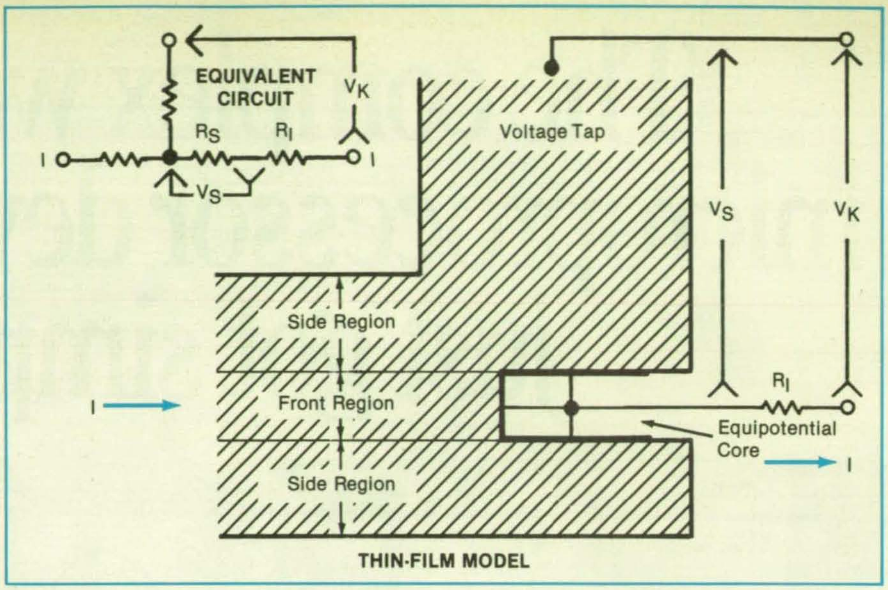


Figure 2. The **Thin-Film Model** is a simplified quasi-two-dimensional potential model that accounts adequately for the complicated three-dimensional, nonuniform current densities in the test structure of Figure 1. The effects of nonuniformity caused by lateral current flow in the strips are summarized in the equivalent resistance R_S and voltage V_S.

This equation must be solved iteratively. However, the solution converges rapidly: a FORTRAN program on a VAX (or equivalent) computer requires only about 0.3 s of central-processor time.

The model has been used to analyze square contacts of AuGeNi/GaAs. The areal resistivities of the contacts were found to be 2 to 8 times lower than extracted previously (without subtraction of R_S) and independent of contact size in the range of 1.5 to 10 μm.

*U. Lieneweg and D. J. Hannaman, "New Flange Correction Formula Applied to Interfacial Resistance Measurements of Ohmic Contacts to GaAs," IEEE Electron Device Letters, in print.

This work was done by Udo Lieneweg and David J. Hannaman of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 135 on the TSP Request Card.* NPO-17096

Flexible Ceramic-Insulated Cable

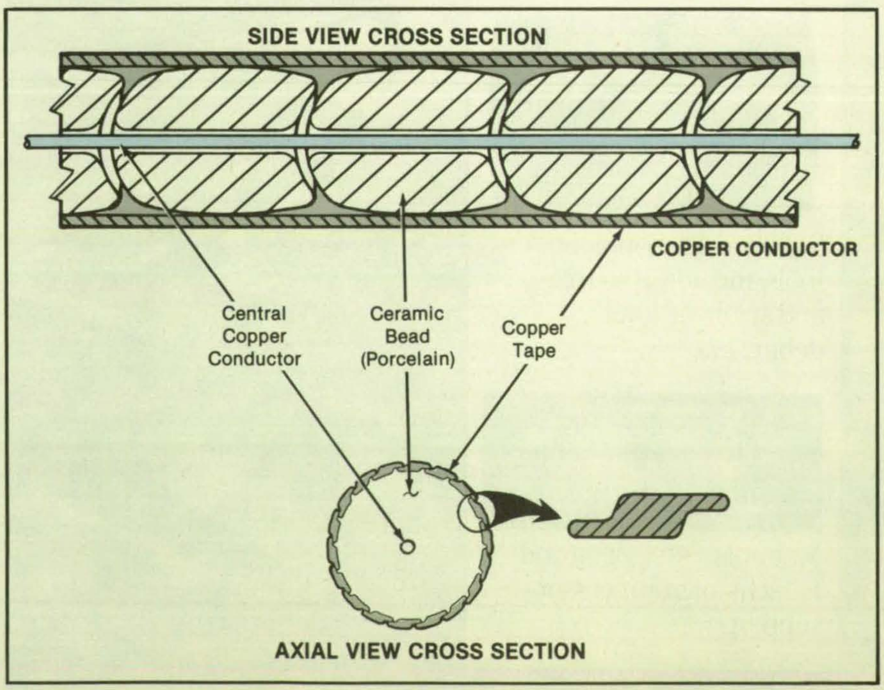
The cable withstands heat, radiation, and oxidation.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed ceramic-insulated cable would be flexible, would protect its metal conductor from ionizing radiation, and would resist high temperatures. Developed for use in outer space, the cable is also suitable for furnaces, nuclear reactors, and robots operating in hot, radioactive environments — in dismantling aging nuclear power plants, for example.

The cable would include a central conductor of copper surrounded by ceramic beads shaped so that their ends slide on each other, thus allowing the cable to flex (see figure). Two layers of copper tapes would be wrapped diagonally around the beads to absorb or deflect ions, electrons, protons, and electromagnetic radiation. An indium tin oxide coating on the surface of the outer tape would protect against oxidants.

To ensure reliable service at temperatures up to 800 °C, copper was selected as the conductor rather than aluminum because the former has a higher melting point. The insulating beads would be made of a porcelain that offers high dielectric



Ceramic Beads would electrically insulate a copper conductor from a sheath of copper tape.

strength, high electrical volume resistivity, and low dielectric loss factor.

The beads would be fabricated by casting. The central hole for the copper conductor could be drilled by a laser beam. The ends of the beads would be finished by grinding and polishing to provide smooth sliding surfaces for adjacent beads. The ends of the central holes would be rounded so that the conductor could flex easily in the beads. Lubricants, which would deteriorate in a hot, radiation-filled environment, would not be used. All the beads along a cable would be identical except for those at the ends of the cable, which would be slotted to hold the ends of the tapes.

Each tape would be wrapped at an angle of 30° to 45° with a small amount of slack to prevent binding. To prevent the formation of gaps during flexing, each tape would overlap each adjacent tape by about one-eighth inch (3 mm).

For service at higher temperatures, the tapes could be made of tantalum instead of copper. In addition, for added tensile strength, a wire of metal that does not soften as much as copper does in the range of operating temperatures could be twined around the copper core or around the ceramic beads.

This work was done by Frank L. Bouquet of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 113 on the TSP Request Card. NPO-16917*

Acoustical Convective Cooling or Heating

A small, efficient ultrasonic device circulates a fluid.

NASA's Jet Propulsion Laboratory, Pasadena, California

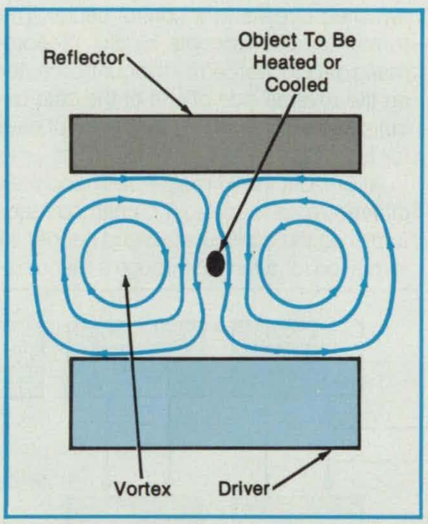
A device provides convective cooling or heating by acoustical streaming. It produces vortexes in a small volume in which a liquid or gas flows at speeds up to about 50 meters per second. It employs no fans or rotors. Conceived to generate convection for heating or cooling electronic equipment in zero gravity, where there is no natural convection, the device can also be used on Earth to apply localized or concentrated cooling to individual electronic components or other small parts.

With suitable design, the device can direct convection in a small, localized volume and can control the rate of cooling or heating. It therefore can be used to cool particularly hot components on a circuit board, for example. A fan, in contrast, circulates air uniformly over the board rather than where the most heat is generated. Also, unlike a fan, the acoustical cooling device consumes only a fraction of a watt of power.

In containerless processing of materials by acoustic levitation, the convector can augment cooling or heating of freely suspended samples when natural convection is insufficient. Fans or pumps cannot be used in such processes because they would interfere with levitation.

The device consists of a piezoelectric driver and a reflector. Vibrating at ultrasonic frequencies, the driver creates a pair of counterrotating vortexes in the space between it and the reflector (see figure). An object in this space is cooled by the flow if heat is removed from either the driver or reflector (or heated if heat is supplied to the driver or reflector).

The frequency of the driver can be chosen at a value between 10 and 500 kHz to adjust the diameter of the vortexes to a value between 10 cm and 0.5 mm. At 40 kHz, for example, the distance between the driver and the reflector is 1.2 cm, about three-fourths the wavelength of the sound in air at room temperature.



Vibrating at an Ultrasonic Frequency, a piezoelectric driver sets up vortexes that transfer heat to or from an object in the space, depending on whether the reflector is heated or cooled.

In a demonstration, the temperature of a thermistor measured at various voltages was substantially lower when acoustical cooling was applied. At 10 V, for example, the thermistor operated at about 260 °C when the sound was off and 150 °C with the sound on. At higher voltages, the effect was even more pronounced.

This work was done by Eugene H. Trinh and Judith L. Robey of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 90 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 12]. Refer to NPO-17278.

Programmable Data Formatter

A system adapts data in diverse formats for transmission.

Goddard Space Flight Center, Greenbelt, Maryland

A programmable formatting system assembles digital data signals in various formats into standard blocks for transmission over switched telecommunications circuits. With the system, diverse data systems can be connected over long distances by space- or land-based relay stations.

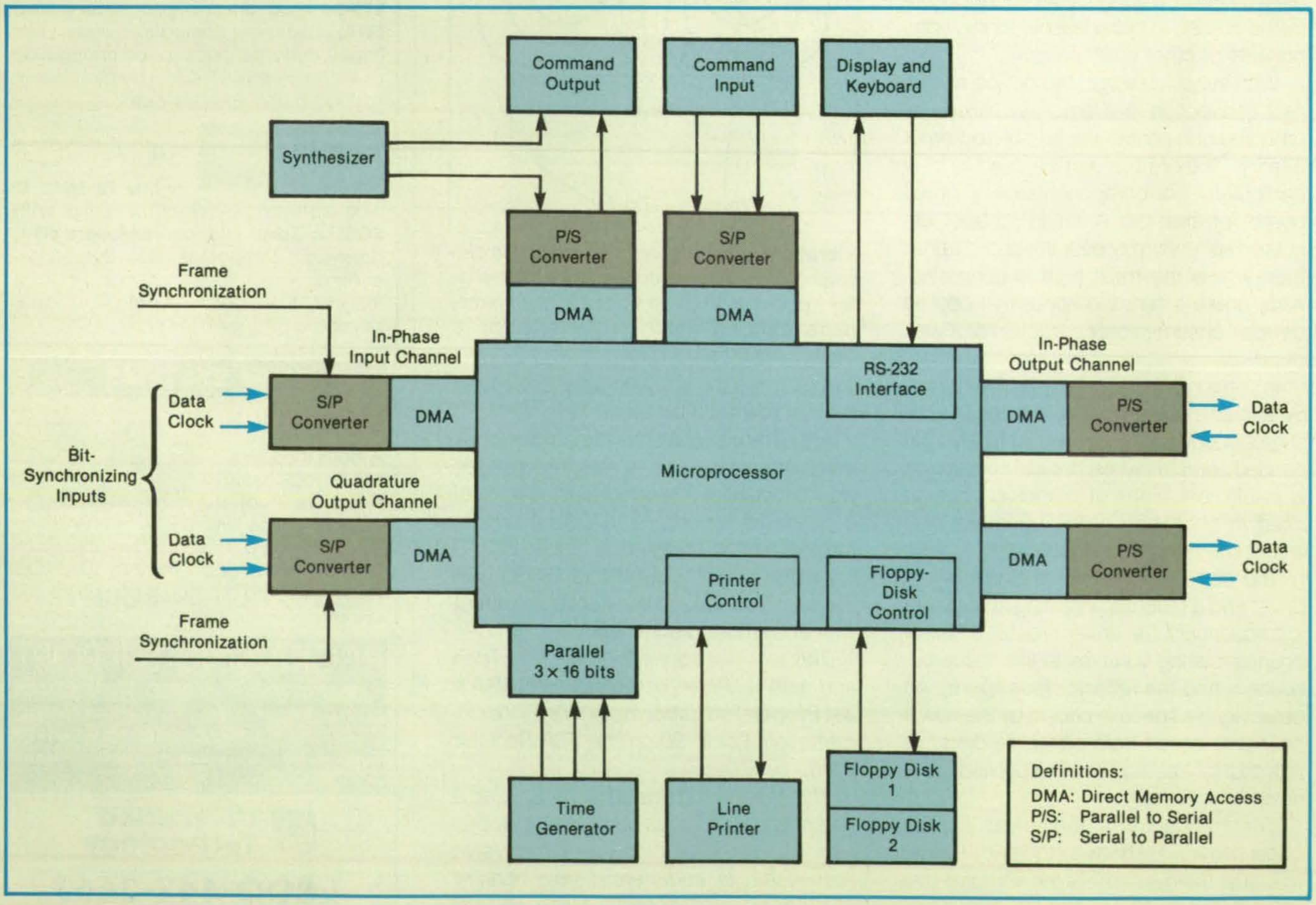
The formatter can be programmed to handle any data block or package format in lengths up to 65,000 bits. Any type of information can be transferred, either on separate lines or on multiplexed lines. The formatter can be tailored to the requirements imposed by users upon both equipment and computer programs. The formatter can be used to simulate, test, and control data networks.

In its present form, the formatter assembles data streams from two sources into blocks and forwards them over two switched circuits to a control center. The formatter also accepts blocks of command data forwarded by the control center on the reverse side of one of the data circuits and disassembles the blocks of data for transmission to the data sources.

At present the formatter can handle six different data formats. A human operator furnishes the configuration and header information for a format through a menu display. For each of a total of five formats, this information can be stored in an overlay file on a disk and recalled when desired, and the formatter automatically loads the correct program overlay.

The formatter has been tested in dual-channel operation at data rates from 9.6 through 224 kb/s. Preliminary testing has been done at a data rate of more than 1 Mb/s on one channel. Eventually, the formatter may be able to handle at least two 1.5-Mb/s channels simultaneously.

The formatter was developed as a replacement for a multiplicity of small data-blocking systems. These microprocessor-



A **Microprocessor Controls the Complex Activities** of data formatting, error checking, and transmission-priority arbitration. The shaded blocks are specially designed interfaces; other blocks represent standard commercial products. The system was developed for formatting signals from and to telemetry units on spacecraft for a widespread telecommunication network.

based systems stored their formatting programs in read-only memories. Program changes were therefore time consuming and difficult; it was impossible to handle many different data formats and data rates. Moreover, each system could format data at a maximum rate of only 250 kb/s.

The controller of the new formatting system is a microprocessor with a video display, memory, and interface circuitry (see figure). The operator loads the system software on 8-inch (20.3-centimeter) floppy disks. A line printer logs and prints out the command data, which can also be recorded on a floppy disk. A timing generator provides time tags for the data blocks and the commands.

Direct-memory-access units control the input and output channels, arbitrating priorities for data transfer. The data-input channels are driven by serial-bit synchronizers or parallel-bit (frame) synchronizers — the choice is made by software through custom-made interface circuits equipped with internal buffers (first-in/first-out memories). The input data are placed in reserved buffers in memory with header information. When a data buffer is full, its contents are presented to the output channels.

The command-input channel accepts formatted blocks, storing a complete block in a reserved command buffer. After a command block has been checked, it is forwarded to the data source.

This work was done by Robert E. Martin of **Goddard Space Flight Center**. *For further information, Circle 28 on the TSP Request Card.*
GSC-13104

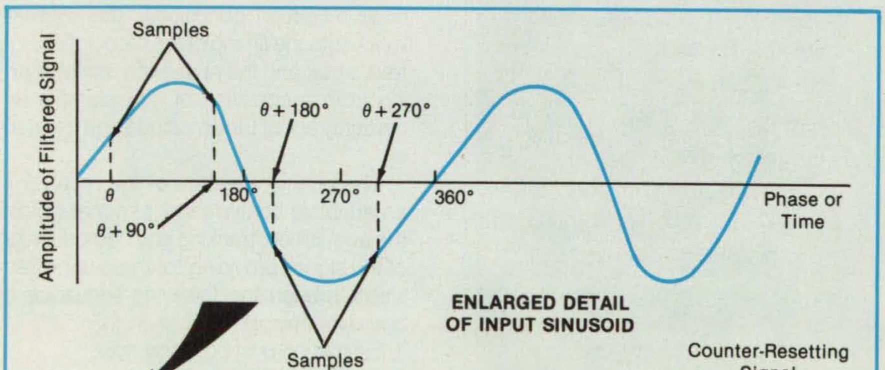
Fast Synchronization With Burst-Mode Digital Signals

An oscillator is quickly synchronized with the data clock.

NASA's Jet Propulsion Laboratory, Pasadena, California

A clock-signal-extracting system reduces the time required by a receiver in a burst-mode digital communication system to synchronize its data-sampling oscillator with the digital signal to be sampled. By reducing the number of bit periods required for synchronization, the system reduces the required length of the preamble at the beginning of each burst of transmission, thereby increasing the amount of time available for the transmission of information during the burst. The system is compatible with most modulation techniques used for digital transmissions, and because it consists mostly of digital components, it reduces the complexity of the receiver.

The receiver includes circuits that sample the modulation of the received signal. For correct sampling and to minimize the bit-error rate, the sampling clock must be brought quickly into synchronism with the beginnings of the symbol periods; in effect, the system must extract the data-clock



The **Sampling Clock Is Synchronized** with a sinusoid by a feedback technique. The feedback signal is a measure of the phase-error angle θ and is generated digitally by a technique related to the calculation of θ from periodic samples of the sinusoid.

signal from the data signal.

The digital sequence "0101..." is contained in the preamble of each burst. The input signal is passed through a channel filter to remove noise; this filter has such a narrow passband that it strongly attenuates the harmonics of the 0101... square-wave modulation, so that its output is almost a pure sinusoid with a frequency equal to half the symbol rate.

The sampling clock causes the sinusoid to be sampled at intervals of approximately one-fourth the sinusoidal period (see figure). If the time of the sampling signal differs from the zero crossing of the sinusoid by a phase angle θ with respect to the sinusoid, then the samples have the values $\sin\theta$, $\cos\theta$, $-\sin\theta$, and $-\cos\theta$, respectively. In principle, θ can be calculated by taking the arc tangent of the sine and cosine samples and the result used to generate a control signal to adjust the oscillator to the correct timing.

The system functions according to a variation of this principle. To make the phase of the sampling clock digitally controllable, the clock includes an analog voltage-controlled oscillator that runs at a higher frequency, and the sampling signal is obtained by dividing the frequency in a resettable digital counter. Initially, the clock runs freely at its nominal frequency. The even-numbered samples e_i are collected in one group, and the odd-numbered samples o_i are collected in another group.

When n samples in each group have been accumulated, the system computes the averages

$$\bar{e} = \frac{1}{n}\sum_{j=1}^{n} |e_i| \text{ and } \bar{o} = \frac{1}{n}\sum_{j=1}^{n} |o_i|$$

The values of $\bar{e}$ and $\bar{o}$ are quantized, then fed as address inputs to a read-only memory "lookup" table that contains digital oscillator-phase-correction values for every possible combination of $\bar{e}$ and $\bar{o}$. The correction value is sent to the frequency-dividing counter, causing it to reset to the proper phase. Once synchronization is acquired, the digital decision feedback loop of the receiver takes over the responsibility of maintaining the correct sample timing.

This work was done by Lin-nan Lee, Ajit Shenoy, and Michael Kitming Eng of Comsat Laboratories for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 48 on the TSP Request Card. NPO-16925*

Adaptive Receiver for Coded Communications

Acquisition and tracking of the signal are controlled automatically.

Ames Research Center, Moffett Field, California

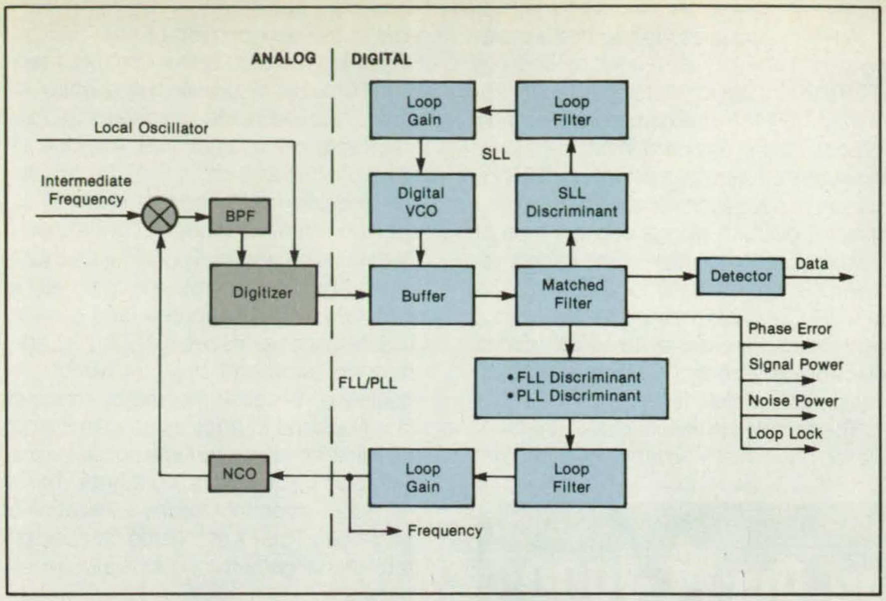
A radio receiver operating under automatic control processes Manchester-coded binary-phase-shift-keying signals under difficult reception conditions. The receiver locks onto the timing of the modulation, the frequency, and the phase of a signal, starting from a condition of considerable uncertainty about the amplitude and frequency.

The principal feature of the receiver is an adaptive control algorithm that guides the acquisition, tracking and demodulation of the signal, providing for the orderly transition through the following sequence of operating modes:

1. Estimation of out-of-band noise;
2. Acquisition of the coarse frequency and timing of the data signal employing a sequential probability-ratio test and a handover process;
3. Synchronization with the symbols and frequency of the data signal;
4. Synchronization with symbols and phase of the data signal; and
5. Confirmation of lock in the feedback loop.

After loss of lock, the mode control transfers the receiver operation back to the appropriate restart mode.

The acquisition of the signal begins with a sequential probability-ratio-test (SPRT) search of the frequency-uncertainty band.



The **Receiver Is Constructed in Analog and Digital Portions** so that signal-processing functions that would otherwise be unwieldy can be performed economically by digital microprocessors.

This is done by sweeping the band with a 4-point discrete-Fourier-transform (DFT) filter bank. Each filter is matched to the 512-Hz Manchester symbol rate, which is twice the coded-symbol rate 1/T = 256 Hz, so that the bandwidth covered by the filter bank is 1,536 Hz.

Two filter sets separated in time by an offset of T/2 are formed at the Manchester symbol rate. At each dwell, the DFT filter outputs are accumulated and compared with SPRT thresholds until it is decided that the signal is or is not present. After the signal is detected, the residual 1536-Hz frequency uncertainty is too large to permit the frequency-lock loop (FLL) to start. Consequently, a handover procedure is initiated to narrow the uncertainty band to 512 Hz.

In handover, multiple DFT filters are formed to cover the uncertainty regions of frequency and time. Outputs are accumulated, and the filter with the largest sum is chosen. The chosen filter center frequency and time offset are accepted as estimates of the signal frequency and timing if, in addition, the sum passes a Neyman-Pearson false-alarm-threshold test.

Following handover, the FLL and symbol-lock loop (SLL) are initiated. The FLL tracks the frequency and enables the performance of a least-squares estimate of the frequency and the rate of change of frequency. These estimates are calculated at the end of the FLL operation and are used to start the phase-lock loop (PLL).

The SLL tracks the symbol timing. When the PLL is turned on, its bandwidth is opened wide to improve acquisition and gradually narrowed to its operating value under the control of the PLL lock-detector statistic. After lock is confirmed by the other lock detectors, the demodulator output data are considered to be valid, and telemetry data are measured.

Preferably, the receiver is constructed as a hybrid analog/digital system (see figure). This partitioning enables the computation-intensive operations to be performed by programmable digital microprocessors. After being heterodyned to the intermediate frequency, the input signal is mixed with the output of the numerically controlled oscillator (NCO), limited in bandwith by a bandpass filter (BPF), and synchronously translated to baseband where it is digitized with 8-bit resolution. The resulting in-phase and quadrature digital data streams are processed to form the set of 4-point (DFT) filters at the Manchester symbol rate. DFT outputs are used to form the tracking-loop discriminants, the lock detectors, and the symbol-detection filter that provides the soft-decision demodulator output.

The FLL, PLL, and SLL operate at the symbol rate. FLL and PLL outputs drive the NCO, and the SLL output drives the digital voltage-controlled oscillator (VCO). This VCO is a digital integrator, the output of which is a pointer that selects the starting time for the DFT matched filters. Since the SLL resides in the processor, the digitizer operates at 4 times the Nyquist rate of 2 kHz for the DFT filters. This enables the SLL to select the DFT timing at time increments of T/32. Every T/2 seconds, the DFT filters are formed, and at T-second intervals, the receiver state is updated. To improve the performance, the loop bandwidths for the FLL, SLL, and PLL are opened wider at turn-on and then reduced with time.

This work was done by U. A. von der Embse of Hughes Aircraft Co. for **Ames Research Center**. *For further information, Circle 27 on the TSP Request Card.*
ARC-11815

Books and Reports

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

Simulating Instrument Helicopter Takeoffs and Landings

Advantages and disadvantages of computer-based simulations are reviewed.

A report evaluates the merits of simulations of terminal instrument procedures (TERP's) for helicopters. Currently approved TERP's for helicopters apply only to airports having standard instrument landing system (ILS) equipment. New TERP's are needed for such nonstandard landing sites as offshore oil rigs and the tops of buildings and mountains. The report reviews current methods for the evaluation of TERP's. It discusses the feasibility, benefits, and liabilities of the substitution of electronically controlled flight-simulation equipment for flight tests.

The study led to the conclusion that simulation offers many advantages over flight tests in the development of new TERP's. Simulation provides better control of test conditions, better quality and quantity of data, increased safety, and greater flexibility in the modification of tests. After the initial expenditure for equipment, the simulation also offers reduced test costs — as low as one-tenth the cost of flight testing.

Simulation also has potential disadvantages. The use of a simulator could lead to erroneous or unwarranted (and possibly unsafe) conclusions because the simulator may not represent the real world adequately or because it could be misused. The likelihood of error can be diminished by following extensive tests on a simulator with a limited series of flight tests. This is especially important for the verification of enhanced TERP's standards for such potentially dangerous conditions as zero visibility.

The report recommends that flight simulators be used to duplicate previous helicopter flight tests to verify that simulation produces accurate data. Such simulations would also provide a comparison between simple fixed-base and elaborate moving-base simulators. The report also recommends that mathematical models be developed for low-speed helicopter dynamics, nonconventional navigation sources and guidance avionics, data bases for computer-generated imagery, and wind.

This work was done by Anil V. Phatak and John A. Sorensen of **Ames Research Center**. *Further information may be found in NASA CR-177408 [N86-28931/NSP], "Evaluation of the Usefulness of Various Simulation Technology Options for TERP's Enhancement."*

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 12]. Refer to ARC-11813.

Synchronous Versus Asynchronous Flight Control

Both types of digital systems have been evaluated in flight and on the ground.

A report compares synchronous and asynchronous digital flight-control systems. It evaluates four different systems by such criteria as software reliability, cost increases, and schedule delays.

Flight-control systems have undergone a revolution since the days of simple mechanical linkages. Today, the most advanced systems are full-authority, full-time digital systems controlling unstable aircraft. With such systems, an aircraft can incorporate aerodynamic features that boost performance and save fuel. The digital control provides the stability and handling characteristics that ensure safe flight.

A key question, however, is whether a multichannel digital control system should be synchronous or asynchronous. Each channel in a synchronous system operates at the same point in the software cycle at any given time. Each channel in an asynchronous system may be operating at any point in its software cycle; data are passed when available, and the other channels receive the data when they are ready. Synchronous systems are said to be more reliable and to yield lower design and testing costs. Asynchronous systems are reported to provide greater protection against lightning, electromagnetic interference, and battle damage.

The report covers the following systems, which range from simple to highly complex:

- A digital fly-by-wire (DFBW) system for the F-8 aircraft;
- An asynchronous resident backup software (REBUS) system;
- A combined synchronous/asynchronous system for highly-maneuverable-aircraft-technology (HiMAT) vehicles; and
- An asynchronous advanced-fighter-technology-integration (AFTI) system for the F-16 aircraft.

The AFTI/F-16 system is complex in its control laws and management of redundancy. Its asynchronous operation and multimode control structure resulted in a series of anomalies in both flight and ground testing. The HiMAT system, also complex, was tested in an integrated environment that closely simulated the flight environment, thus allowing the early detection of potential problems so that anomalies could be minimized. The REBUS system has a simple control structure and limits the data cross-link to avoid problems ordinarily associated with asynchronous operation. The F-8 DFBW system, while not extremely complex, nevertheless was complicated enough to show that for some situations, a synchronous system may be better for complex systems. The F-8 DFBW system avoided problems that could have occurred and yielded a highly-successful, relatively trouble-free test.

Asynchronous or synchronous operation was not in itself a determining factor in the number of anomalies and difficulties in testing. However, the complexity of a system can cause major effects in terms of anomalies. A simple asynchronous system without a complicated data-cross-link structure may be easier to develop than is a synchronous system of the same size. A system designed as an integrated system, including all interactions and interfaces, is likely to encounter fewer difficulties in testing and operation.

This work was done by Victoria A. Regenie, Claude V. Chacon, and Wilton P. Lock of **Ames Research Center**. *Further information may be found in NASA TM-88271 [N86-29866/NSP], "Experience With Synchronous and Asynchronous Digital Control Systems."*

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

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center *[see page 12]**. Refer to ARC-11799.*

Fault-Tolerant Software for Flight Control

A redundant system performed well in flight tests.

A report discusses the design and testing of a redundant control system for the F-8 digital fly-by-wire airplane. The outstanding feature of the system is the fault-tolerant software [resident backup software (REBUS)] that resides in the primary digital computers. The transition to operation on backup software is smooth.

The basic F-8 airplane control system that was modified for operation with REBUS is a fail-operate, fail-safe digital fly-by-wire system with a frame-synchronized triplex digital primary system and a triplex analog-computer bypass system as backup. Commands for the control surfaces are passed through analog midvalue voting circuits, which can declare any one of the digital outputs to have failed. The analog backup is a direct electrical link between the pilot's stick and the servo-drive electronics, and its outputs are passed through the same midvalue voting circuits as those used by the primary system.

The REBUS software provides an augmented control law with three-axis, fixed-gain rate damping. Many of the self-check functions of the primary software are eliminated to reduce complexity. Overall, the REBUS software requires less than one-tenth the memory required by the primary software.

The system automatically transfers to the backup mode when there are failure declarations in two of the three primary channels. On the assumption that a generic software error may degrade the record of the state of the aircraft in the memories of the primary computers, the REBUS software is initialized to the control-surface commands at the moment of transfer: this generates no transients other than the small ones that result from the reinitialization of any active filters and changes in loop gains from state-dependent to fixed values.

To reduce complexity further, REBUS was established as an asynchronous system. Therefore, unlike the primary system, the backup system does not support the exchange of data among computers. Each computer operates on independent, dedicated sensors. Because of this interchannel independence, one important issue in testing is the variations among channels.

The REBUS system was tested in an F-8 simulator on the ground and in an F-8 airplane in flight, using simulated software errors. The channels tracked each other closely. The transfer transients were negligible, even during high-transverse-acceleration (high-g) maneuvers. In most cases, the transfer to REBUS could not be detected in the control-surface measurements. There were no unwanted transfers. The success of the F-8 REBUS flight tests, coupled with the incorporation of similar backup-software approaches in other advanced aircraft, is evidence that the underlying control concept will find industry-wide acceptance as a viable solution to the generic software-error problem.

This work was done by Dwain A. Deets and Wilton P. Lock of **Ames Research Center** *and Vincent A. Megna of Charles Stark Draper Laboratory. Further information may be found in NASA TM-86807 [N86-19325/NSP], "Flight Test of a Resident Backup Software System."*

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Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center [see page 12]. Refer to ARC-11763.

GPS Satellite Multipath Range Errors

Measurements are proposed to resolve uncertainties.

A report discusses errors in range measurements in the Global Positioning Satellite (GPS) system due to multipath transmissions originating at the satellites. At present, large uncertainties in the sizes of multipath errors limit the precision of GPS measurements. Experiments are proposed to determine the systematic multipath errors under various operating conditions, with a view toward applying corrections to increase the precision of future GPS measurements.

The use of properly-designed GPS receivers is expected to enable the accurate measurements of baselines up to thousands of kilometers in length. A key to these accurate measurements is the common-mode rejection of instrumental errors originating at the satellites through differencing of the measured pseudoranges to a pair of ground receivers from a single satellite.

This measurement technique fails in the presence of effects that originate at a satellite but that are not the same for different ground receivers observing the same satellite. Multipath caused by some of the signal power from a satellite antenna bouncing off other parts of the satellite is an example of this: The additional signal delay caused by multipath transmission is dependent on the angle between the centerline of the antenna and the line of sight to the receiver on the ground, also called the "angle off boresight" or "boresight angle."

It has been estimated that a multipath effect with a magnitude of a few centimeters may remain after differencing and cannot be calculated with confidence. It is, therefore, necessary to conduct experiments to quantify the effect, to determine whether it can be ignored, must be modeled, or presents a fundamental obstacle to the use of P-code (a pseudorandom-noise code used in the GPS system) measurements to resolve carrier-cycle ambiguities.

At an antenna-testing range, a GPS antenna was mounted on a ground plane and used to transmit P-code ranging signals toward a GPS receiver 800 ft (240 m) away. The P-code delay was measured as a function of the boresight angle from 0° to 14° and found to have variations of as much as 67 times the 0.03-ns accuracy required for the use of P-code pseudorange measurements to reliably resolve carrier-cycle ambiguities. However, the measurements may have been strongly affected by multipath effects of the test range itself, and experiments are being conducted with a satellite in orbit to determine whether the variations due to the satellite and its antenna are either less than, or can be calculated to, within 0.03 ns.

The experiments exploit the fact that the changes in delay due to multipath are expected to be much larger in the P-code than in the carrier signals in most instances. The differential change in range between the carrier and P-code is monitored as a function of the satellite elevation. The remaining sources of experimental error include system noise, multipath at the ground antenna, errors in ionospheric calibration, noncoherence of carrier and P-code circuits at the satellite or ground receiver, and errors in the orientations of satellites. Possible variations of effects among satellites, or dependence of delay on the azimuth angles of the satellite antennas will be investigated.

This work was done by Lawrence E. Young of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "An Experimental Technique To Monitor the In-Orbit Multipath Performance of Satellite Antennas," Circle 136 on the TSP Request Card. NPO-17020*

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Quick-Change Optical-Filter Holder

A dark slide and interlock protect against ambient light.

Goddard Space Flight Center, Greenbelt, Maryland

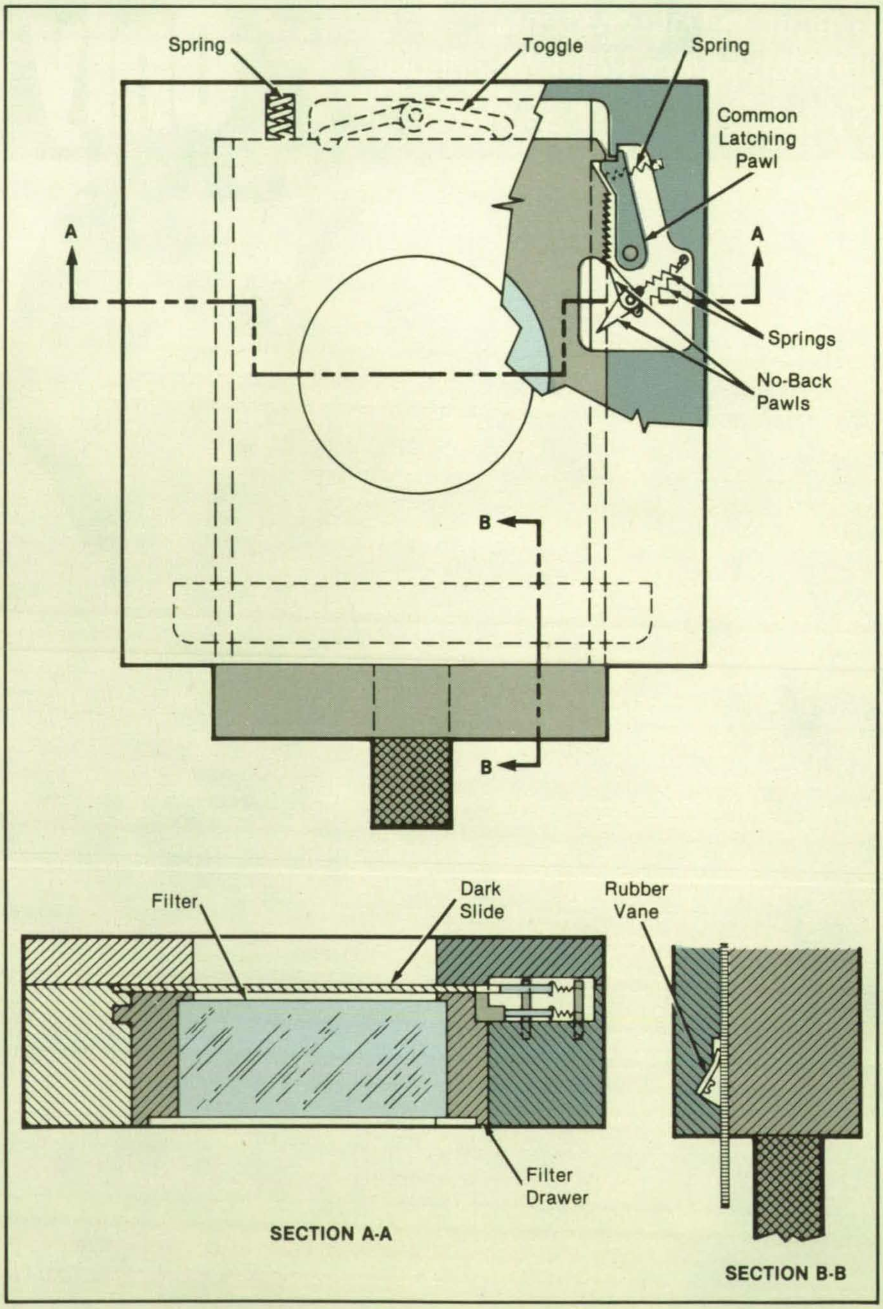
A mechanism enables a technician to remove and insert optical filters quickly and protects delicate parts of an optical system against ambient light. Designed for use with band-pass optical filters in 10 channels leading to photomultiplier tubes in a water-vapor lidar/ozone instrument, the mechanism can be modified to operate in other optical systems that require the rapid change of filters.

Previously, to change a filter without damaging a photomultiplier tube, it was necessary to turn the tube off and remove it from the instrument to gain access to the filter holder. Care had to be taken not to expose the face of the tube to ambient light. The operation was both tedious and time consuming.

With the new mechanism, it is not necessary to remove the photomultiplier. The mechanism (see figure) includes a filter drawer that operates in interlocking fashion with a dark slide. To remove the filter drawer, the technician first inserts the dark slide firmly into its slot; this releases the drawer. The technician then pulls the drawer out; this latches the dark slide in place, and the dark slide shields the photomultiplier from stray light during the entire time in which the drawer is removed. The technician places the new filter in the drawer, the drawer is reinserted firmly to release the dark slide, the drawer becomes latched, and the dark slide is removed.

Both the drawer and the dark slide have ratchet serrations that engage a common latching pawl. The sliding members also engage separate spring-loaded, no-back pawls that ensure that once either member is inserted, it must be inserted fully before it can be withdrawn. A newly inserted member must be fully latched by the common pawl before the no-back pawls release. Strong springs help to release the previously latched member when the newly inserted member disengages the common latching pawl.

To assure that both members are not latched simultaneously, a bilevel toggle pawl pushes the other member out when the new one is inserted. A rubber vane blocks the entrance hole of the dark slide to prevent the entry of stray ambient light when the dark slide is removed.



The **Quick-Change Filter Holder** contains an interlocking mechanism that prevents the simultaneous removal of both the dark slide and the filter drawer.

This work was done by Peter Leone of **Goddard Space Flight Center**. *No further documentation is available.*
GSC-13148

Device Maintains Water at the Triple Point

A modified commercial freezer keeps water at 0.01 °C for over 10 weeks.

Langley Research Center, Hampton, Virginia

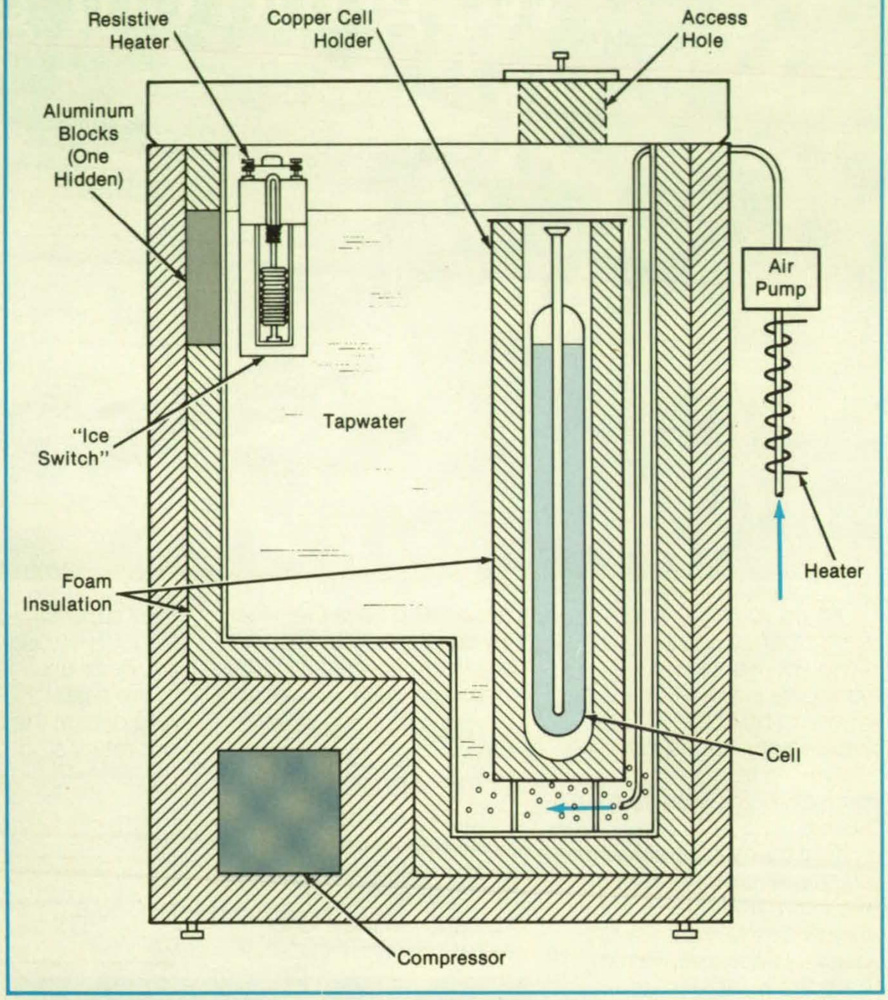
A relatively inexpensive device maintains the triple point (T_p) of water for 10 weeks or longer. The T_p of water, 0.01 °C, is the most useful and important of the defining temperature points for the calibration of standard platinum resistance thermometers (SPRT's). The freezing of a T_p cell is tedious and time consuming, and because a usable cell can rarely be maintained for more than a few hours, fewer T_p measurements can be made than desired. Attempts to extend the lives of T_p cells by the use of crushed-ice baths have not been successful.

The new device (see figure) consists of four basic assemblies: a small, commercial chest freezer containing an insulated water tank; an insulated copper cell holder; an "ice switch" for cycling the freezer compressor; and an externally-mounted air pump for circulation. The tank is made of stainless steel and lined with 2-in. (5-cm) R-10 foam insulation on all interior surfaces. An access hole cut in the freezer lid allows T_p measurements without opening the lid.

The copper cell holder, mounted on standoffs, is filled with foam insulation in which holes have been cut for two cells. Copper "hats" fit over the cell tops. A ring of insulation is added to the outside of the copper box, near the bottom, to displace a portion of the ice that tends to grow in the bottom of the freezer and up the side of the cell holder.

The quantity of ice in the freezer is controlled by the "ice switch," which is constructed from a small bellows, sealed with brass at both ends, in an aluminum housing. A hole drilled in the center of the housing is lined with 2-in. (5-cm) PVC (polyvinyl chloride), and the aluminum is coated with epoxy to prevent corrosion. The bellows is filled with distilled water and bolted to the bottom of the hole. The airspace between bellows and PVC is filled with silicone oil. A spring and nylon plunger are fitted above the bellows to activate a standard 20-A miniature switch.

The bellows assembly is immersed in one corner of the freezer, with the switch well above the surface of the water. Two aluminum bars, inserted between the freezer walls and the water tank, cause ice to form in the "ice-switch" corner first. The fluid in the bellows freezes and expands, causing the plunger to open the switch, shutting off the compressor. As the fluid in the bellows melts, the plunger falls, closing the switch and turning on the compressor. Two parallel 5-kΩ, 2-W resistors, mounted across the switch and thermally bonded to the bellows housing, add heat to reduce the cycle time while the compressor is off.



This **Modified Freezer** is used to calibrate standard platinum resistance thermometers.

The bath water is circulated by air pumped to the bottom of the tank and bubbling to the surface. The air-intake line is wrapped with heater tape to prevent ice from blocking its outlet at the bottom of the tank. A flexible wire run down through the air line may be necessary to prevent the formation of ice during long periods of operation.

The triple-point-of-water maintenance device has been in operation over a year. Daily checks of working SPRT's were used in identifying errors before they were introduced into critical test data. Experience shows that, before cell storage is attempted, the freezer should be in operation and monitored closely for about a week to ensure a stable bath temperature that will not overfreeze the T_p. In fact, turning the freezer control to maximum was found to give better results than did a lower setting.

Typical bath temperatures swing from −10 m°C to +27 m°C over a 24-h period. The cell should be visually inspected daily before measurements are made to ensure the ice mantle is "free." If excessive ice crystals (dendrites) begin to grow from the bottom of the mantle, a 5- to 10-s immersion in ambient water keeps them at bay while minor freezer adjustments are made. Finally, 1 to 2 tablespoons of household bleach, added as needed, help prevent the bath water from discoloring and acquiring an unpleasant odor after several months of operation.

This work was done by J. W. West and C. G. Burkett of Wyle Laboratories for **Langley Research Center**. *No further documentation is available.*
LAR-13708

Holocinematographic Velocimeter

Holographic movies are used to study turbulent flows.

Langley Research Center, Hampton, Virginia

A dual-view, high-speed, holographic movie technique has been developed for studying the physics of the control of turbulent flows. This approach, which eliminates some of the limitations of previous holographic techniques, uses the holocinematographic velocimeter, or HCV. The data from this system can be used to verify the results of theoretical models and numerical simulations of turbulence, to visualize and measure coherent structures in "nonsimple" turbulent flows, and to examine the mechanisms operative in various turbulence-control/drag-reduction concepts. This system shows promise for giving the most-complete experimental characterization of turbulent flows yet available.

In this technique, a high-speed movie is composed of single-exposure holograms of tracer particles in each of two simultaneous orthogonal views of a flow. The time resolution is set by the movie frame rate, and the total time is limited by the length of the movie.

These holographic movies are reduced to velocity data in three steps. First, the coordinates of the tracer particles are found by scanning the reconstructed images from the holograms. Next, the two views are combined to allow equal position accuracy to be obtained for all three coordinates. Finally, the particles are tracked in successive time steps for the entire holographic movie to determine the time-varying velocity field through the entire test volume. The size of the tracers is a compromise between the quality of the image and the spacing of the tracers. Commercially-available, 40-μm-diameter, hollow glass spheres called microballoons have been used.

Because of limitations on the movie frame rate, the HCV will be used to study turbulence physics in slow flows of water. A new type of vertical water tunnel was developed to satisfy the requirements of this study. This tunnel is like a vertical towing tank, but the tank, rather than the model, is moved. The tunnel has a very low disturbance flow and is far less expensive to construct than are continuous-flow or intermittent-flow tunnels.

Even though the tunnel velocity is low (⩽1 m/s), the film-transport speed required to obtain 500 frames/s is 17.5 m/s. This motion plus vibration could cause smearing of the images in the holograms. Smearing is avoided by the use of a pulsed copper-vapor laser. An argon-ion laser has been used during the reduction of the holograms.

The HCV appears to be capable of obtaining data uniquely with resolutions in time and in three-dimensional space that approach those of full real-time realizations of complex flows. Although the system can be used only for low-speed flows, it could help in the solution of a large number of problems in the physics of fluids and, particularly, problems in the control of flows.

This work was done by Leonard M. Weinstein and George B. Beeler of **Langley Research Center**. *For further information, Circle 19 on the TSP Request Card.*
LAR-13699

Simultaneous Sampling of Two Spectral Sources

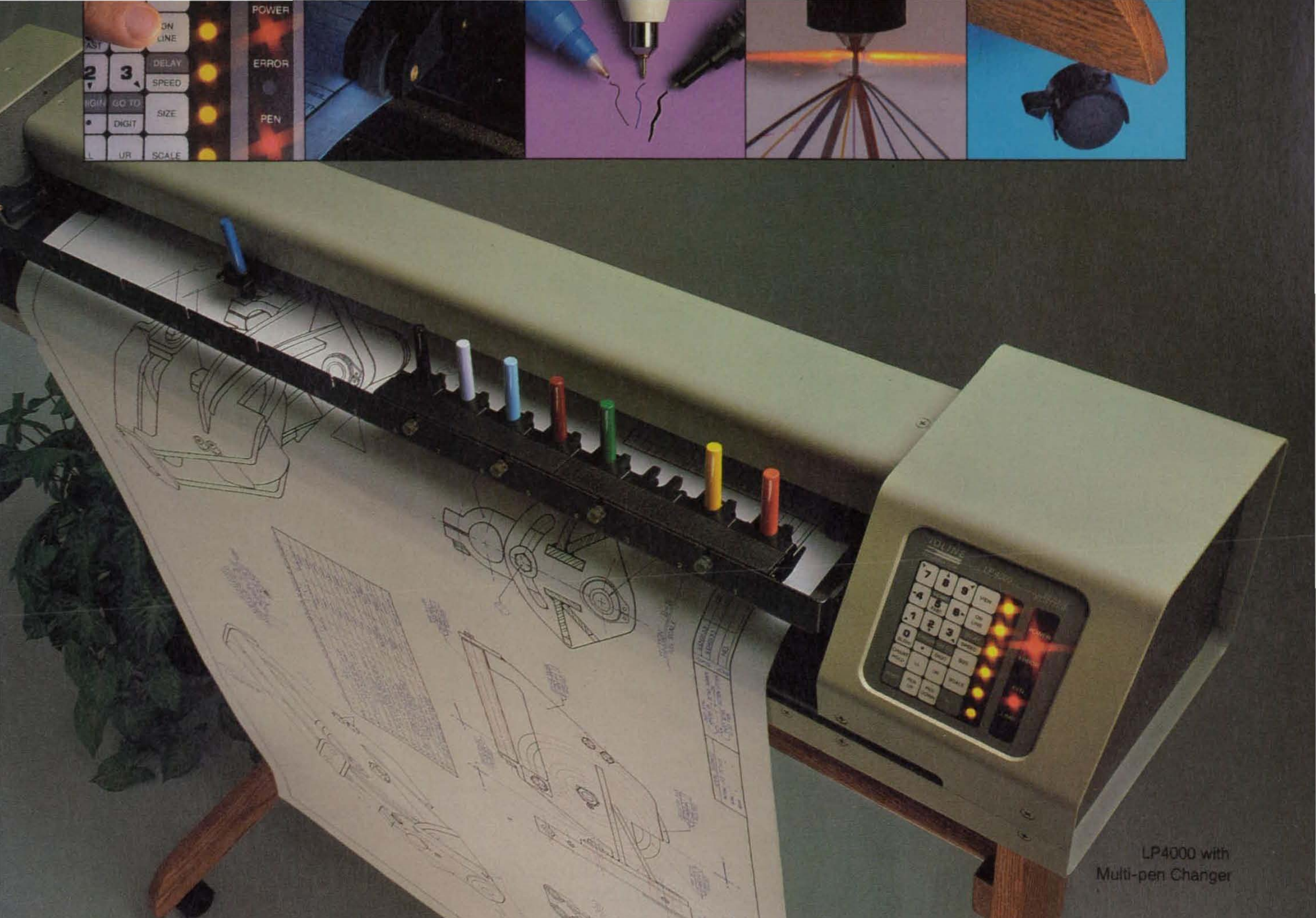
A fiber-optic bundle is used to sample a dye laser and a spectral lamp.

Langley Research Center, Hampton, Virginia

Many applications of broadband dye lasers require that the spectral outputs be accurately known. A new technique uses a bundle of fiber optics to sample a dye laser and a spectral lamp simultaneously. By use of a real-time display with this sampling technique, the two signals are superimposed, and the effect of any spectral adjustments can be determined immediately.

Figure 1 shows some of the major components of the system. The fiber-optic bundle is split into two bundles at the input end. A portion of the beam from the dye laser is reflected to one of these bundles by an uncoated microscope slide. A spectral lamp is sampled with the other input bundle. The effect of the fiber-optic bundle is to mix the light from the two sampled sources at the output end before insertion into a detector.

For convenience, the input ends and the spectral lamp are mounted in a block. The dye-laser energy accepted by the fiber-optic bundle is attenuated by rotating the block to adjust the input angle. The output end of the fiber-optic block is fastened to the input slit of the sampling monochroma-



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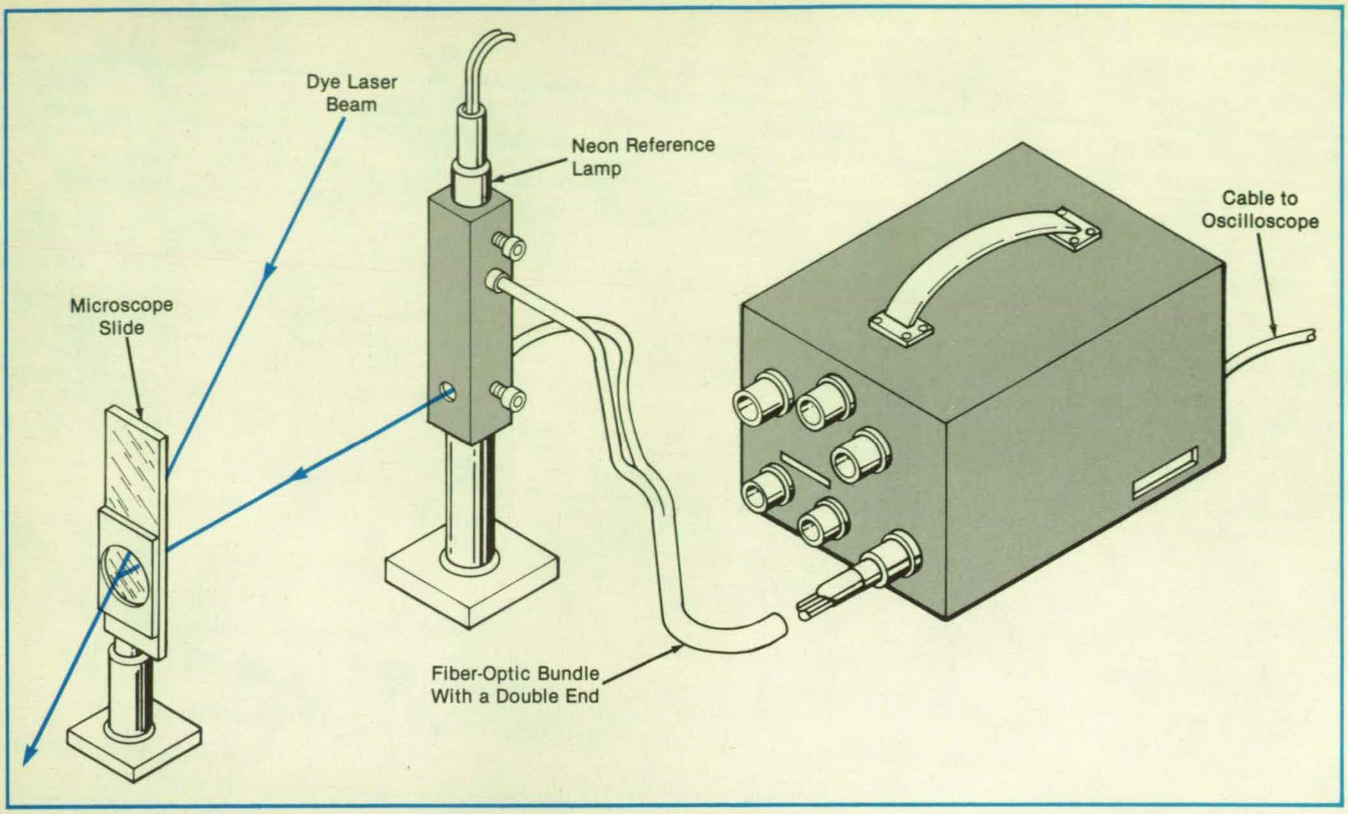


Figure 1. A **Split Fiber Optic Bundle** mixes the light from a broadband dye laser and a spectral lamp.

tor. A rapidly scanning spectrometer and oscilloscope are used to display the laser and spectral-lamp data as a function of wavelength.

Figure 2 illustrates the display obtained during the sampling of a dye laser centered at 606.5 nm. Neon reference lines at 603.00, 607.43, and 609.62 nm are also displayed, thus enabling the simultaneous determination of the dispersion and the wavelength. By the use of this system, adjustments can be made to the dye laser, and the effect can be determined immediately.

This technique is routinely used as part of the Coherent anti-Stokes Raman Scattering (CARS) system at NASA Langley Research Center. In the system, the dye laser mixes with a simultaneously-pulsed Nd:YAG laser at 532 nm to probe the vibrational levels of nitrogen. This system is used to diagnose combustion.

This work was done by Olin Jarrett, Jr., of **Langley Research Center**. *No further documentation is available.* *LAR-13756*

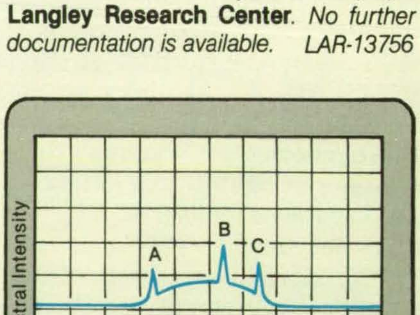


Figure 2. An **Oscilloscope Display of the Spectrum** of a broadband dye laser, centered at a wavelength of 606.5 nm, also shows neon reference lines at wavelengths A, B, and C.

Materials

Hardware Techniques, and Processes

Halogenation Enhances Carbon-Fiber/Epoxy Composites

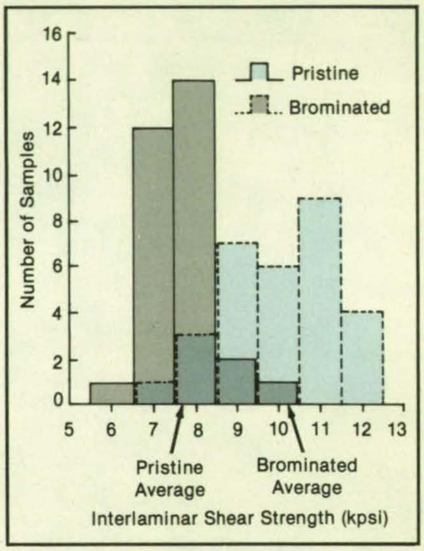
Interlaminar shear strength is increased by an inexpensive treatment.

Lewis Research Center, Cleveland, Ohio

Recent work has identified a new, relatively-inexpensive surface treatment for carbon fibers that enhances the interlaminar shear strength (ILSS) without altering the tensile strength significantly. One of the factors that limits the usefulness of carbon-fiber/epoxy composites is the comparatively poor strength of the bond between the fibers and the matrix, often measured in terms of the ILSS. For example, conventional S-glass fiber composites typically have an ILSS on the order of 15 kpsi (100 MPa), while untreated carbon-fiber composites can have ILSS as low as 4 kpsi (28 MPa).

Many different surface treatments have been proposed to improve the interfacial bond between the fiber and the matrix by either modifying the functional groups on the surface of the fiber or by enhancing the surface area of the fiber. These include wet and dry oxidative etching, chemical-vapor deposition, whiskerizing, and a multitude of polymer coatings. Although threefold to fivefold improvements in ILSS can be achieved with some of these surface treatments, the treatment process often degrades the tensile strength or is prohibitively expensive.

The exposure of polyacrylonitrile-based T-300 (or equivalent) fibers to bromine vapor at room temperature improves the ILSS of epoxy composites made from these fibers by 30 percent, from an average of 7.7 kpsi (53 MPa) to 10.0 kpsi (69 MPa), as shown in the figure. The mechanism responsible for the improvement is still under investigation. The improvement may be due to adsorbed or reacted bromine on the surface of the carbon fibers or to an increase in the surface area of the carbon fibers as a result of exposure to bromine. Amoco pitch-based P-100 (or equivalent) fibers show similar results but to a lesser degree. The ILSS of the P-100 increases from 3.8 kpsi (26 MPa) to 4.5 kpsi (31 MPa). The effect of bromination on the tensile strength of the composite samples is minimal: 122 ± 16 kpsi (840 ± 110 MPa) for the pristine P-100 composite compared to 122 ± 7 kpsi (840 ± 48 MPa) for the brominated P-100 composite. The enhanced ILSS obtained from the halogenation of carbon fibers may prove to be beneficial in many aerospace and terrestrial applications.



The **Interlaminar Shear Strengths** of pristine and brominated samples of composite material are compared.

This work was done by Donald A. Jaworske and Raymond D. Vannucci of **Lewis Research Center** *and Reza Zinolabedini of Cleveland State University. No further documentation is available.*
LEW-14584

Graphite/Epoxy Deicing Heater

Heat is applied close to the surface to be protected.

Lewis Research Center, Cleveland, Ohio

Both military and civilian aircraft of the future will have an increasing number of components fabricated from composite materials. This trend stems from not only the desire to reduce the aircraft weight but also to make aircraft surfaces smoother for more laminar flow and hence less drag.

If leading edges of lifting surfaces (i.e., wings and tails) and engine inlets are to be made from composite materials, then one problem that must be addressed is that of protection from ice. Thermal anti-icing and deicing systems that have been used for years by the aircraft industry do not appear to be useful for composite designs, because composites characteristically have low thermal conductivities in their transverse directions, and hence, large amounts of heat would have to be provided to ensure that the outer surfaces reach the required anti-icing or deicing temperatures.

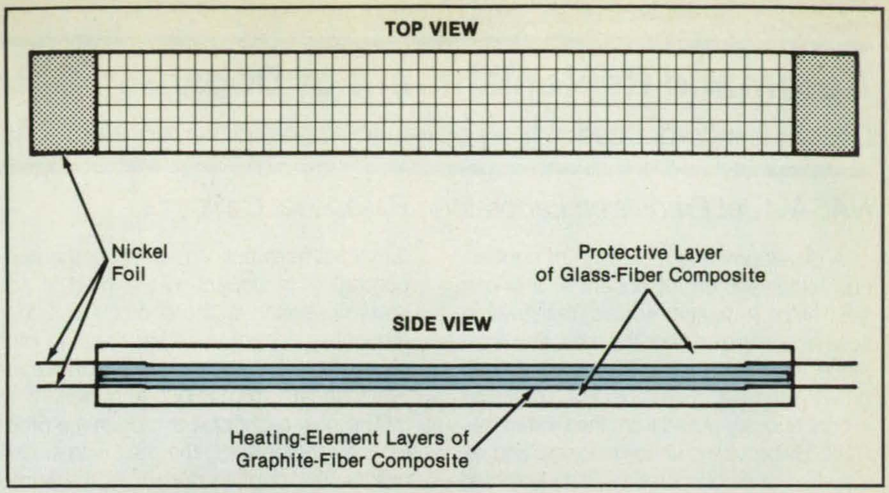
A surface heater developed to remedy this deficiency includes a graphite-fiber/epoxy composite as the heating element. This heater can be thin and highly electrically and thermally conductive and can conform to irregular surfaces. Therefore, it can be used in the thermal deicing system of an aircraft to heat the surface of the aircraft quickly and uniformly.

The basic design of the heater is illustrated in the figure. One ply of highly electrically- and thermally-conductive brominated-graphite-fiber composite was laminated between two plies of electrically-insulating composite material, with nickel foil making contact with the end portions of the graphite fibers. Part of the foil was exposed beyond the composite to serve as an electrical contact. Several model heaters were fabricated to demonstrate the concept and perform the preliminary experiments.

The electrical resistivity, thermal conductivity, and density of the fibers were $50 \mu \cdot cm$, 270 W/m•K, and 2.30 g/(cm)^3, respectively. The electricity was found to penetrate through the composite in the transverse direction to make the resistance of the contact between the foil and the composite acceptably low. When the electrical current was applied, the increase in the temperature of the heater reached 50 percent of the steady-state value within 20 s.

There was no overheating at the ends of the heater, provided there was no corrosion by water. Where the foil/composite bond failed during storage, exposure to liquid water was found to have oxidized the foil. Such failure of the bond can be avoided if perforated nickel foil is used, so that the plies of the composite can bond to each other through the perforated holes and therefore lock the foil in place. However, further study is needed to address the corrosion of the foil/composite bonding by liquid water.

This work was done by Ching-cheh Hung of **Lewis Research Center** *and Michael E. Dillehay and Mark Stahl of Cleveland State University. Further information may be found in NASA TM-88888 [N87-12559/NSP], "A Heater Made From Graphite Composite Material for Potential Deicing Application."*



This **Graphite/Epoxy Composite Heater** was developed to prevent and reverse the formation of ice on advanced composite surfaces of aircraft.

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

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, Lewis Research Center [see page 12]. Refer to LEW-14551.

Metal/Ceramic Bond Coatings for High Temperatures

Features include low thermal-expansion mismatch and resistance to oxidation.

Lewis Research Center, Cleveland, Ohio

A new class of reduced-thermal-expansion bond coatings has been developed for use at high temperatures in thermal-barrier-coating systems. These bond coatings are composed of low-pressure-plasma-sprayed metallic matrices dispersed with low-thermal-expansion, high-bulk-modulus ceramic particles. The new coatings and the method of application represent improvements over the prior practice of applying a ceramic coat directly over a metallic bond coat in that they lower the thermal-expansion-mismatch strain while maintaining integrity at high temperatures.

The dispersoids are initially processed so as to possess high cohesive strength, low porosity, and roughly spherical shapes. The anticipated optimum microstructure would be obtained by adjusting plasma-spraying conditions so that the metallic particles melt completely while the dispersoids exhibit only surface melting and remain roughly spherical.

The resulting bond coat ideally consists of a dense matrix of metal with well-bonded, roughly-spherical ceramic dispersoids. However, in practice, many dispersoids may melt completely and flatten upon impact. The volume fraction of the ceramic is kept sufficiently low so that the dispersoids tend not to be in contact with each other, thereby enabling the dispersoids to constrain the thermal expansion of the metal matrix while maintaining inherent resistance to oxidation.

This work was done by Robert A. Miller of **Lewis Research Center** *and George W. Leissler of Sverdrup Technology, Inc. No further documentation is available. LEW-14541*

Wear-Resistant, Thermally Conductive Coating

A new process makes a coating with unusual properties.

Lewis Research Center, Cleveland, Ohio

Coatings resistant to wear are used in a variety of applications ranging from earth-moving equipment to space vehicles. One of the most severe environments for such coatings involves both high temperatures and abrasion.

If it becomes necessary to remove large quantities of heat from a wear surface, high thermal conductivity is also necessary and further complicates the selection of a coating material. Copper and copper alloys have high thermal conductivity but only limited resistance to abrasion. Attempts to overcome this poor resistance to wear generally lead to plating or coating of copper substrates with materials that have greater resistance to wear but less thermal conductivity.

A process developed at the Lewis Research Center applies a wear-resistant, highly thermally conductive coating to a copper substrate. The coating is copper or copper alloy with a controlled dispersion of oxide or carbide particles. The process results in a coating that has thermal expansion similar to that of the base material, increased resistance to abrasion when hot, and high thermal conductivity.

This work was done by Brian J. Edmonds of **Lewis Research Center**, *George W. Leissler of Sverdrup Corp., and William J. Waters of Waters and Associates. No further documentation is available.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Lewis Research Center [see page 12]. Refer to LEW-14562.

Automatic Replenishment of Dopant in Silicon Growth

Dopant is incorporated in feed pellets to maintain the required concentration.

NASA's Jet Propulsion Laboratory, Pasadena, California

A developmental technique of continuous replenishment of dopant in a silicon melt helps to ensure correct resistivity in solid silicon grown from the melt. The technique is to be used in the dendritic-web growth process, in which a ribbon of silicon is continuously pulled from the molten material. By providing uniform doping and resistivity in the ribbon, the technique should enable the production of high-quality silicon ribbon at high yields for use in semiconductor devices.

Although it is common practice to replenish the silicon in a melt by automatic continuous addition, dopant has been added to the melt in the form of pellets when a pull has ended and a new one is about to start. Because silicon rejects dopant to the surrounding melt when it solidifies, the concentration of dopant in the melt increases during a pull, and the concentration at the growing end of the ribbon increases as a consequence.

Moreover, the amount of ribbon extracted varies from pull to pull. Thus, the concentration of dopant in the melt is not known precisely at the end of a pull. The amount of dopant to add at the start of a new pull has to be estimated, and the resistivity can vary from ribbon to ribbon.

The new technique avoids these problems by replenishing the melt with silicon pellets that contain dopant in the same concentration as that desired in the grown crystal. For example, an n-type silicon crystal of 2 $\Omega \cdot cm$ resistivity contains 1.05×10^{15} atoms of phosphorus per gram of silicon. The ratio of phosphorus concentration in the crystal to that in the liquid silicon is 0.35, which means that initially the melt must contain 3×10^{15} atoms of phosphorus per gram of silicon to produce the requisite concentration in the crystal. Once the withdrawal of the crystal from the melt has begun, the inclusion of 1.05×10^{15} atoms of phosphorus with every gram of silicon added to the melt will ensure that the required concentration in the liquid is maintained but not exceeded.

The phosphorus is included by diffusion into the silicon pellets. In a demonstration, silicon pellets were heated in a quartz crucible in a heated diffusion tube while a carrier gas containing $POCl_3$ vapor flowed over them. The extent of diffusion of phosphorus from the vapor depended on the time, temperature, pellet size, vapor concentration, and cooling rate. Under the proper conditions, the desired concentration of phosphorus can be attained.

Eventually, dopants might be added as part of a fluidized-bed process used to make the silicon pellets. Dopant gases would be added to the process gas stream and would condense in the silicon particles as they form by chemical vapor deposition.

This work was done by E. L. Kochka of Westinghouse Electric Corp. for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 22 on the TSP Request Card.*

NPO-17138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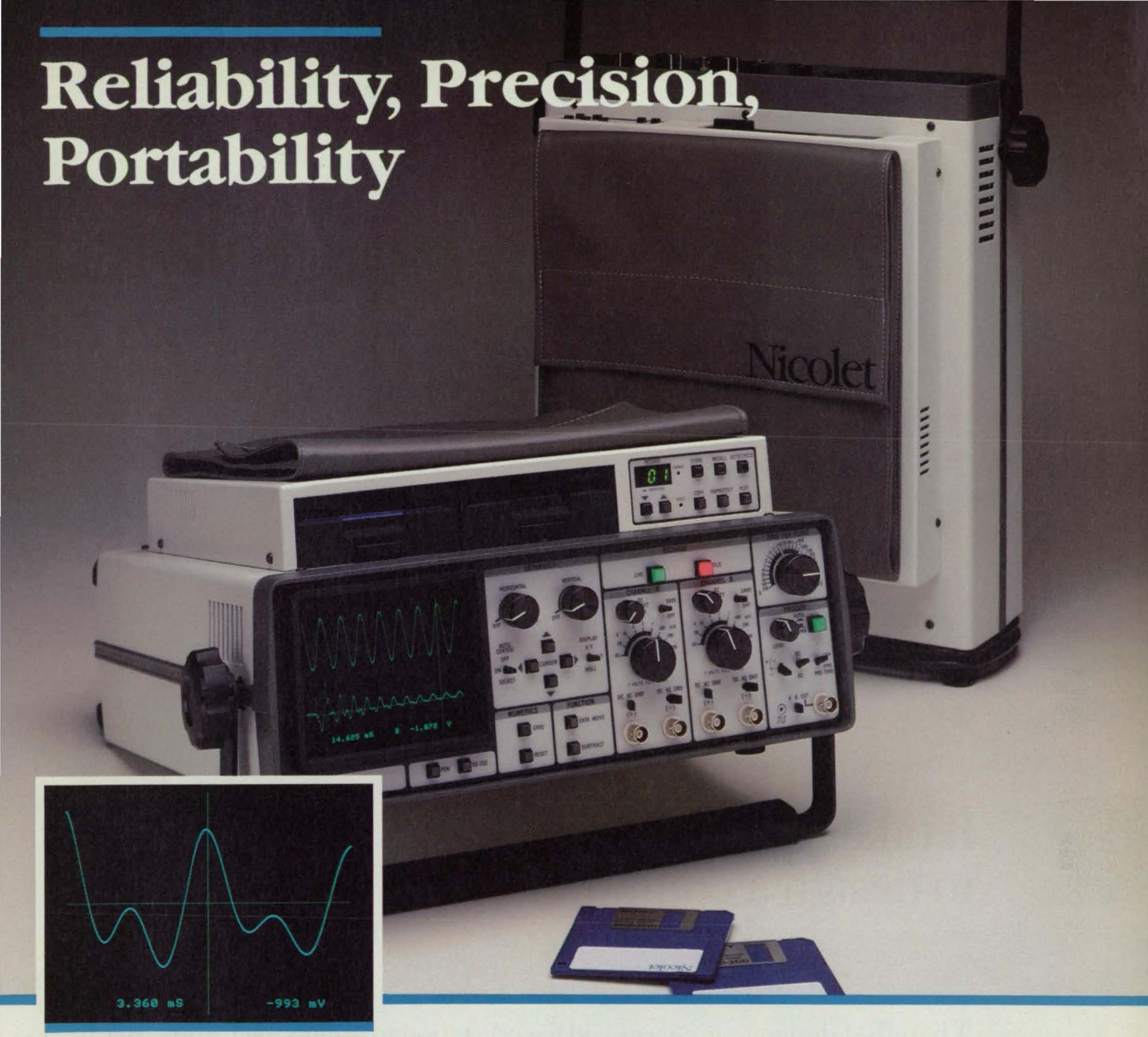

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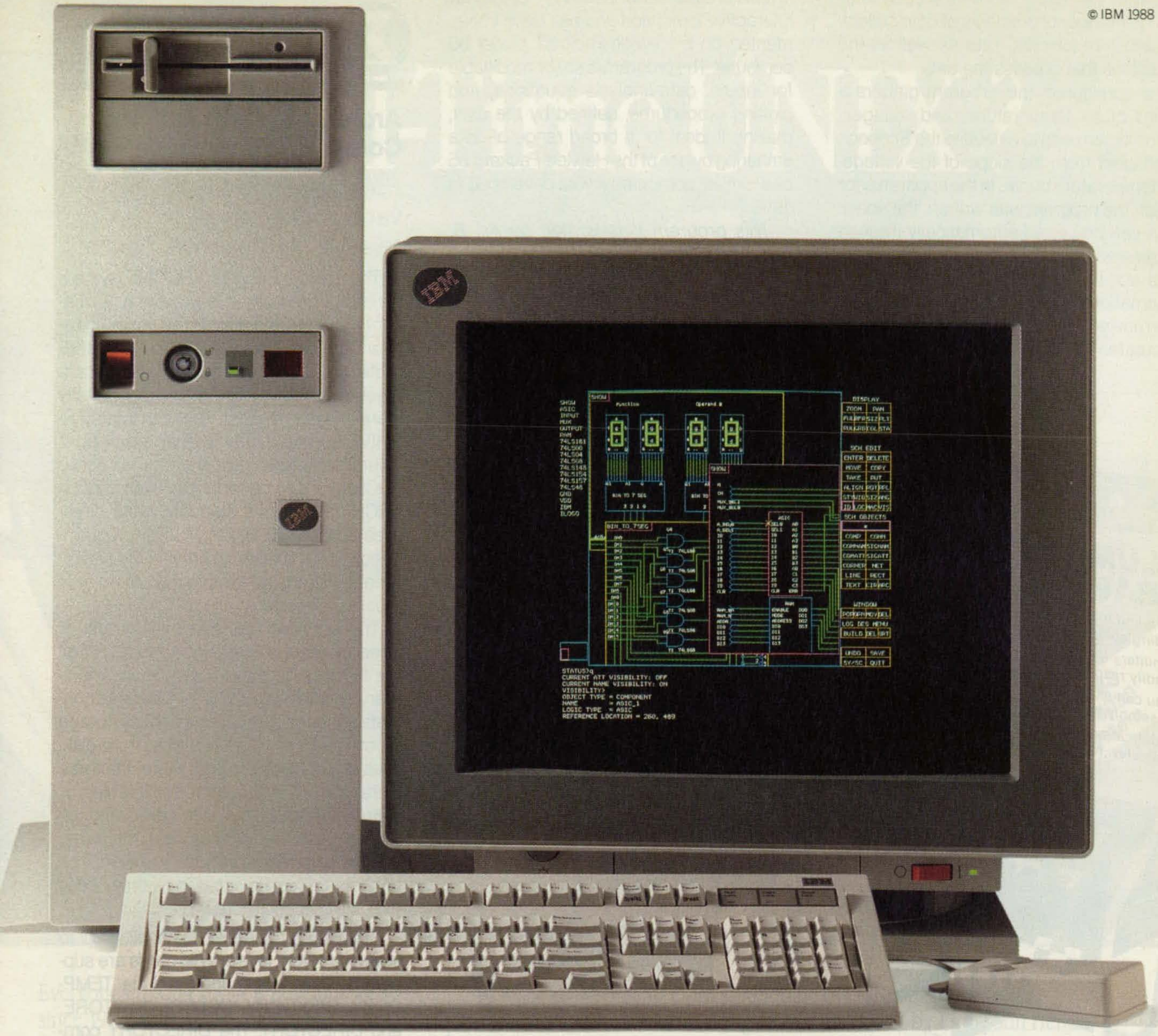


Mechanics

Measuring Flow by Holographic Interferometry

The flow field is reconstructed by computer-aided tomography.

Ames Research Center, Moffett Field, California

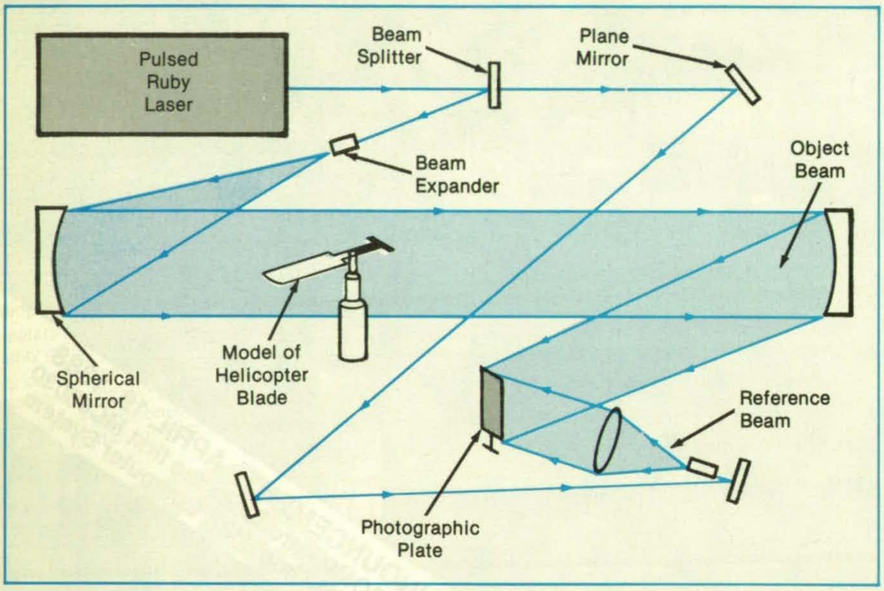


Figure 1. A **Holographic Interferogram** is formed on the photographic plate by the interference between the object and reference beams. Double-exposure interferograms taken with the blade rotating and stationary at various positions are processed to reconstruct mathematically the airflow about the blade.

A method for determining the flow of air about a model helicopter-rotor blade combines the techniques of holographic interferometry and computer-aided tomography. The transonic flow field obtained by applying the method to a 1/7-scale blade operating at a tip speed of mach 0.90 agreed well with a nonviscous theoretical flow field, except in a small region near the tip where the computer code did not predict a shock wave that is observed there.

The holographic apparatus is illustrated in Figure 1. A single rotor blade balanced by a counterweight is mounted in the object beam with a field of view 2 ft (0.6 m) in diameter. Holographic interferograms of the blade and the surrounding air are recorded on photographic plates, using pulses from a ruby laser having a duration of 20 ns, wavelength of 694.3 nm, and energy of 1 J. At each of 40 azimuthal positions of the blade, two holograms are taken in a double exposure: one when thé blade is stationary and one when the blade is rotating at the speed for which the flow is to

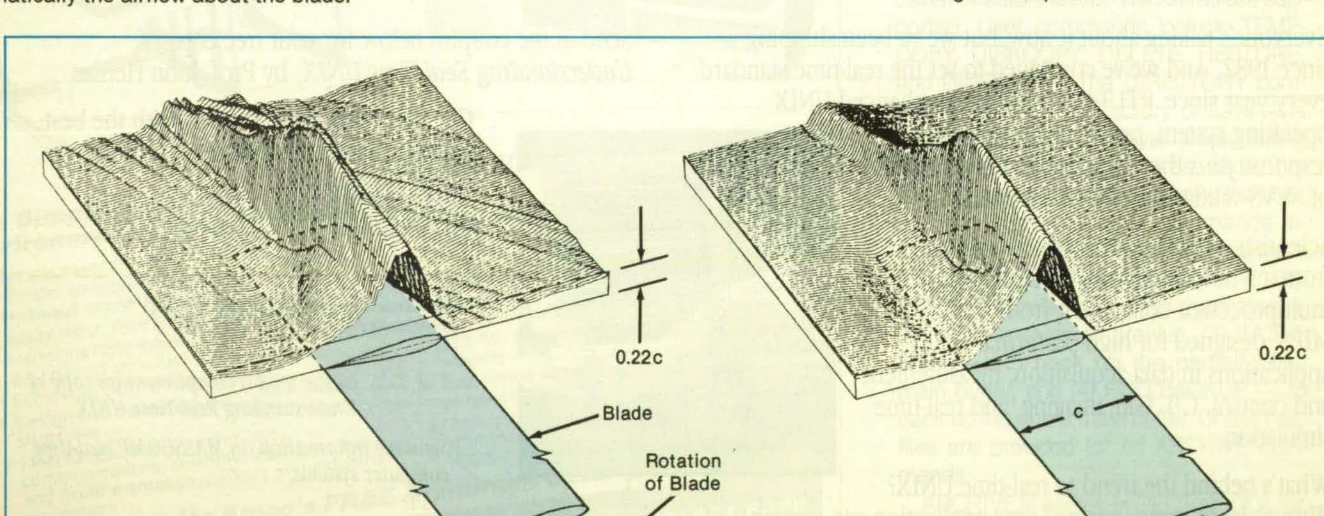


Figure 2. **Perturbation-Velocity Distributions** on a plane above the blade in the tip region were obtained by the holography/computer-aided-tomography method and by numerical simulation of the flow. The greater roughness in the former may be due to vibrations of the measuring instruments, noise, or coarseness of the experimental-data grid.

be measured.

The first exposure on each plate contains the interference-fringe pattern that arises from the spatially uniform index of refraction of undisturbed air; the second exposure contains the fringe pattern due to the nonuniform refractive-index distribution of the flowing air. Thus, the local fringe order in the developed photographic plate represents the integral, along the line of sight, of the difference between the refractive indices in the presence and absence of flow, respectively.

The interferograms in the plates are digitized, and the fringe-order numbers and coordinates are recorded along scans at various heights above the blade. The fringe-order data serve as input for a filtered-back-projection computer-aided-tomography code used to compute the refractive-index field at designated points in a horizontal plane above the plane of the blade. The density field of the flowing air is obtained from the refractive-index field via the simple proportionality between the density and the index of refraction minus 1.

Bernoulli's equation for steady, compressible, isentropic flow in the frame of reference of the moving blade is used to obtain the perturbation-velocity field from the density field (see Figure 2). These calculations are performed in several planes above the blade to obtain the entire three-dimensional velocity field in the vicinity of the tip of the blade.

This work was done by Yung H. Yu of **Ames Research Center** *and John K. Kittleson of the University of California, Los Angeles. For further information, Circle 134 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center [see page 12]. Refer to ARC-11728.

Linear-Alignment Testing Grips

Lateral movements of grips are eliminated for thin specimens.

Langley Research Center, Hampton, Virginia

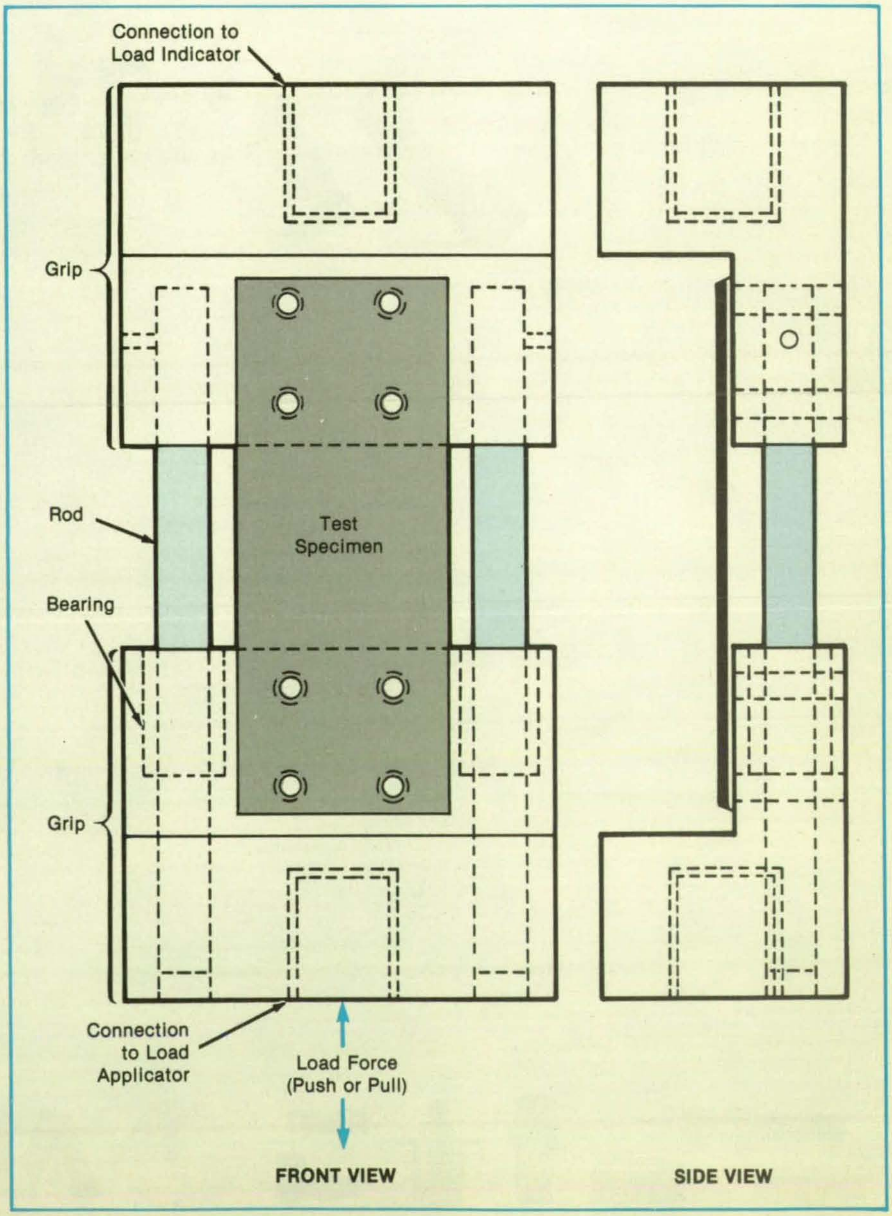
Conventional methods of tensile or compressive fracture testing use the independent grip system: one grip is attached to the load-indicating device, the other grip is attached to the load-producing force, and the test specimen is gripped between the two. These standard grips provide no lateral alignment. This arrangement is acceptable for most test specimens because they are usually quite stiff in the transverse direction, and lateral motion of the grips does not occur. However, this is not the case for thin composite specimens, particularly in compression loading. Lateral motions of the grips during compression tests bend the specimen and, therefore, can substantially affect the data.

To prevent lateral motions, a newly designed set of grips provides lateral alignment by the use of two rods (see figure). The new design integrates linear bearings with close-tolerance matching rods into the gripping chain. The rods are fixed into the load-measurement grip, and the load-applicator grip slides along them. These rods do not interfere with the force being applied but prevent lateral motion of one grip relative to the other.

These grips have been machined and are being used successfully at Langley Research Center in tests of the compressive fracture of thin, notched composites. Additional grips have since been designed with four rods and bearings for greater resistance to lateral motion.

This work was done by Mickey R. Gardner of **Langley Research Center**. *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Langley Research Center [see page 12]. Refer to LAR-13493.



Rods and Linear Bearings keep the grips laterally aligned as they move up or down.

Books and Reports

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

Stiffening Rings for Rocket-Case Joints

Loss of seal may be preventable.

Stiffening rings may help to prevent the loss of seal at joints between segments of solid-fueled rocket motors, according to a report. The rings were developed and tested in response to the catastrophic failure of the *Challenger*, which has been attributed to the rotation of the tang with respect to the clevis and the consequent opening of an O-ring seal in such a joint. The stiffening-ring concept may also be applicable to segmented terrestrial pressure vessels.

A pair of stiffening rings is to be installed near each joint — one on the tang side, the other on the clevis side. The rings are meant to alter the deformation of the case, which occurs under the pressure of rocket firing. The new pattern of deformation is to be such that the rotation of the components of the joint with respect to each other is reversed from that caused by the normal outward bulge at the joint, or else eliminated. Elimination or reversal of the rotation by a suitable amount should prevent the opening of a gap on the O-ring, thus preserving the seal.

The alteration in the behavior of the structure is primarily a function of the stiffness of the rings, which is the product of the hoop modulus and the cross-sectional area of the ring. Graphite-fiber/epoxy composite was chosen as the ring material because of its high ratio of stiffness to weight. Two rings were wound, one near the tang on one segment and the other near the clevis on a mating segment of a test rocket case. The rings and the joints were instrumented to measure stresses and strains. The joint was assembled and tested twice without shims, with custom shims, and with offset shims. In each test, the interior of the case was pressurized to 1,020 psi (7.03 MPa) for 130 s.

The measured hoop strains showed that the rings reversed the rotation to approximately the anticipated degree. In the presence of custom shims, the O-ring gap opening was kept to an average of 0.1 mil (2.5 μm), as compared to 30 to 40 mils (0.8 to 1.0 mm) without the stiffening rings. Although the rings became unbonded from the cases in some areas early in the tests, they continued to work without adverse effects. The maximum principal stresses behind the pinholes on the clevis were 40 percent lower than the corresponding stresses in the absence of the rings. The hoop strains were nearly identical in all the tests.

This work was done by Bryce W. Thompson, Larry G. Adams, and Meldon J. McIntosh of Morton Thiokol, Inc., for **Marshall Space Flight Center**. *To obtain a copy of the report, "SRM Joint Deflection Referee 2A (Composite Overwrap) Test Report," Circle 160 on the TSP Request Card.*
MFS-28269

Acoustical Tests of a Scale-Model Helicopter Rotor

Data are obtained in simulated hovering flight in an open environment.

A report discusses measurements of the sound generated in an outdoor hovering test of a 1/6-scale, four-bladed helicopter rotor. The outdoor environment is relatively well suited to the acquisition of good acoustical data because most of the undesired echoes and streaming effects of wind tunnels are not present.

The report provides information on the delineation between the acoustic near field and far field and on the effect of a simple boundary-layer-tripping device. In addition, the report covers rotor acoustics at low thrust and at high thrust.

Hovering tests yield insight into flow and noise phenomena of forward flight. The acquisition of acoustical data is much simpler in hovering flight because flow noise, shear layers, and Doppler effects are absent. In general, acoustic data obtained during hovering tests tend to be of a higher quality than those from wind-tunnel or flight tests.

The 2.13-m-diameter rotor was mounted in the standard thrust-up, wake-down configuration at a height of about 6 m above the ground, with a large unobstructed area around it. An array of microphones in a single vertical plane acquired data at a variety of distances and angles. The tip mach number and the rotor thrust coefficient were the primary test variables.

The test showed that a microphone should be positioned no closer than two rotor diameters to measure the far acoustic field of a rotor at all harmonics of the blade-passage frequency. The use of a simple device (strips of adhesive tape) to trip the boundary layer resulted in aerodynamic effects that are not completely understood: the use of tape was tried as a quick and easy alternative to the fairly-involved conventional procedure of attaching small particles of the correct size, spacing, and position to the surface near the leading edge. The results, however, were inconclusive.

The data obtained at nearly zero thrust indicate that although loading-noise effects are not completely eliminated, they can be reduced enough to enable the identification of thickness noise. This knowledge will be useful in future efforts to correlate predictions of thickness noise with measurements.

As the thrust coefficient rises from 0.09 to 0.11, the noise emitted by the rotor changes abruptly from a buzz-saw sound to a roar. This effect probably results from the interaction of the unsteady wake with the support apparatus; it does not seem to be related to rotor-stall phenomena.

This work was done by Cahit Kitaplioglu of **Ames Research Center** *and Christopher Kinney of H. S. Robinson, Inc.*

Copies of the report, "A Study of Helicopter Main Rotor Noise in Hover," may be purchased [prepayment required] from AIAA Technical Information Service Library, 555 West 57th Street, New York, New York 10019, Telephone No. (212) 247-6500.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center [see page 12]. Refer to ARC-11773.

Machinery

Hardware Techniques, and Processes

Books and Reports

Coding Ropes for Length and Speed Measurements

Ferromagnetic staples would serve as markers.

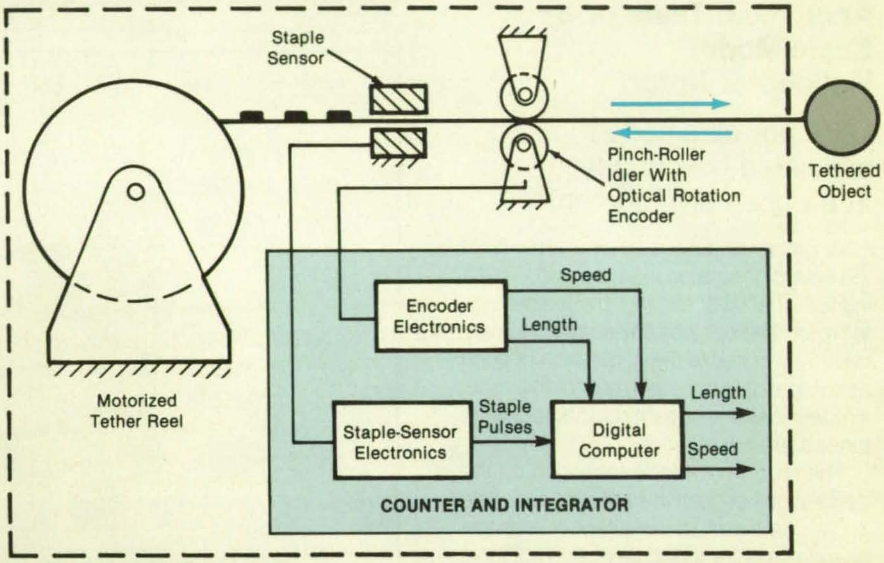
Marshall Space Flight Center, Alabama

A concept for coding space tether ropes would give instantaneous readings of the length of line deployed and the speed of deployment. The concept may be adaptable to such terrestrial tasks as laying submarine cables and the construction of suspension bridges. According to the concept, steel staples would be inserted in the rope with a predetermined pattern and spacing. As the rope is unreeled, a sensor would produce a pulse each time a staple passed it. Logic circuits would interpret the pulses to detemine the length, speed, and direction of the line.

The staples could also be used by a vehicle such as an elevator traveling along the rope. A sensor on the moving vehicle would produce pulses each time a staple was passed. From the pulses, the speed, direction, and position of the vehicle would be determined.

After the rope has been manufactured, it would be transferred from its storage reel to a takeup reel a short distance away. The rope would pass a stapler, which would insert staples at preset intervals. The staples would be designed to minimize compression of the line. After stapling, a protective coating would be applied to the line. The distances between staples may range from centimeters to hundreds of meters, depending on the intended use.

An electronic controller and a system of pulleys would maintain the expected operating tension on the rope so that the distance would be nearly the same as in the stretched line. Locally, the staples would be grouped according to a code to provide data on the direction of motion and speed. A verifying unit after the stapler would test the stapled codes. It would compare a code with the stapler program and stop the drive in case of error.



Like a Crude Magnetic-Tape-Playback Head, a sensor would detect the ferromagnetic staples as the rope is unwound or wound. The pulses from the staples would be analyzed electronically; the numbers of pulses and the intervals between them would be interpreted in terms of the velocity of the rope and the length payed out.

In use, the codes would be read out by a sensor of ferromagnetic material. The sensor pulses would be analyzed by a counter and integrator (see figure).

The concept promises greater accuracy than is offered by conventional methods of measuring payout. For example, the measurement of deployed length by a rotating idler wheel is subject to error because of slippage and stretching of the line, and marking the line with stripes for optical recognition tends to produce unreliable results because of the small diameter of the line.

This work was done by Charles C. Rupp and Georg von Tiesenhausen of **Marshall Space Flight Center**. *For further information, Circle 79 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 12]. Refer to MFS-28226.

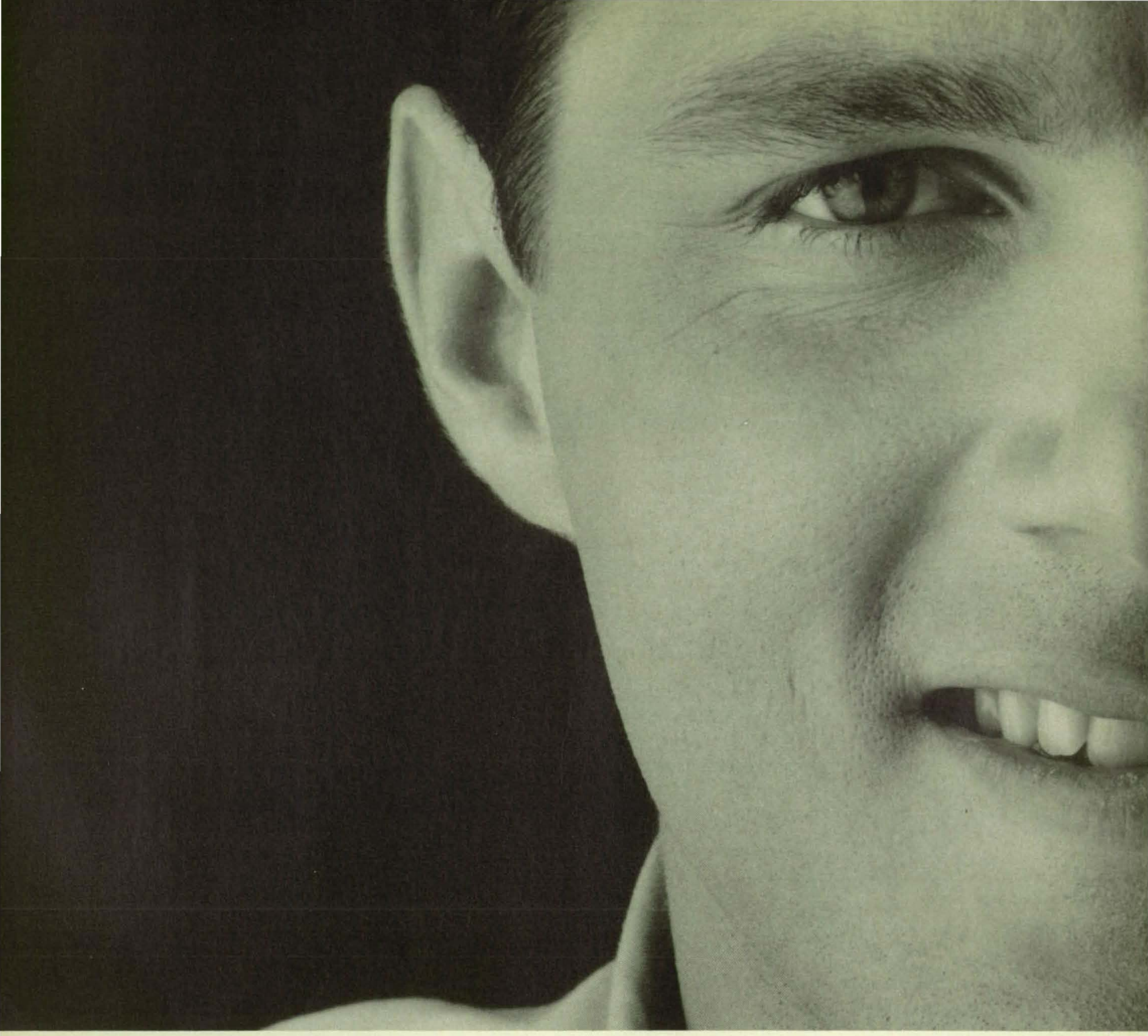
Predicting Temperatures in Ball Bearings

Computer simulations speed design studies.

Marshall Space Flight Center, Alabama

The thermal analysis of high-speed, rolling-contact bearings has matured so much that computerized numerical simulations can sometimes replace expensive, time-consuming full-scale experiments. With currently-available computer programs, engineers can now obtain false-color graphical maps of transient and steady-state temperature fields in bearings and races, even in the presence of such complicating factors as cooling by convection. With the help of these plots, the effects of changes in design or in operating conditions can be visualized quickly and easily.

Analyses can be performed in two or three dimensions. The sizes and shapes of components are approximated by zones



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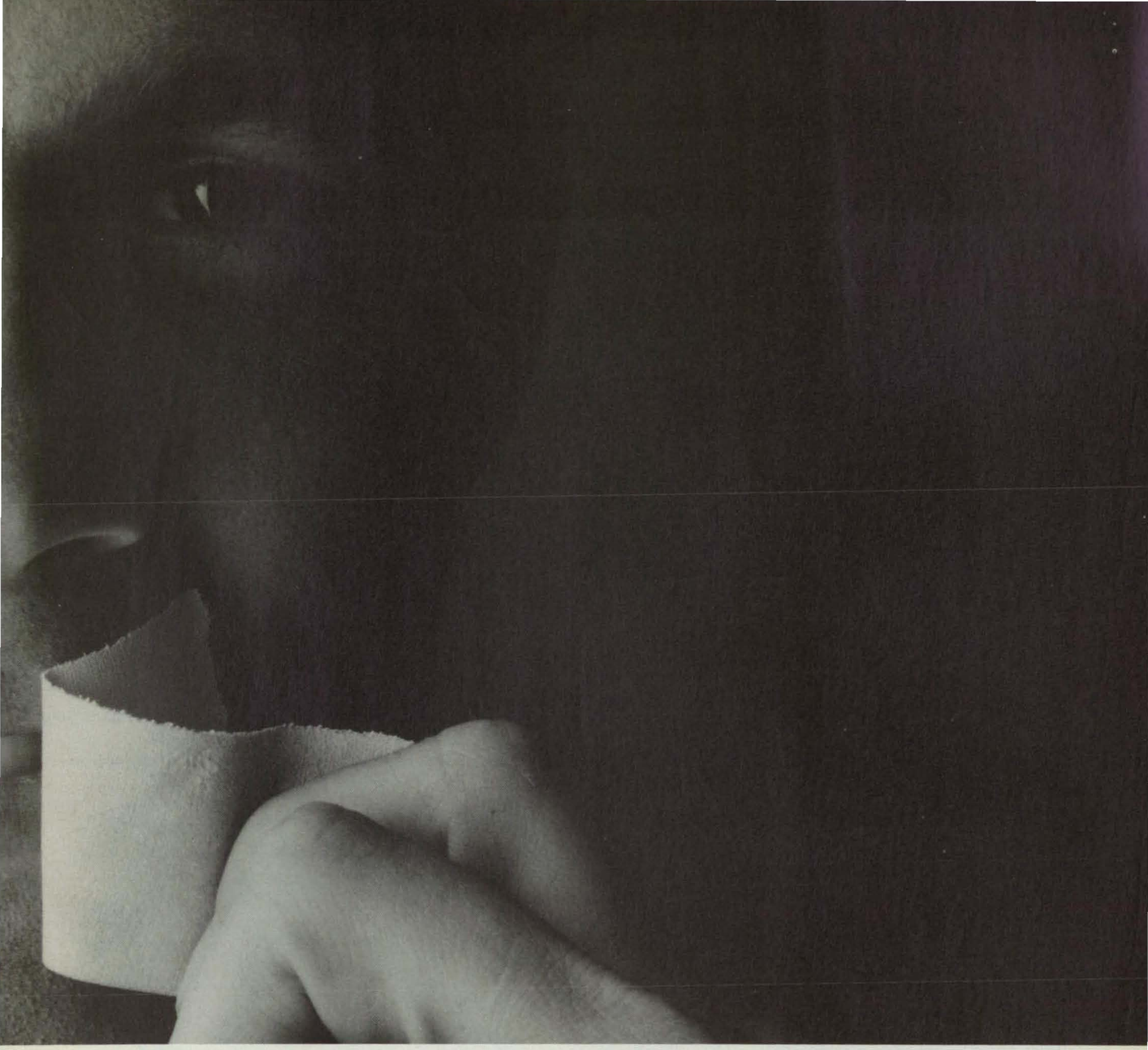

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CONTROL DATA

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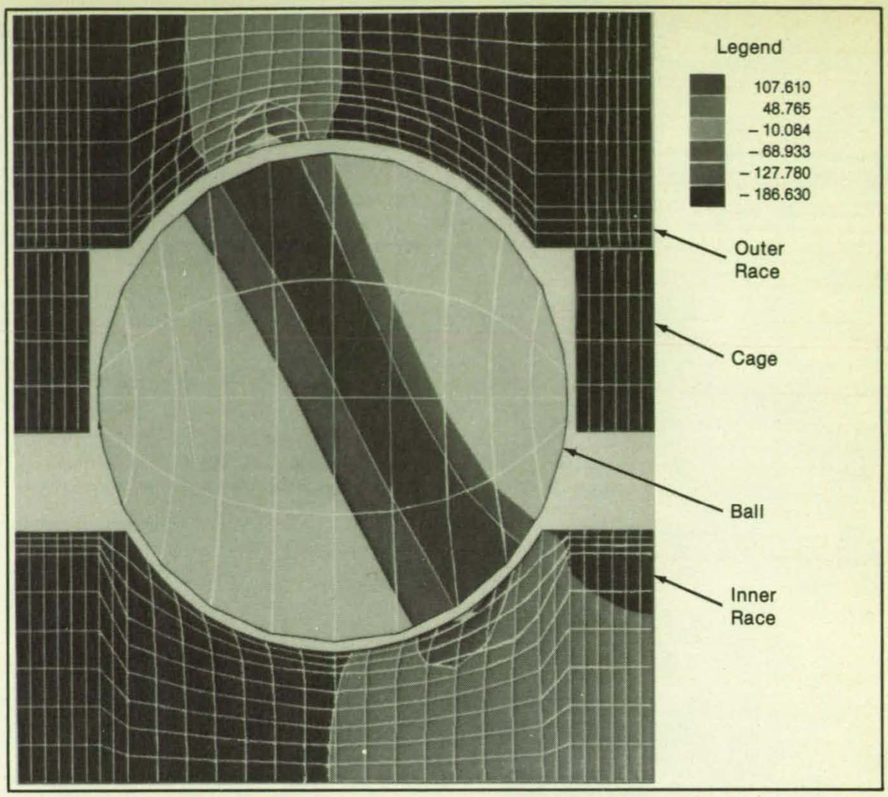
or nodes connected by gridlines. From the geometric information about the grids and from boundary conditions, the properties of the bearing and lubricant materials, and other information supplied by users, the thermal-analysis programs generate mathematical models for thermal transport. These models resemble electrical circuits, with thermal capacitance, thermal resistance, temperature, and the flow of heat as the analogs of electrical capacitance, electrical resistance, voltage, and current, respectively. The differential equations of the models are solved by finite-difference techniques.

The figure shows the results of a steady-state analysis of a ball and the races in a thrust bearing designed to operate in liquid oxygen. The ball is modeled as five concentric spherical shells. Each of the four inner shells is represented as one node. The fifth shell, which depicts the outer surface of the ball, contains 55 nodes. Each surface node is connected to the adjacent nodes, and all are radially connected to the fourth node.

As the ball rolls around the races, frictional heating at the two contact spots forms heated bands on the races and on the ball. The band on the ball does not spread all over the surface because the ball rolls along the same great circle on its surface over a relatively long time.



Isothermal Bands are depicted in color on the computational grid that represents a thrust bearing. The numbers denote the temperatures at the edges of the color bands.

This work was done by William R. Wagner and Brad R. Hemmings of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information, Circle 147 on the TSP Request Card. MFS-29285*

Spark Igniters Fit in Correct Locations Only

Pins create interference if incorrect assembly is attempted.

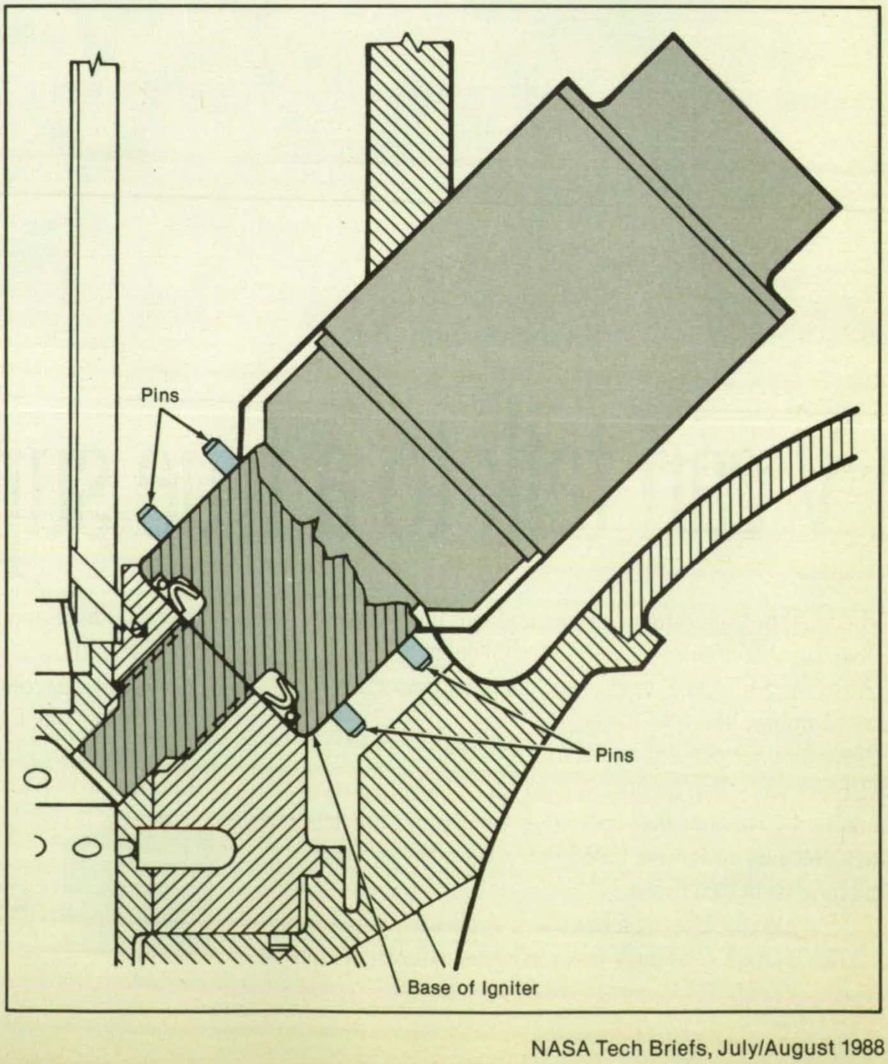
Marshall Space Flight Center, Alabama

When two different types of spark igniters must be used on the same engine, a simple expedient ensures that each igniter is inserted in the correct hole. Damage to the engine and consequent failure are thereby avoided.

A set of four solid or roll pins is added to the base of one type of spark igniter but not to the other type. The pins are oriented in such a way that they will interfere with the engine structure if the base is inserted in the wrong socket.

The base of an igniter can be reworked at minimal cost to accommodate the pins. The wall of the base is heavy enough that blind holes can be drilled in it for the pins.

This work was done by Fred J. Wendland of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available. MFS-29370*



Pins in the Base of a spark igniter allow the part to be inserted in only one type of hole.

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Continuous-Flow Centrifugal Separator

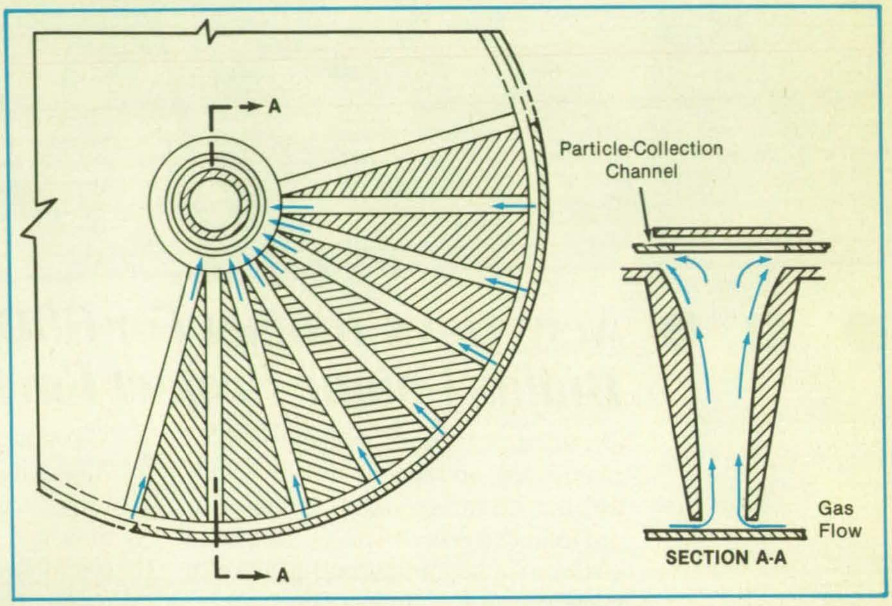
Rotational speed, flow, and pressure are adjusted to achieve separation.

Lyndon B. Johnson Space Center, Houston, Texas

A proposed apparatus would combine some of the operating principles of centrifugal and cyclone separators to control the movement of solid or liquid particles suspended in a flowing gas. It would stratify the particles or move them with or against the gas flow while segregating them according to size or mass.

The apparatus would include a rotating disk containing radial channels, the cross section of each of which would decrease with the distance from the center of rotation (see figure). Particle-bearing gas would flow from the periphery of the disk toward the center. The rotational speed, the rate of flow, and the gas pressure at the inlet would be adjusted so that the particles would move with or against the flow or remain in place depending on their size or mass. The particles would thus be separated. The particles would be introduced or collected by tubes on the axis of the disk and at its periphery.

The separation scheme might be used in low-gravity manufacturing processes or in the collection of dusts or aerosols in normal gravity. It might also be used to remove volatile components from a liquid; in this case, the liquid would flow from the center of the disk outward. Gas bubbles formed at the periphery would flow against the current toward the center, where they would be collected.



The **Spinning Disk Would Contain Radial Channels,** the width of which would vary as a function of distance from the center. Gas would flow from an outer ring around the disk toward the center. Particles — either liquid or solid — in the gas would be collected at the periphery, the center, or both.

This work was done by Robert D. Waldron of Rockwell International Corp. for **Johnson Space Center**. *For further information, Circle 70 on the TSP Request Card. MSC-21173*

Large-Angle Magnetic Suspension (LAMS)

Two degrees of angular freedom are provided within a single magnetic-suspension system.

Langley Research Center, Hampton, Virginia

The spherical LAMS is a new magnetic suspension that provides the dual functions of a magnetic bearing and a rotor-gimbal system. It provides two degrees of angular freedom within a single magnetic-suspension system. The approach employs spherically-shaped magnetic-gap surfaces to achieve much-larger angular freedom than that available from previous suspensions.

The demand for power is satisfied by increasing or decreasing the rotor speeds symmetrically. The demand for attitude-control torque is satisfied by gimbaling the rotors. The applications of the LAMS in spacecraft include gimbaled reaction wheels, control-moment gyroscopes, advanced systems for the storage and transfer of angular momentum, energy-storage wheels, integrated power and attitude-control systems (IPACS's), vibration isolators, and precision vernier pointing systems.

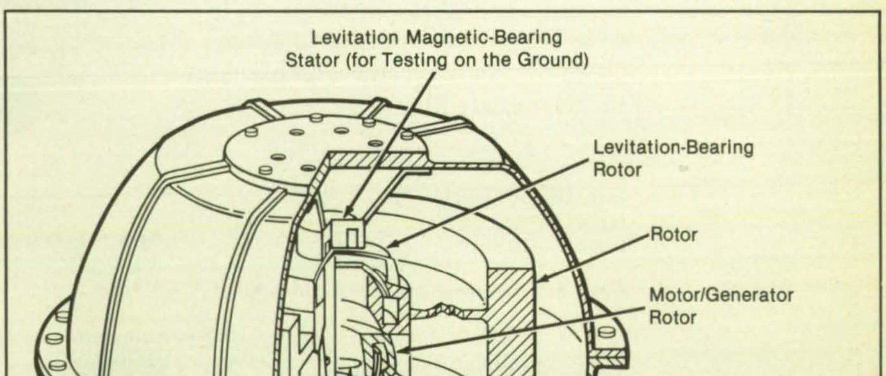


Figure 1. The **Spherical LAMS** includes both magnetic bearings and a rotor-gimbal system.

The LAMS concept was originally developed for an advanced IPACS for the Space Station and is illustrated in Figure 1. This version of the LAMS employs a Lorentz-force magnetic suspension and permits gimbaling of the rotor spin axis up to approximately 23° relative to the armature, with only a small mass penalty. Although the limitation on the gimbal constrains the capacity for the transfer of angular momentum, the IPACS rotor has an abundance of capacity, and the requirement for transfer of angular momentum in the Space Station can be met with gimbal angles within this range. Figure 2 shows one of eight stator-mounted coils that is used to produce five-degree-of-freedom actuation when it interacts with the nominally-radial magnetic field produced by the rotor-mounted magnetic circuit of the Lorentz-force LAMS.

The primary advantage of a magnetic suspension for a satellite flywheel is the lack of physical contact between the rotor and the stator. Reductions of vibrations and structural interactions can also be obtained through active control. Because

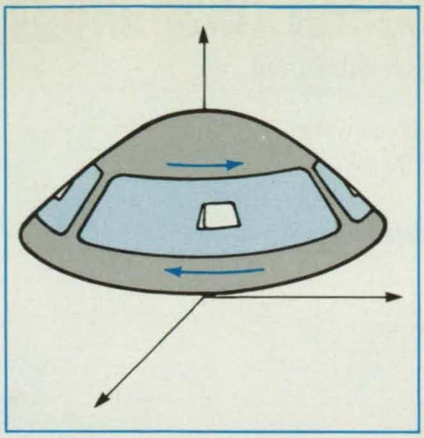


Figure 2. **Stator-Mounted Coils** enable actuation in five degrees of freedom.

magnetic suspensions require no lubricant, they are well suited for use in a vacuum. The magnetic suspension is required to exert control torques on the spacecraft and to cause the flywheels to precess. The flywheels, however, are allowed to operate on touchdown bearings during severe maneuvers. The magnetic suspension must allow the rotor sufficient angular freedom (precession and nutation) to transfer the required angular momentum between the flywheels and the Space Station. In some configurations, the LAMS must also allow sufficient angular freedom to reconfigure the flywheels to a nominal zero net angular momentum in the event of the failure of a single wheel.

This work was done by Ronald E. Oglevie of Rockwell International Corp. and David B. Eisenhaure and James R. Downer of Charles Stark Draper Laboratory, Inc., for **Langley Research Center**. *Further information may be found in NASA CR-3912 [N86-15338/NSP], "Advanced Integrated Power and Attitude Control System (IPACS) Study."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.
LAR-13587

Books and Reports

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

Nonlinear Analysis of Rotor Dynamics

Progress is made toward understanding rotor vibrations.

A study explores the analytical consequences of the nonlinear Jeffcott equations of rotor dynamics. The analyses should eventually lead to better understanding of excessive vibrations in rotating machinery.

Section 1 of the report includes a summary of previous studies. Section 2 begins with the Jeffcott equations, which describe the lateral displacement of the center of the rotor from the equilibrium position in an inertial, Cartesian coordinate system. The Jeffcott equations are nondimensionalized, then combined by transformation to the complex plane to simplify the subsequent analyses. The complex, nondimensional equations are generalized by the inclusion of multiple forcing functions, which include such special cases as mass imbalance, side force, rubbing, and any combination of these. The second section concludes with the application of the method of multiple scales, which is an asymptotic-expansion method, to approximate the solutions to the Jeffcott equations.

A previous study had shown that the nonlinear frequency that arises when the homogeneous Jeffcott equations provide a part of the total steady-state solution can be absent or present, depending on the magnitude of the forcing function. Section 3 of the report proves two theorems that provide inequalities on the coefficients of the differential equations and the magnitude of the forcing function in the absence of side force. These inequalities are useful in deciding a priori whether a given set of equation parameters will produce a steady-state response that depends solely on the forcing function (yielding a circular displacement trajectory) or a response that also includes a nonlinear frequency term (yielding a displacement trajectory that occupies an annulus). Several numerical examples along with frequency-response curves are then studied in light of these theorems.

Section 4 begins the numerical investigation of the multiple-forcing-function problem by introducing both side force and mass imbalance; this combination is the most intensely studied special case. The addition of the side force to the nonlinear problem is predicted to cause a constant shift of displacement in the solution of the corresponding nonlinear problem without side force and to deform circular trajectories and annuli to elliptical trajectories and annuli, respectively. This prediction is confirmed by examination of a previous study of the effects of bearing deadbands on bearing loads and instabilities of rotors.

Section 5 presents examples of numerical solutions of the complex, generalized Jeffcott equation with two forcing functions of different frequencies f_1 and f_2. The power spectral densities of the calculated displacements contain not only f_1 and f_2 but also some or all frequencies

$$|n_1 f_1 + n_2 f_2 \pm \beta|,$$

where β is the nonlinear frequency from the homogeneous portion of the Jeffcott equation, and n_1 and n_2 are integers. Which of these frequencies appears depends on the relative magnitudes of the coefficients of the homogeneous equation and the amplitudes of the forcing functions.

Section 6 deals with the boundedness and stability of solutions. Two theorems along with a novel mathematical representation of the Jeffcott equations are presented. New boundedness results are also studied by comparing the behavior of the nonlinear solution with that of the corresponding linear problem. Finally, numerical results are included to illustrate the conjecture that the boundedness of the nonlinear solution is predicted by that of the linear solution.

Section 7 concludes the report by reviewing the analytical results and their significance. It also calls many solutions, including those of this report, into question by observing that heretofore the initial conditions have been ignored as a vital factor in determining the analytic solution. Therefore, the authors suggest further examination of the effects of initial conditions.

This work was done by William B. Day and Richard Zalik of Auburn University for **Marshall Space Flight Center**. *To obtain a copy of the report, "Nonlinear Rotordynamics Analysis," Circle 76 on the TSP Request Card.*
MFS-26051

Fabrication Technology

Hardware Techniques, and Processes

Argon Welding Inside a Workpiece

Canopies convert a large, hollow workpiece into an inert-gas welding chamber.

Marshall Space Flight Center, Alabama

A large manifold serves as its own welding chamber for the attachment of liner parts in an argon atmosphere. Every crevice, opening, and passageway is provided with an argon-rich environment. Weld defects and oxidation are thereby dramatically reduced; welding time is also reduced considerably.

The manifold is part of the Space Shuttle main engine. The liner creates a space for coolant to flow around the manifold. The liner is constructed by welding together panels and tubes of assorted shapes inside the manifold shell (see Figure 1). Ample quantities of gaseous argon must be directed against all sides of a piece as it is welded. This is difficult to do in the confined space between the shell and the liner piece.

An argon atmosphere is assured by the installation of flexible gloved canopies on the manifold openings used by the welding operator for access to the work. All unused openings are sealed, and argon is supplied through the manifold coolant inlets (see Figure 2).

The flowing gas, which escapes through small holes in the gloved canopies, purges air from the interior of the manifold so that oxidation cannot degrade the weld quality. Maintained at a gauge pressure of 1 to 2 inches of water (250 to 500 N/m^2), the argon puffs out the clear plastic-film canopies. With hands placed in the gloves, the operator manipulates the welding gun, which is placed inside the manifold before the canopies are attached. This welding technique should be useful in the fabrication of heat exchangers, pump bodies, and other complicated, enclosed assemblies containing flow passages.

This work was done by Gene E. Morgan of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*
MFS-29167

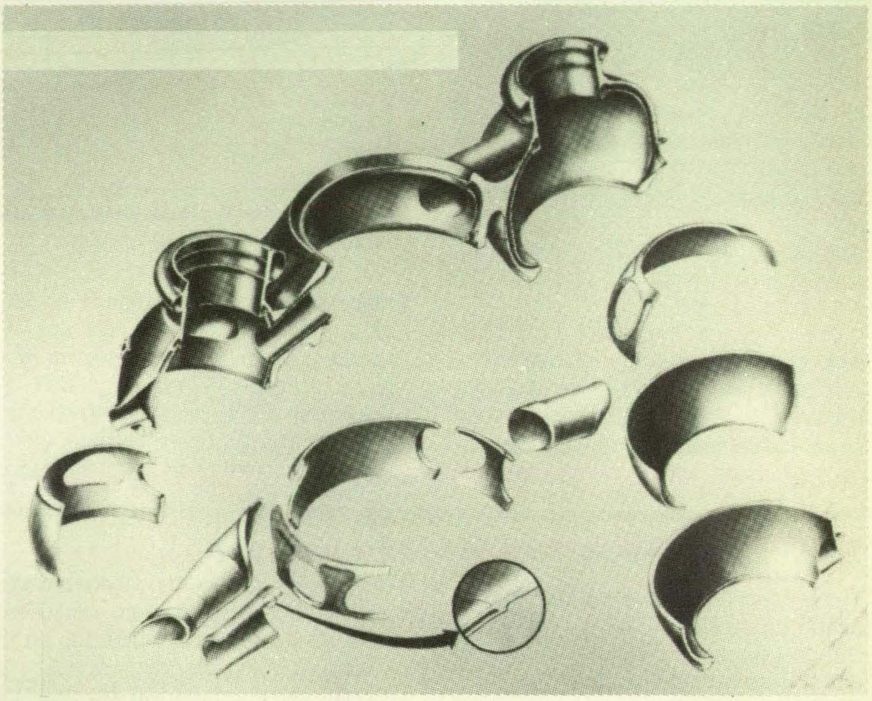


Figure 1. The **Manifold Liner** is made from smaller pieces that are welded in place inside the manifold.

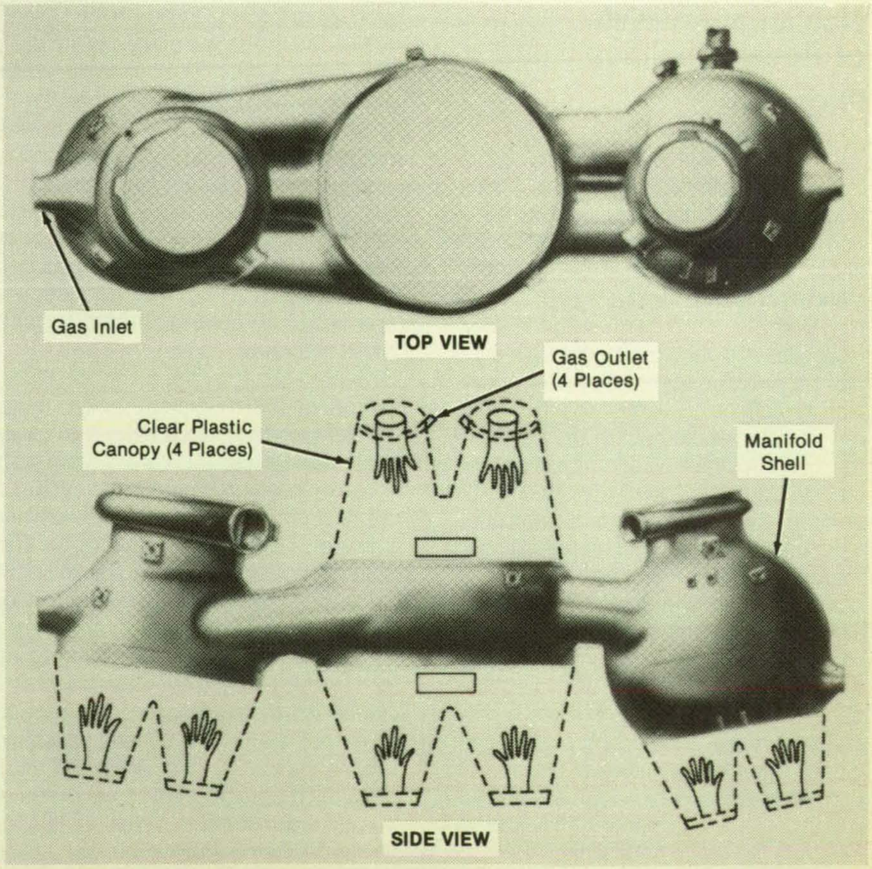


Figure 2. **Gloved Canopies** over large openings retain an atmosphere of flowing argon inside the manifold. Other openings are sealed during welding, except for the argon inlet.

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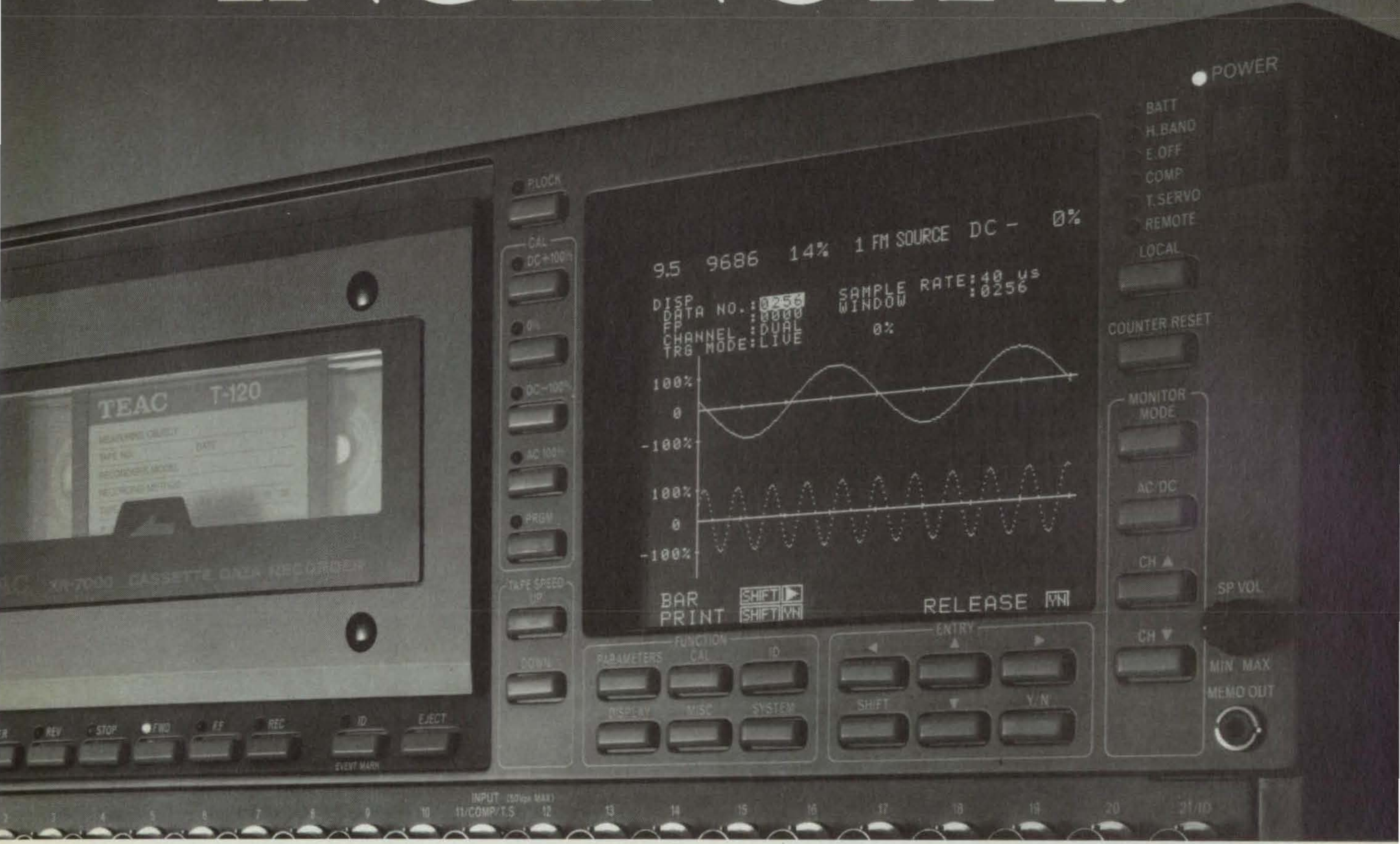

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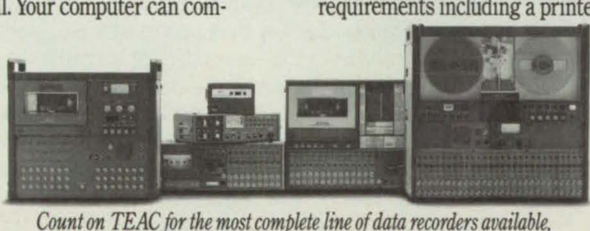

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Computer Programs

Least-Squares Frequency-Acquisition Algorithm

Performance rivals that of the FFT algorithm.

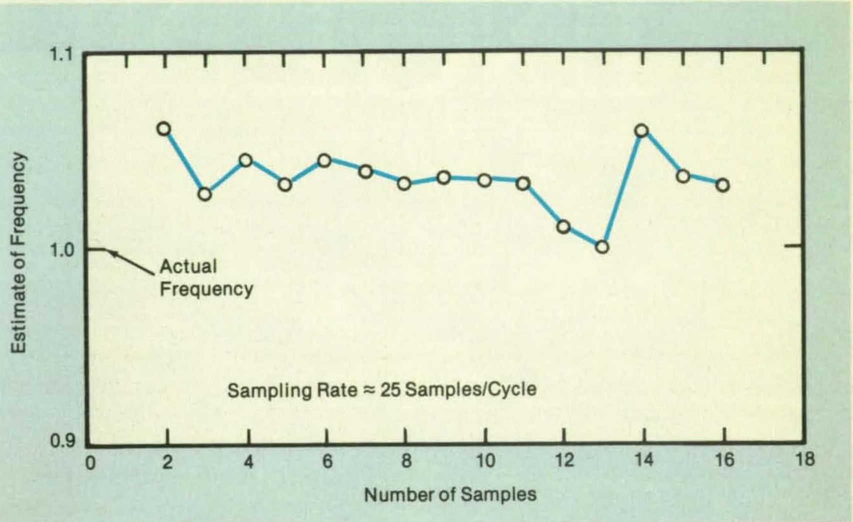
NASA's Jet Propulsion Laboratory, Pasadena, California

A least-squares algorithm finds the frequency and phase of a sinusoidal signal in the presence of noise (see figure). The algorithm is a special case of more-general, adaptive-parameter-estimation techniques. The computational requirements of the new algorithm are comparable to those of the corresponding fast-Fourier-transform (FFT) algorithm. The new algorithm works directly in the time domain, whereas the FFT algorithm transforms the data into the frequency domain for estimation and detection and requires a secondary algorithm to interpolate between frequencies.

The received signal is assumed to be demodulated by a carrier reference signal of known frequency and phase and by its 90°-phase-shifted version. The problem is to determine the frequency and phase of the received signal from the noise-corrupted in-phase and quadrature samples of the demodulated signal plus noise.

The basic equations for the measurements express the noisy samples as a truncated (nth-order) series involving the unknown frequency and phase, the sampling times, and the noise samples. The equations can be put in linear form involving a matrix of parameters that depend on the frequency and phase and from which, in principle, the frequency and phase can be extracted.

The algorithm obtains the matrix of parameters from a sequence of N pairs of measurements. It involves the inverse of an $n \times n$ matrix (the "state-vector" matrix) that contains terms dependent on the sampling times and that can be precomputed, multiplied by a matrix formed from the measurements. The state-vector matrix has a special structure that makes it possible to use a rapid inversion algorithm: as a result, the desired matrix of parameters can be obtained in about $6n\log_2(n)$ operations, much fewer than the number of operations required for the "brute-force" calculation of a general matrix equation of similar form.



In a **Numerical Simulation** without noise, the algorithm gave an estimate close to the actual frequency in a fraction of the signal period.

Initially, the estimation error of the least-squares algorithm approaches zero as the reciprocal of the factorial of the number of measurements. As the number of observations increases, the algorithm converges even faster — at an exponential rate. The computational requirements of the least-squares algorithm are determined predominantly by the product of the signal frequency and the observation period, whereas those of the FFT algorithm depend predominantly on the number of samples.

This work was done by Rajendra Kumar of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 49 on the TSP Request Card.*
NPO-17104

Books and Reports

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

Networks of Executive Controllers for Automation

Important issues for designers of artificial-intelligence systems are reviewed.

A paper discusses principal issues that must be resolved in development of an autonomous executive-controller shell for the Space Station. Such a shell represents a major increase in the complexity of automated systems. Previously, the technology of artificial intelligence and expert systems focused on separate functions like planning, scheduling, monitoring, the diagnosis of faults, and simple feedback control. More-complex control tasks, however, require a system that can deal with many different goals, each requiring sequences of tasks that change the state of the system world in complex ways. This requires the integration of all the functions.

The system must generate plans to achieve the goals, execute the plans, sense the environment to monitor the effects of its actions on the world, recognize obstacles and other problems, diagnose the causes of the problems, and interactively replan and continue on toward the goals. Such a system is called an intelligent autonomous system. Intelligent autonomous systems that can interact with other autonomous systems as well as with the external world are called executive controllers.

The many potential applications for executive controllers in the Space Station program include communications, tracking, life support, data-processing support, guidance, navigation, control, power, ground support, crew activity, support systems for the crew, support of payloads and experiments, and the control of thermal and structural subsystems. A demonstration scheduled for the year 1990 will focus on the combination of these components into an integrated executive controller with cooperative sharing of data and commands with a second executive controller on a peer level. Later demonstrations will focus on building full-fledged hierarchical networks of executive controllers, with lower-level autonomous systems providing support to complete space systems and higher level executives providing overall management and guidance.

One of the first considerations to be addressed in the design of an intelligent autonomous system is the degree of autonomy supported. A system that must be completely autonomous presents, to the designer, problems different from those presented by a system that must interact with a human user. Because of the wide range of potential problem domains and applications, the demonstration project can define the degree of autonomy for a given system only on a case-by-case basis. Hence, an intelligent autonomous system shell must support a full range of potential degrees of autonomy.

A problem in the real world involves three dimensions of complexity: regional, functional, and hierarchical. As an example, separate habitable modules on the Space Station might each have a life-support executive (regional), managed by a higher-level life-support supervisor (hierarchical), which, with other executives for controlling power, thermal, and other systems (functional), is managed by a top-level supervisor executive (also hierarchical).

Regardless of the dimension of complexity, each executive controller in a network should be as independent from the others as possible. This independence reduces the load on the underlying communication network and simplifies coordination of the activities of the various component executives.

Each executive in a network of executive controllers can have a different view of the world, depending on its particular goals. This can result in problems in sharing information. One executive may have the data for deducing the information desired by a second executive but, because of differing world views, may not have the data in a form that the second executive can use. It may therefore be necessary to augment each executive so that it translates information from its own world model to those of the executives that request the information. Alternatively, a global model may handle the details of translation of information from the world model of one executive to the world model of another.

While executing the first part of a plan, an intelligent autonomous system can be simultaneously monitoring the environment and developing a later part of the same plan. To support this capability, the functional modules should be implemented as separate processes, running either on a single processor in a multitasking environment or on different processors. Because of the high demand on computing resources made by functional modules, the multiple-processor alternative seems the most viable for an operational executive, although prototype versions could be developed on a single processor.

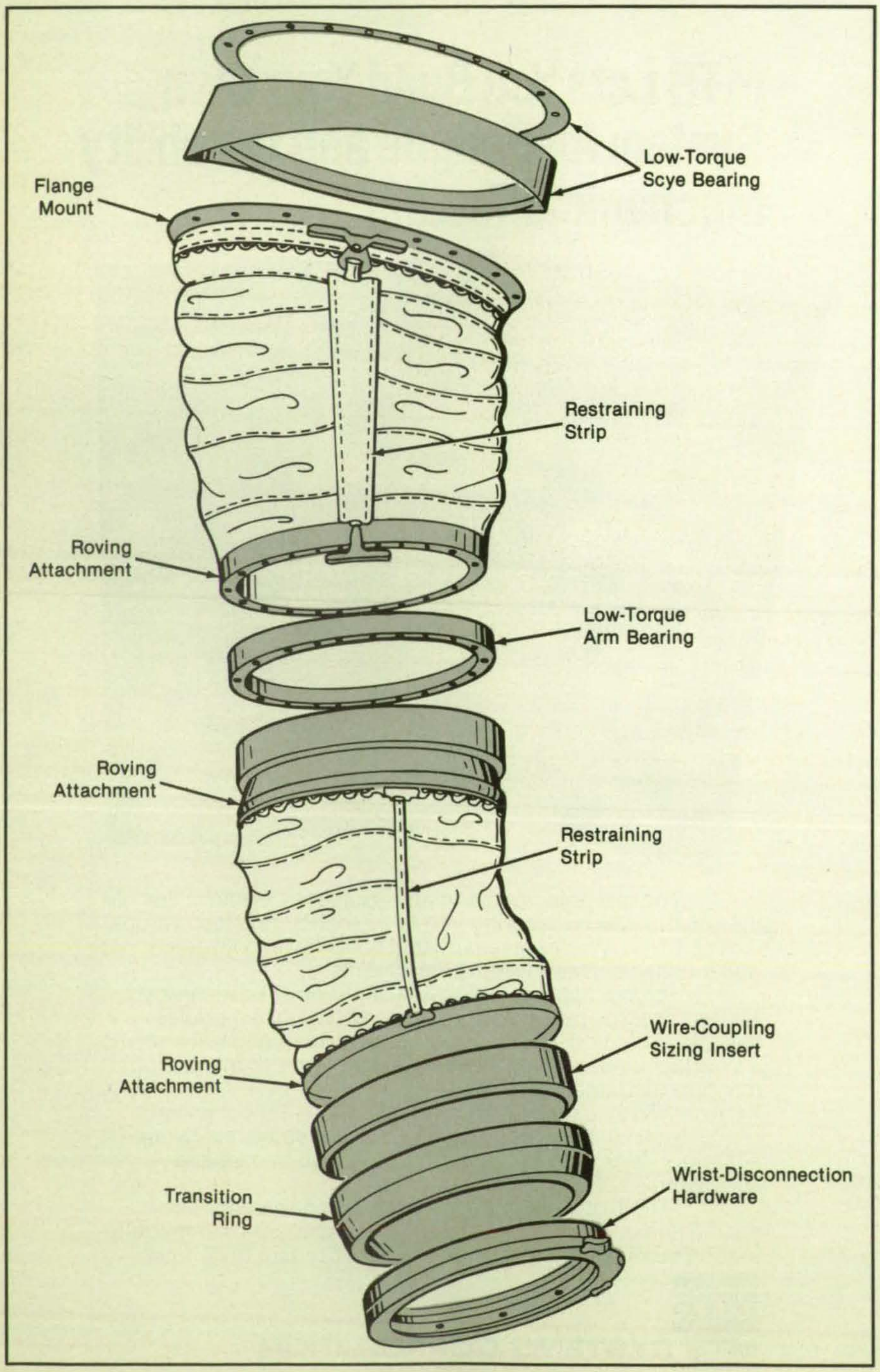
This work was done by William K. Erickson of **Ames Research Center** *and Peter C. Cheeseman of the Research Institute for Advanced Computer Science. To obtain a copy of the report, "Issues in the Design of an Executive Controller Shell for Space Station Automation," Circle 83 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center [see page 12]. Refer to ARC-11780.

Pressurized Sleeve

A garment part sustains a pressure differential without unduly restricting the user.

Lyndon B. Johnson Space Center, Houston, Texas



The **Pressurized Sleeve** consists of low-torque joint hardware, sewn fabric sections, and lengthwise strips of fabric that restrain the sections.

A fabric sleeve withstands a pressure difference of 8 lb/in.^{2} (55 kPa) while allowing the wearer fairly easy movement. Developed as a replacement for a space-suit sleeve rated only to 4.3 lb/in.^{2} (30 kPa), the new sleeve gives greater range of movement with lower restrictive torques. The sleeve offers the same advantages in such terrestrial applications as protective clothing and sleeves for manipulation of objects in isolation chambers.

The sleeve consists of upper and lower fabric sections fitted with shoulder, elbow, and wrist hardware (see figure). Longitudinal strips of fabric on the upper and lower sections restrain the sleeve so that it does not balloon axially under its internal pressure.

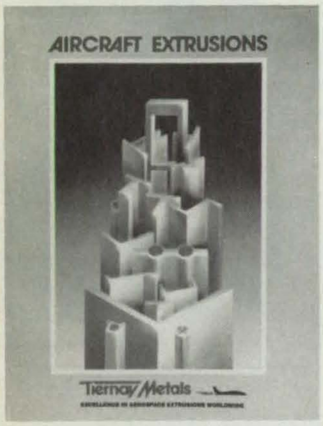
The sleeve is made of a polyester biaxial-weave fabric like that used previously in this type of space suit. The patterns of the sewn fabric sections have been modified to yield improved mobility. The restraint strips are made of a new material woven of high-strength, low-elongation polyethylene fibers. The hardware joints feature ball bearings for low torque. The center joint has a quick-connect and quick-disconnect coupling.

The sleeve was subjected to a series of tests of fabric properties, endurance of flexure cycles, torques, and ranges of movement during its development. A final group of tests by wearers gave subjective evaluations of comfort, range, and torque.

This work was done by Amy Lerner of ILC Dover, Inc., for **Johnson Space Center**. *For further information, Circle 2 on the TSP Request Card.*
MSC-21280

New on the Market

The world's first **plastic laser** has been created by Amoco Laser Company, Naperville, IL. Amoco's new solid-state microlaser features a resonator made from an injection-molded high-performance polymer. This innovation paves the way for future low-cost, mass production of microlasers, according to company officials. **Circle Reader Action Number 792.**



Tiernay Metals, Redondo Beach, CA, is offering a free 1200 page **catalog** that lists, cross references, and provides technical data on virtually all **aluminum extrusions** found on airframes world-wide. The catalog lists extrusion shapes and alloys by customer and/or mill, and contains a comprehensive Army-Navy index. **Circle Reader Action Number 800.**

The Zero Corporation of Los Angeles, CA has developed a new line of **shock-mounted cases** designed for the safe transportation and field operation of delicate electronic instruments. The Val-An Series 900 cases are available with removable front and rear covers for easy access and equipment installation, and feature an interlocking design for secure stacking. **Circle Reader Action Number 796.**

BRAINSTORMER, a **software tool** for finding solutions to difficult science and engineering problems, is now available from Soft Path Systems, Eugene, OR. Using a technique called Morphological Analysis, BRAINSTORMER provides a way to list and examine the possible combinations that might be useful in solving a given problem. The user refines ideas with program commands that recombine portions of the problem to trigger new solution strategies. Applications include new product development, process and product improvement, and generation of marketing plans. BRAINSTORMER can be used on MS/PC-DOS microcomputers with at least 512K memory. **Circle Reader Action Number 782.**

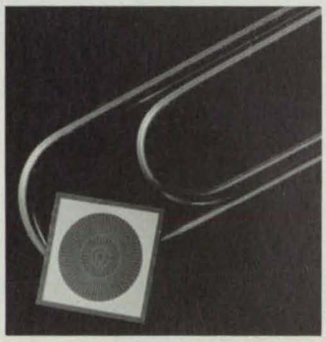
The AXIOM 2/20 **Laser Measurement System** from the Zygo Corp., Middlefield, CT, provides laser interferometer accuracy for the measurement of linear displacement, angle, straightness, and refractive index of air. Targeted at manufacturers of precision positioning equipment, the AXIOM 2/20 features velocity up to 1.8m/sec, measurement update rates of 7-13 MHz, and unlimited acceleration. The system consists of a two-frequency laser head, beam directing and splitting optics, receivers, wavelength compensators, and electronics. **Circle Reader Action Number 786.**

ANVIL-5000pc™ from Manufacturing and Consulting Services Inc., Irvine, CA, is the first **3D CADD/CAM software system** to provide complete mainframe capability on a personal computer. The system features a 64-bit floating point design and an open architecture. ANVIL-5000pc consists of six software modules that run on most 80386-based PCs. **Circle Reader Action Number 794.**

The 3M Company's Aerospace Materials Department has developed a new **graphite prepreg composite material** called Scotchply Brand SP-500. The new composite's advanced resin system provides superior hot/wet strength properties and damage tolerance, as well as low moisture absorption. SP-500 is designed for primary airframe construction, and can be processed using conventional layup, tooling, and autoclave equipment. **Circle Reader Action Number 790.**

Two new **brushless DC motors** from Fasco Industries Inc., St. Louis, MO, offer a ceramic-magnet rotor design for higher power outputs and greater efficiency in a smaller package. Units are available in 12 to 48 volts, with speeds from 1,000 to 5,000 RPM and power levels to ¼ H.P. **Circle Reader Action Number 784.**

A new **Wide Word/VMEbus Host Interface** from the Dataram Corp., Princeton, NJ, allows system designers to apply Dataram's Wide Word 2000 memory on the VMEbus at 640MB capacity per Wide Word unit. This makes it easy to combine supercomputer memory depth and speed with the flexibility of the open VMEbus architecture. Wide Word's eight-port capability permits data capture at rates up to 200MB/sec. The captured data can be transferred to other devices at the same rate or downloaded to a VME system at VMEbus maximum rates. **Circle Reader Action Number 780.**



A **gallium arsenide solar cell** that converts sunlight to electricity with 28.1 percent efficiency has been developed by Varian Associates, Palo Alto, CA. The single-junction cell, one-quarter the size of a postage stamp, offers applications in both terrestrial power systems and orbiting satellites. The silicon cells currently used on satellites are only about 14 percent efficient. **Circle Reader Action Number 798.**

MASSCOMP, Westford, MA, has introduced the 6000 Family of **real-time computer systems.** Based on the Motorola MC68030, the four new systems are binary-compatible, share a multiple processor architecture, and offer up to five custom VLSI floating point accelerators and four vector accelerators. The systems implement the UNIX® operating system and feature industry standards such as the VMEbus™, Multibus™, NFS™, and the X Window System™. **Circle Reader Action Number 788.**

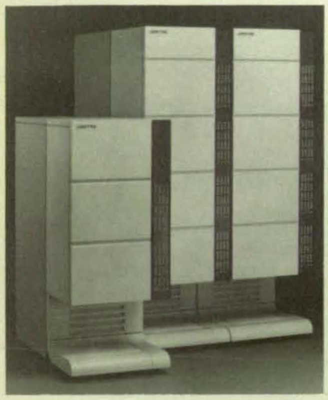
The System-40 **Logic Analysis System** from Bitwise Designs Inc., Troy, NY, features 25 MHz synchronous or asynchronous sampling, 125 MHz timing analysis, 256 state pass counting, and memory mapped word recognition. A menu-driven windowing environment can simultaneously display multiple timing diagrams, state tables, disassembled code, trigger setups, and system configuration. The portable system is XT-compatible with a 10 MHz 8088 microprocessor. **Circle Reader Action Number 778.**

Equipto Electronics Corp., Aurora, IL, is offering a **free electronic enclosure design kit**. Included in the kit are samples of the company's Heavy Duty and Challenger frames, an EMI/RFI technical guide, a galvanic compatibility chart, vertical and sloped front enclosures order/quote forms, and a 304 page full line catalog. **Circle Reader Action Number 774.**

(continued on the next page)

New on the Market *(continued from previous page)*

The Formulated Systems Group of CIBA-GEIGY Corp., Madison Heights, MI, has introduced the Araldite® **adhesives application gun.** The gun accepts a dual cartridge with separate compartments containing resin and hardener and dispenses adhesive through the static mix tip as the handle is depressed. Bead size is controlled by adjusting handle pressure.
Circle Reader Action Number 766



The Series 2010 **parallel processing system** from the Ametek Computer Research Division, Monrovia, CA, offers peak performance figures of over four billion instructions per second (4000 MIPS) and 20 billion floating point operations per second (20 GigaFLOPS), and can interface more than four trillion bytes of online storage (4000 Gigabytes) for parallel data access. The system's Automatic Message Routing Devices™ free computing resources from the burden of message routing, thereby significantly increasing performance over previous generations of massively parallel systems.
Circle Reader Action Number 758.

Eclipse Logic Inc., Huntington Park, CA, has introduced the ELI-41™, a **professional scientific calculator software package** that allows users to perform Hewlett-Packard 41 series programs on a PC. The ELI-41 features 15 digits of precision for calculations, disk access for storage and retrieval of programs, and visual displays of the calculator, stack, flags, and registers. ELI-41 runs on an IBM PC/XT/AT or compatible.
Circle Reader Action Number 760.

The V- Store **instrumentation tape recorder**, a portable, VHS-based unit with up to 24 channel capability is now available from Racal Recorders Inc., Irvine, CA. The V-Store can record signals from all types of sensors with electrical output from DC to 100 KHz. Soft keys allow access to such features as automatic channel set-up, dynamic bargraph and waveform displays, and built-in track sequencing for extended record/replay times.
Circle Reader Action Number 754.

A new **polyimide resin** that can withstand higher temperatures than current commercial plastics has been developed by the Du Pont Company, Wilmington, DE. Parts formed with the resin show excellent thermal stability at temperatures up to 650°F, and can take excursions to 900°F. Potential applications include automotive and aerospace parts as well as components for heating systems, business machines, and electronics.
Circle Reader Action Number 750.

Plantronics' new Liteset™ **cordless telephone** replaces the traditional cordless telephone handset with a three-inch capsule combining both earpiece and microphone. The capsule perches comfortably on the ear, thereby freeing the user's hands for other activities while talking. The capsule is connected to a dial pad that features a mute switch, number redial, and two-position volume control. A base unit provides up to 1,000 feet of cordless mobility and plugs into standard modular wall jacks.
Circle Reader Action Number 748.

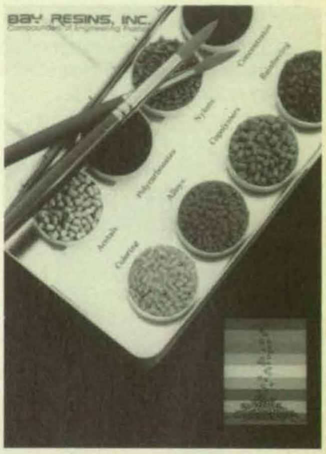
National Instruments, Austin, TX, has announced availability of the **AT-GPIB plug-in circuit card**, a new IEEE-448 interface for the IBM PC/AT and compatible 16-bit PCs. Data can be transferred between a computer equipped with the AT-GPIB and thousands of IEEE-448 bus-compatible engineering, scientific, and medical instruments. A computer configured with the AT-GPIB becomes an IEEE-448 controller that can be used for numerous applications in laboratory and production testing as well as in process monitoring and control.
Circle Reader Action Number 755.

A **pocket-size microscope** for industrial and laboratory inspections is now available from Edmund Scientific Co., Barrington, NJ. The microscope's clear acrylic base rests directly on the subject for stability and concentrated illumination. The device features a 3/16 inch field-of-view and a ¾ inch working distance, and is powered by two "AA" batteries.
Circle Reader Action Number 768

The VX series of **high vacuum positioning stages** has been introduced by New England Affiliated Technologies Inc., Lawrence, MA. Available in a wide range of axis configurations and travels, the VX series is designed for operation in vacuums up to 1×10^{-7} torr. The stages are made from electroless nickel-plated aluminum, and feature stainless steel leadscrews, anti-backlash nuts, and precision ball or crossed-roller ways.
Circle Reader Action Number 762.

Alsys Inc., Waltham, MA, has developed the first **Ada compiler** to run under OS/2, the new protected mode operating system developed by Microsoft. The compiler can run on any 286- or 386-based machine with a minimum of two megabytes of main memory, accompanied by the OS/2 system (Version 1.0 of the Standard Edition) provided by the manufacturer. A full set of programmer's tools, including AdaProbe, Alsys' high-level debugger, complement the compiler.
Circle Reader Action Number 764.

Aptec Computer Systems Inc., Beaverton, OR, has introduced the VSP-1, an **integrated vector/scalar processor board** for the company's IOC-24 I/O computer. The processor board, which connects directly to the IOC-24 data interchange bus, contains a powerful scalar processor and a vector processor that can perform 20 million 32-bit floating point operations per second. The software package includes VAX-based cross development tools, FORTRAN and C compilers, and an extensive application subroutine library.
Circle Reader Action Number 752.



A free four-color **information packet** from Bay Resins Inc., Millington, MD, describes the characteristics and typical uses of all Baylon™ **molding and extrusion compounds.** The packet also highlights Bay Resins' research and development program and computerized color matching capabilities.
Circle Reader Action Number 756.

NEC America, Wood Dale, IL, has introduced a new line of **CCD cameras** that provides sharp images of high-speed objects for playback in slow-motion or stop-action. Equipped with electronic shutters, the cameras are suited for manufacturing or research applications involving high-speed motion analysis, non-destructive testing, image processing, and pattern recognition.
Circle Reader Action Number 770.

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