NASA Tech Briefs

THE DIGEST OF NEW TECHNOLOGY

Official Publication of the
National Aeronautics and
Space Administration
November 1994 Vol.18 No.11

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Technology 2004 Commemorative Cover by Peter Max

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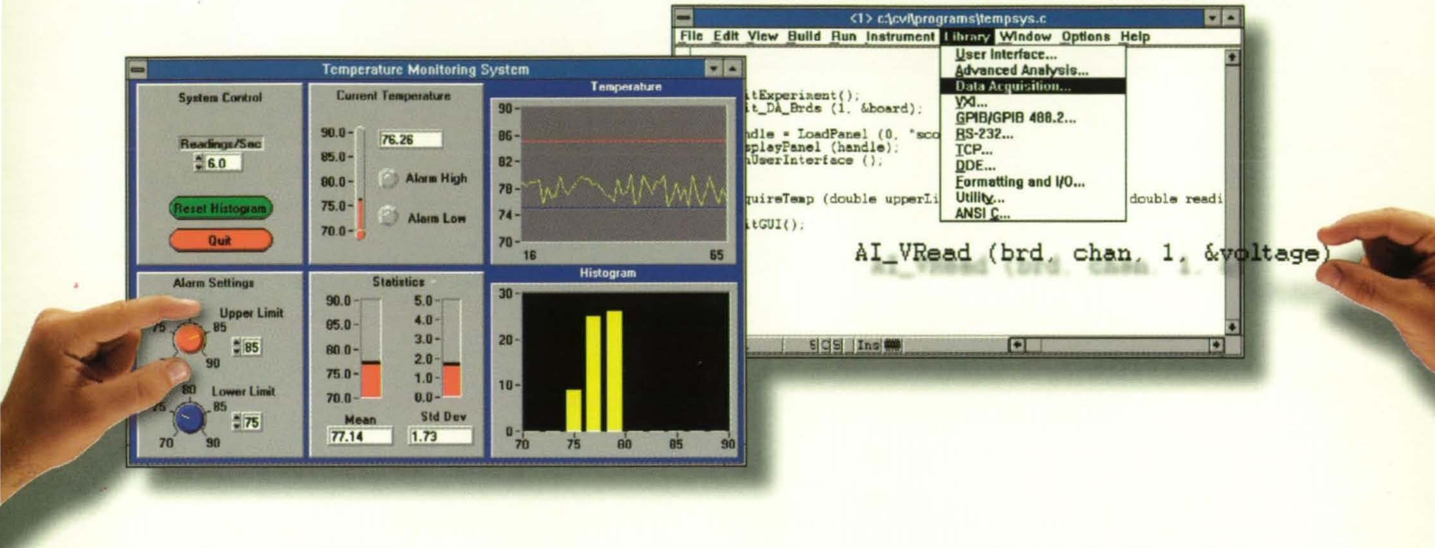

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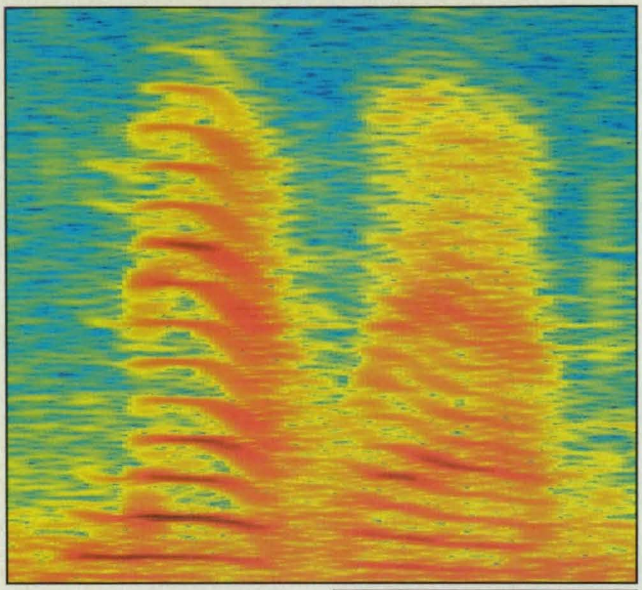
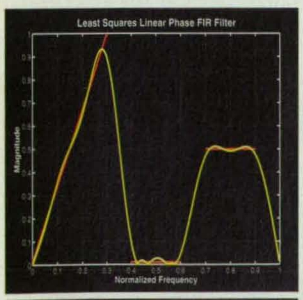


MATLAB simplifies analysis and algorithm development with integrated modeling, design, and visualization tools. This spectrogram shows how a speech signal varies with time and frequency.

Speak the language of signal processing with MATLAB®

The MATLAB Signal Processing Toolbox is a powerful interactive environment for signal analysis, algorithm development, and DSP design.



Leading-edge filter design tools make it easy to design filters to fit any specification.

Because its matrix language is ideal for vector processing and data analysis, MATLAB helps you solve the widest range of signal processing problems.

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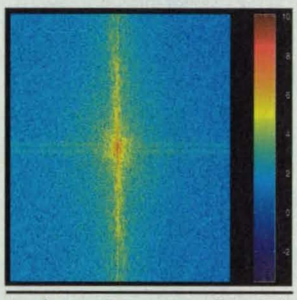

Visualization of a 2-D FFT. Efficient FFT algorithms form the basis for powerful spectral analysis and estimation functions.

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With the high-level MATLAB language, it's easy to modify the source code for any toolbox function, or add your own. Or combine signal processing with other toolboxes to design custom solutions to complex problems.

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November 1994
Volume 18 Number 11

Contents

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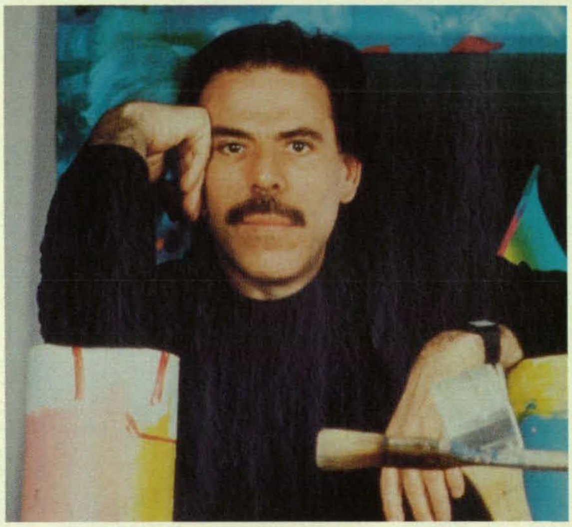
FEATURES

TECHNICAL SECTION

(continued on page10)



On the Cover:

World-renowned artist Peter Max designed this month's cover using a computer from Silicon Graphics Inc. (SGI). When Max speaks of SGI, his tone turns reverential. "When I found out about SGI, I immediately flew [there]," he said. "It was like a pilgrimage, like walking into a playground of a new kind." In his eyes, the computer system that has helped engineers visualize the dynamic interplay of forces working on aircraft and spacecraft also can allow artists to reinvent their craft.

Max found his new epiphany in SGI's Indy™ system, a desktop computer that combines a digital color video camera with a host of digital media and 3D graphics capabilities. If Max's brightly colored, improvisational images of the 1960's defined the Beatles era, his current approach aims "to bring futuristic art forms into the new millennium."

Recently, Max has been using this electronic canvas to add the dimension of time to his work, with instantaneously changing colors and forms. He also devised a digital gallery, in which the "visitor," at a computer monitor, "walks" through the gallery and views the paintings apparently hung there. For the cover of this issue, the artist used mixed media, incorporating some of his computer-generated kaleidoscopes in the collage. He said his intent was "to create a fantasy of what is out there in space."

Thus, through art, NASA has chalked up a new kind of spinoff. In the early 1980s, the newly-formed SGI began seeking customers for a new 3D graphics technology. NASA engineers at Ames Research Center needed a way to visualize the oceans of data collected from computational fluid dynamics research. NASA found its answer at SGI, whose machines, along with software developed by SGI and NASA, turned these data sets into active 3D images, which in turned provided insight into improving airplane designs.

Max expressed excitement about being a part of a NASA spinoff. He had tried other computer equipment, only to be disappointed. "I thought, I am so much faster with a razor blade or with my pen," he said. But with the SGI equipment he found he could create complex moving images with the immediacy of painting.

Max has a history of high-profile works, from the 1974 "Preserve the Environment" postage stamp to the 1994 White House commission to paint the "Peace Accord" commemoration of the handshake between Israeli Prime Minister Yitzhak Rabin and PLO Chairman Yassr Arafat. He was named the official artist of Super Bowl XXVII and created the art for World Cup '94.

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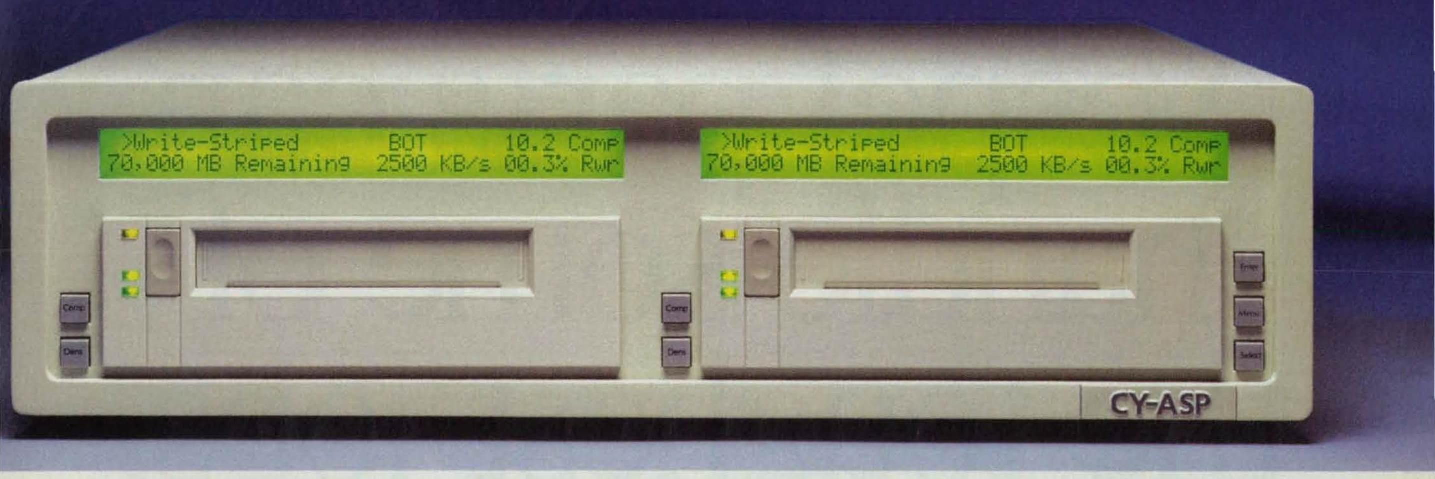

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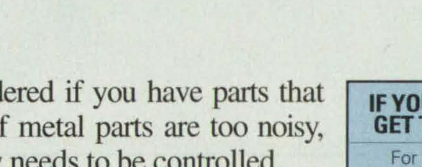
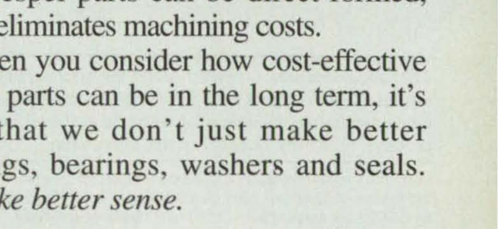
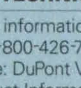


Bushings. *In aircraft engine vanes, Vespel bushings withstand high-frequency vibration dithering and offer excellent stability and lubricity at high temperatures. They also reduce assembly time.*





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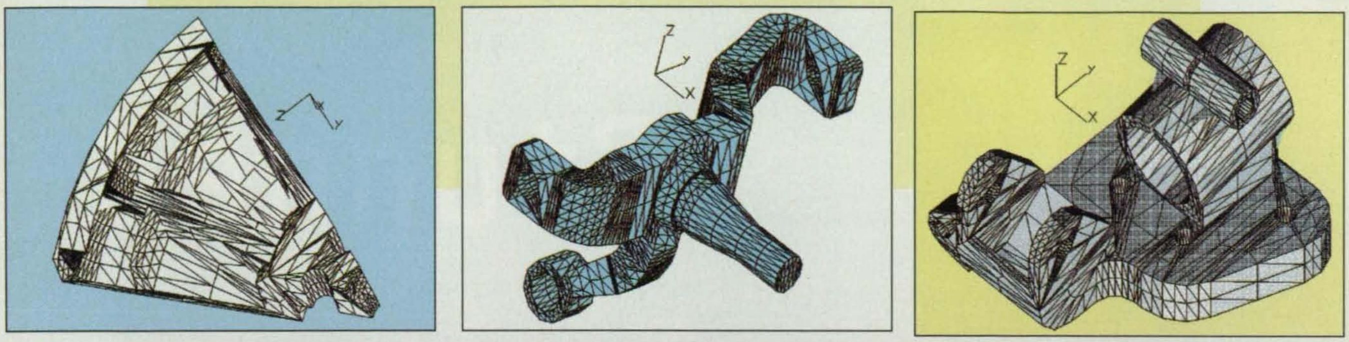

After Merlin™ one-step mesh enhancement technology

(Algor brick element models above shown with an 85% shrink-element factor.)

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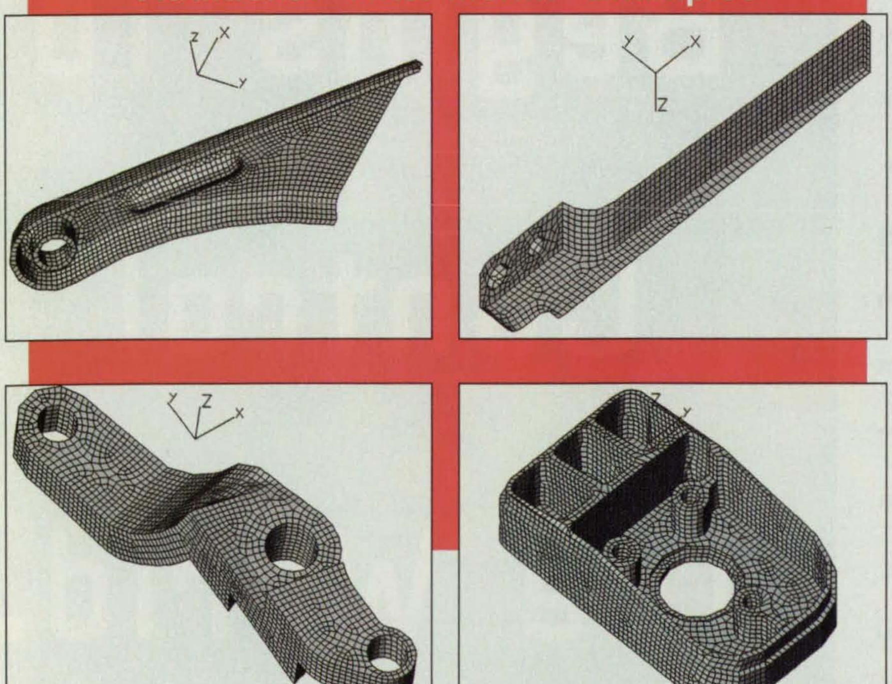
Additional "After Merlin" Examples



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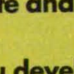
Many developers have never been introduced to the MATRIX$_X$® product family from Integrated Systems. And still, it's revolutionizing the way control systems engineers develop software.  MATRIX$_X$ is the only integrated family of development tools for real-time control systems. It guides you through the dynamic process of design, analysis, simulation and code generation, allowing you to evaluate and modify system models as you develop. So you can be confident that you'll get the very best performance from your system.  Each MATRIX$_X$ product is the best in its class. And

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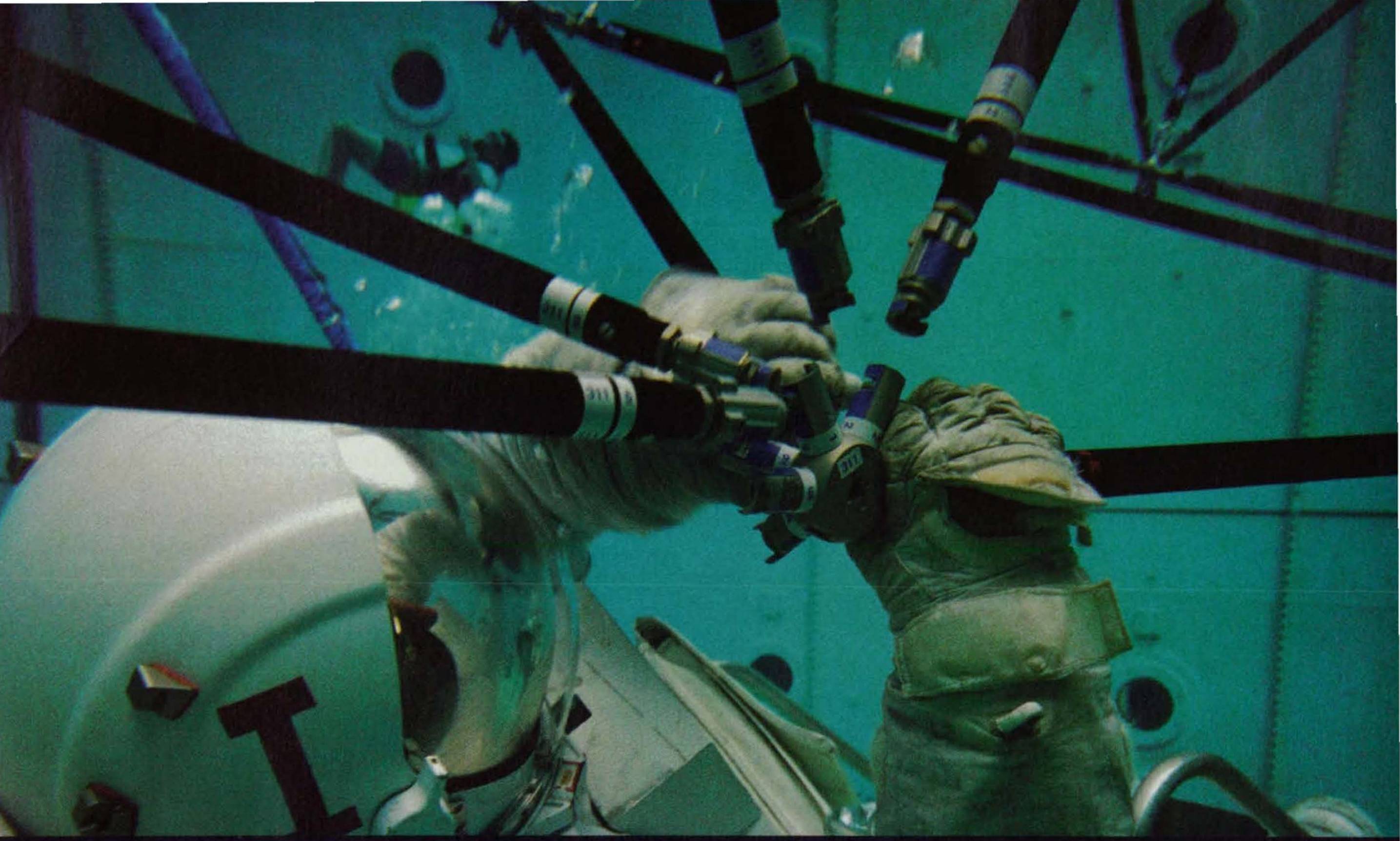


NASA's INNOVATORS

Technology 2004, the fifth national technology transfer conference and exposition (November 8-10, Washington, DC Convention Center), will feature presentations by more than 50 of NASA's leading technologists detailing a broad array of commercially promising inventions and processes. Here's a look at some of these innovators and their cutting-edge work.

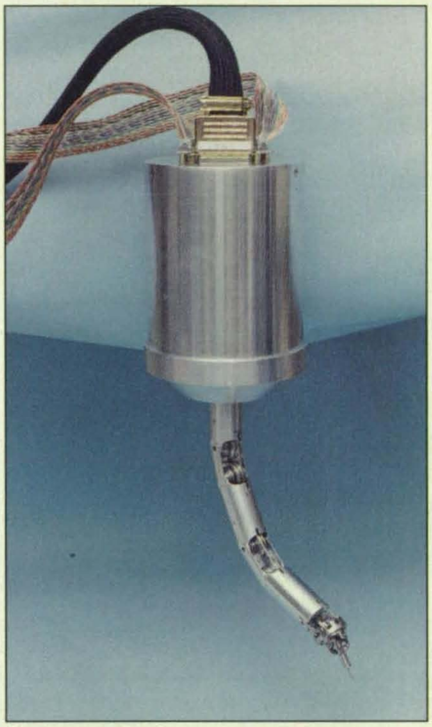
Small Surgery, Big Results

No matter how steady the hand of a gifted surgeon, the latest advances in surgical technique require a precision and dexterity beyond the humanly possible. To address the rigors of microsurgery, a research team at NASA's Jet Propulsion Laboratory (JPL) has adapted high-precision space robotics technology to the new Robot Assisted MicroSurgery (RAMS) system.

According to Paul Schenker, JPL's group supervisor of Man-Machine systems, the best way to characterize the RAMS system is as an extension of the surgeon's finesse. Just as the microscope enhances the microsurgeon's vision, so the robot enhances the microsurgeon's dexterity. Some surgeons, unaided by robots, are sensitive to movements of their surgical tools to within 100 microns, said Schenker. The JPL team set out to improve the relative positioning of surgical tools by two to three times and so pave the way for ever more "micro" microsurgeries, such as procedures on the inner eye.

Not a typical robot, the RAMS system is a mere 25 cm long and 2.5 cm in diameter and can work in an operating volume of over 20 cm^3. By comparison, the operating volume for a full-size robot is often several cubic meters. The microsurgery robot features a one-to-one continuous correspondence over space, enabling it to translate the natural telepresent position of the operator. The robot enables relative positioning of surgical tools to an accuracy of 25 microns.

"There's some hocus-pocus going around about moving '100 times smaller,'" Schenker said, "but the surgeon doesn't need this. Surgeons will point out that 'If you can help me move two times smaller, I can do many times more important work.'" The improved relative positioning of the robot allows the surgeon to work in such sensitive areas as the eye, ear,



The six-degree-of-freedom Robot Assisted MicroSurgery (RAMS) system improves the accuracy of surgical tools to enable surgery in sensitive sites such as the inner eye.

and perhaps the brain, hand, face, and nerves.

To improve the chances that the team develops a machine that doctors will want, Schenker's group is working with Dr. Steven T. Charles, a physician and CEO of MicroDexterity Systems. JPL has formed a Technology Cooperative Agreement with MicroDexterity Systems to develop the microsurgery robot. Dr. Charles provides the medical expertise and helps set system requirements.

In the last year, the team conceived the robot design and engineered, built, and tested a prototype at JPL. The next step is to develop the master hand control. Instead of directly manipulating a tool, the surgeon will manipulate a joystick-like device, which will have the same six degrees of freedom as the robot. By translating the surgeon's motions, the device offers "kinesthetic control." It will provide force feedback, giving the operator a true sense of the force exerted.

JPL developed the Spatial Operator Algebra (SOA) to compute the commands for robot joint motions from the input coordinate changes. The SOA allows rapid control software development and testing. Desired joint positions are downloaded to the PMAC board, which performs joint servo control. Mechanically decoupled joints simplify kinematics computations.

The unit also features drive unit separability, which allows autoclaving of the robot upon removal of the motor/encoder units at the base. Essential to fine manipulation, five of the six degrees of freedom have zero backlash or free play, and the sixth has only 20 microns. Precision ball bearings in every rotating location of the robot minimize stiction, or sticking and slipping, to achieve small incremental movements without overshooting or instability.

Features such as the operator's input to a calibrated virtual reality task interface may permit extension of the technology beyond microsurgery into telesurgery, in which the operator is truly at a distance. The US military foresees telesurgery as a means to enable specialist surgeons to operate on soldiers without being on the battlefield. More generally, when an expert surgeon is not available, the surgeon's expertise could be imported instantaneously using telesurgery. Other applications include biological research requiring micromanipulation and microminiature assembly.

Training in Virtual Reality

A multi-billion-dollar space station is both too dangerous and too precious a resource to risk training future pilots on board. In such high-risk situations, simulated reality has become an increasingly popular and cost-effective training environment.

To improve the flexibility of rapidly changing simulated environments, the Johnson Space Center has devised the Simulation Virtual Machine (SVM). Beyond the space station trainer that inspired it, the SVM also may have applications in commercial airline and military aircraft simulators, high-speed passenger train simulators, and even situations in which real-life simulations are used to test or verify computer software, such as nuclear power plant computer safety controls.

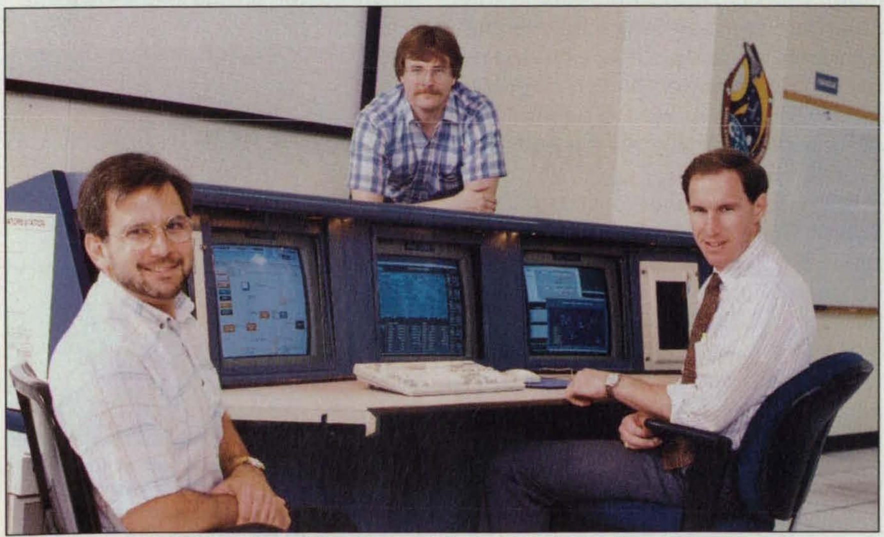
According to Kenneth Hill, real-time sessions manager at NASA Johnson and head of the team that developed the SVM with CAE-Link Corporation, the SVM's uniqueness lies in its executive, or the software that defines the formats for all models running in the virtual reality system. One innovation in the executive is its scheduling technique. Conventional scheduling is frame-based, requiring that each software model have specific deadlines by which it must complete its task. With the time-line divided into evenly spaced frames, each part of the model must finish within the frame.

The SVM, on the other hand, employs rate-monotonic scheduling (RMS), which allows each software model to execute in a time natural for it. Initially, each model is timed to determine its worst-case execution, then a performance rate-monotonic analysis is performed to fit it into the system with its own unique timing and without artificial restrictions.

According to Hill, this improves the simulator by providing "automation you didn't have earlier in assignment of tasks to different CPUs in the system." Without RMS, task assignment would have to be done manually, but since the RMS analysis is automatic, it assures the task will be completed.

Another feature is its software backplane, which provides communication between different software models in the system, keeps track of the memory, and thereby keeps track of the models' locations within the system. The RMS and backplane reduce the time required to configure the system as different models are changed, updated, or improved. Under a frame-based scheduling, it may take many hours or even days to configure the system after altering the models, but with RMS, configuration takes about 20 minutes, according to Hill.

"The SVM is running and tested," said Hill. "In the next two years, we will be executing models that can be performed on the SVM." For companies that are developing their own simulators, he said, setting up the SVM for a large simulator (comparable to, say, that for the space station) would take about two years. For a small simulator—so-called part-task trainers that require only a single monitor—set-up would take about two months.



Jim Turner and Billy Little (Simulation Virtual Machine developers) and Kenneth Hill (system manager) at the Space Station Training Facility console. Computer screens show the instructor station displays.

Clean, Efficient Waste Disposal with Microwaves

Disposing of solid waste, particularly waste that has biological or biohazardous components, presents a problem for hospitals, laboratories, and industry. NASA faces the same challenge as it develops regenerative systems to sustain humans living in space for extended periods.

In NASA's regenerative life support scheme, plants play a vital role. First, they photosynthesize carbon dioxide and water into complex carbohydrates and oxygen. The edible parts of the plant provide a food source for the crew. This leaves the inedible portions for recycling, ideally in a way that could help perpetuate the human/plant interaction.

The Regenerative Life Support Branch at the Ames Research Center has been evaluating a microwave incinerator that oxidizes inedible plant matter to produce CO_2 and water. "We can supply the CO_2 back to the plants. We also can use the water, if it's clean enough, for drinking or watering the plants; if not, for other applications," explained project manager Sidney Sun.

The incinerator under consideration is a commercially available unit manufactured in Japan. It is used in Japanese homes, where typically it is set up in the backyard to incinerate household refuse. Disposing of food waste where it is generated can prevent contamination and infection while also reducing the need for landfill space. The same features that make it ideal for household use make it applicable to other commercial applications and for extended space missions.

The compact unit—50 cm wide by 38 cm deep by 86 cm high—runs on standard 110 Vac electrical power and processes batches of garbage weighing up to 2 kilograms and 5 liters in volume. Its safe and odorless operation produces a sterile ash with a mass just 13 percent of the original waste. Further, the system is automated: the user simply loads the incinerator, closes the door, and pushes a button. During operation, the unit's exterior remains cool to the touch.

"The microwaves work directly on the water molecules, exciting them and drying up the material," according to Sun. "By an indirect process they cause a heating reaction of the waste matter. As the material heats up, it gives off gases that are combustible—ultimately, that's what triggers the incineration process. All incinerators involve a thermal reaction of some sort, but with microwaves, you can have a much more compact unit. It's the difference between your gas oven and your microwave oven."

The entire incineration process takes about two hours and is controlled by a microcomputer. The small incinerator comprises two combustion chambers and a catalytic oxidizer. Waste matter in the primary chamber, which is essentially a bucket, is dried using microwaves at 2,450 MHz. As the waste dries, the microwave susceptor within the chamber absorbs the microwaves, heating the material around it. The gases resulting from the partial combustion in the primary chamber pass to the secondary chamber where they are ignited. Exhaust from the secondary chamber then passes through a catalyst where the unburned gases are oxidized. Once the incineration is complete, the unit enters a cool down mode. At the end, all that is left is a fine ash residue.

Sun and his team have run numerous tests on the incinerator in preparation for its integration into the Laboratory-Scale Controlled Ecological Life Support System. One of their goals is to show that it does not generate toxic compounds as a byproduct of the combustion process.

This compact microwave incinerator oxidizes biological waste into carbon dioxide and water, producing a sterile ash that weighs just 13 percent of the original waste material.

"We're trying to understand exactly what comes off during the incineration," said Sun. "We're looking for carbon dioxide and water vapor, but want to measure carbon monoxide and other organic compounds as well—are there any sulfur dioxides? nitrous oxides? We are running such detailed tests because pollutants are a particular concern for plants in a closed system such as would exist in space."

Sun hopes that by testing and focusing attention on the incinerator's capabilities, the team's work may introduce the technology to a broader audience of potential users. "We've talked to experts in the field of incineration and they really haven't heard about this," he said. "It's a very simple unit and it's got a lot of potential for processing wastes either in the home, in medical or research labs, or in small medical practices."

Stemming the Data Flow

As scientific and medical instruments grow increasingly sophisticated and precise, the amounts of data generated by them turn from streams to oceans. One way to manage enormous quantities of computerized data is to compress them. However, not all compression can guarantee error-free decompression, which is sometimes an unacceptable risk, such as when the image is a CT scan or angiogram.

The alternative is lossless data compression, which does guarantee full and accurate reconstruction of data. A new lossless technique developed at the Goddard Space Flight Center promises fast, efficient data compression for a wide range of advanced instrumentation.

For NASA missions, data compression offers a means to increase the return of scientific data while reducing onboard memory requirements, station contact time, and communication bandwidth. The latest remote sensing instruments generate sensor data at a rate that not only requires increased onboard processing and storage capability, but imposes greater demands on the communication links and ground data management systems—demands that data compression can alleviate.

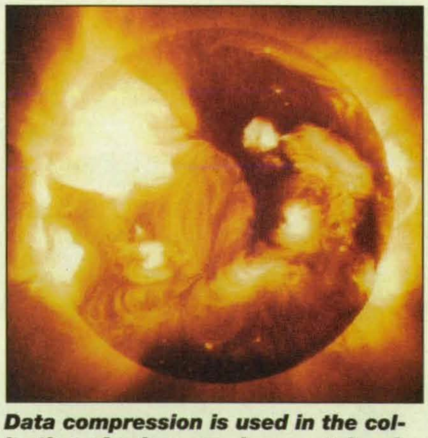
Implementing data compression on spacecraft, according to Goddard's Pen Shu Yeh, requires a technique that adapts easily to the changes in the data; that can be easily implemented with few processing steps, small memory, and little power; and that can be interfaced easily with a packetized data system without any degradation in performance.

Electronic engineers at Goddard Space Flight Center have found that the Rice algorithm, which has evolved at the Jet Propulsion Laboratory since the early 1970s, best meets the challenge. It is readily adaptive and, unlike many other lossless data compression algorithms, requires no extra memory to store tables or statistics. Extending the algorithm to higher quantizations, such as from 8-bit to 16-bit, requires adding only a small piece of circuitry. For many available algorithms, supporting an extra bit of information doubles memory requirements. Not requiring external memory simplifies a system's design and can reduce its cost. According to Yeh, the overall compression performance of the Rice algorithm implementations exceeds that of all algorithms tested including arithmetic coding, UNIX compass, UNIX pack, and gzip.

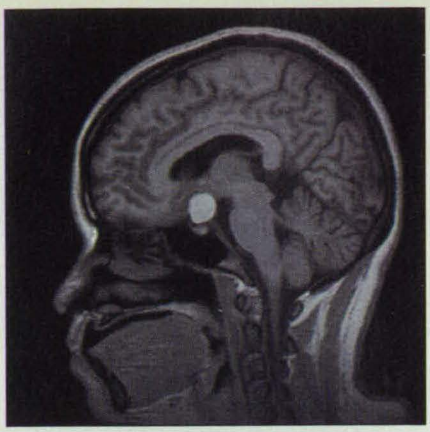
The first hardware engineering model was built in 1991 in an Application Specific Integrated Circuit (ASIC). Later, it was redesigned and implemented in Very Large Scale Integration (VLSI) circuits using gate arrays suitable for space missions. The flight circuit is referred to as the Universal Source Encoder for Space (USES). It can process data up to 20 megasamples/second and will take data quantizations from 4-bit to 15-bit.

The Goddard engineers have performed more than a dozen case studies on post-flight data with the chip and several new missions have adopted the technology. "Here at Goddard, we have two scientific directives: to look down on the Earth and to look up at the sky," said Yeh. "All the different disciplines use remote sensing."

The instruments involved in the studies include: the Landsat thematic mapper for the study of Earth's surface and resources; the soft x-ray telescope on the Yohkoh mission dedicated to the study of solar flares; the acousto-optical spectrometer on the Submillimeter Wave Astronomy Satellite, scheduled for launch in summer 1995 to study the energy balance and physical conditions of the molecular clouds in the galaxy by observing the radiowave spectrum; and the gamma-ray spectrometer on the Mars Observer,



Data compression is used in the collection of solar x-ray images taken by the acousto-optical spectrometer scheduled to fly aboard the Submillimeter Wave Astronomy Satellite in 1995.



Lossless data compression preserves the precision of medical images such as this magnetic resonance brain image, helping physicians to make accurate diagnoses.

launched in September 1992 to study the Martian surface and atmospheric properties.

As in the remote sensing field, advances in medical imaging equipment have created the need to handle large amounts of digital data at high speed. The data carries information on the pathology of a patient and often must first be stored on a memory device, then later processed, analyzed, and displayed. Sometimes, it must be transmitted across a network to another institution for further analysis by specialists. Inherent in these processes are the requirements for a massive storage device, faster device access time, communication bandwidth, and affordable data transmission time.

"There's a good correlation between the needs of space imaging and medical imaging systems," said Yeh. "Medical images also tend to change a lot, with areas that are busy and areas that are quiet. And they require a truthful processing on the data—doctors don't want any distortions."

Studies at Goddard have indicated that the new chip offers improved compression performance for medical imaging techniques such as computed tomography, magnetic resonance, ultrasound, digitized angiography, and nuclear medicine when compared with several commercially available techniques.

"In addition to enabling medical imaging to be sent long distances, consider that the new imaging machines generate huge amounts of data," Yeh said. "One patient's images can use up a lot of disk space. Data compression could result in big savings."

The Commercial Promise of GPS

Descartes revolutionized mathematics by dividing space into coordinates so any object could be located, and Newton gave position a key role when drawing up his laws of mechanics. Now, pinpointing an object's position in space holds new technological promise as the Department of Defense's Global Positioning System (GPS) enters the consumer marketplace.

The GPS is a constellation of 24 satellites in Earth orbit that continuously send out radio signals and can provide time and position to any receiver tuned to their frequency. Although the DOD developed the system to determine position of troops and warheads, it recently has opened access to the general public.

Making the GPS service commercial involves a few tricks. The military receives highly refined GPS signals encrypted by a code, enabling a user to pinpoint an object somewhere on the planet to within a few meters. The Coarse Acquisition receiver code open to the public is highly accurate but less precise, delivering positions to within 100 meters and time to within 1 microsecond. The public user can refine the signal in various ways.

In addition to the DOD, federal agencies such as NASA's Goddard Space Flight Center are lending their expertise to successful commercialization. "The engineering community, ingenious as it is, has developed differential GPS," said Frank H. Bauer, head of the Guidance and Control Branch at Goddard, referring to a method that cancels out errors in the signal until an object can be pinpointed to within a meter. Further improvement of the signal can be made by using at least two antennae at a fixed baseline tuned in to the GPS carrier wave and measuring the difference in the beacon wavelength they receive. Adding more antennae increases the dimensions of the position information. Goddard is working on a four-antenna system to determine position, pitch, and yaw of Earth-orbiting spacecraft.

Goddard also is conducting tests on its spacecraft GPS system to answer several questions: whether Doppler shifts affect GPS attitude sensing; how much high-orbital velocities corrupt the differential measurement of the GPS beacon signal; and whether thermal drifts affect attitude sensing. The researchers also hope to determine whether the GPS Attitude Determination and Control System can stay locked on the GPS beacon and provide accurate attitude data while the spacecraft undergoes major slew maneuvers and whether RF multipath reflections are the same or worse when the spacecraft is in orbit.

GPS applications extend beyond space vehicles to crucial Earthbound activities such as getting around a strange city. Rental car companies are testing a system that combines a map, a computer, and a GPS receiver to give directions to drivers as they explore unfamiliar streets. Bauer imagines something even more adventurous: a lawn mower with a GPS receiver and a computer that records the movements of the mower the first time the user pushes the machine through its routine; from then on, the user would simply start the engine and the mower automatically would go through the motions.

Another application is to robotics. For example, when a robot is attempting to put a peg in a hole, differential antennae can help determine the hole's location.

The commercial potential of GPS service has received a boost from recent developments in electronics, so that receivers are now as small as a computer chip and often the antennae make up the bulk of a GPS device. ❑

For more information about the technologies described above, contact the NASA field center that sponsored the research (see page 20).

CLARIFICATION

Upon review of the cover story in the September issue of *NASA Tech Briefs* (vol. 18, no. 9), representatives of Petrol Rem Inc. became aware that a scientist may have inadvertently misrepresented the status of several contracts involving their petroleum bioremediation product, known as PRP, causing the company to request an immediate clarification. The company confirms that numerous contracts were, and are, under negotiation, including those with Mexico and major utilities. None, however, had been formalized or activated at the date of publication. Regarding the use of PRP in the Chesapeake Bay, while the Maryland Department of Environment has tested and found the product to be effective, it must nevertheless be approved on a site-by-site basis. In addition, tests were performed on oil supplied by producers at Lake Maracaibo in Venezuela, not a lake in Cuernavaca.

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

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

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You can contact NASA's network of RTTCs for assistance in solving a specific technical problem or locating technology or markets that match your interests. The RTTCs are experienced in working with industry to define technology needs and acquire and commercialize applicable technology. User fees are charged for most services. For more information, call 1-800-472-6785 and you will be connected to the RTTC in your geographical region (or you may call or write directly to the RTTC in your region).

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If you are interested in information, applications, research, training, and services relating to satellite and aerial data for Earth resources, contact NASA's transfer point for earth observing technology: **Earth Data Analysis Center, University of New Mexico, 2500 Yale Blvd. S.E., Suite 100, Albuquerque, NM 87131-6031; Dr. Stan Morain, Director (505) 277-3622.**

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; Dr. Doris Rouse, Director, (919) 541-6980**

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If You Have a Question..**NASA Center For AeroSpace Information** can answer questions about NASA's Technology Transfer Network and its services and documents. The CASI staff supplies documents and provides referrals. Call, write or use the feedback card in this issue to contact: NASA Center For AeroSpace Information, Technology Transfer Office, 800 Elkridge Landing Rd, Linthicum Heights, MD 21090-2934. Walter M. Heiland, Manager, (410) 859-5300, Ext. 245.

NASA Commercial Technology Agenda for Change

NASA has a new way of doing business that improves how it works with US industry. A report entitled *NASA Commercial Technology: Agenda for Change*, approved by NASA Administrator Daniel Goldin in July, outlines the agency's commercial technology goals and operating principles. The document was produced by the NASA Commercial Technology Management Team, which is comprised of representatives from all ten field centers and all headquarters program offices.

This set of guiding principles is designed to ensure that NASA's programs contribute directly to our nation's economic security. Also, in times of unprecedented budget constraints, these principles offer potential solutions to NASA researchers and managers through collaborative (jointly funded and managed) research programs.

The *Agenda for Change* draws on three pillars of administration policy: the President's technology policies as outlined in *Technology for America's Economic Growth*, the *National Performance Review* and its many recommendations for improving government services, and the *National Information Infrastructure* and its call for greater exploitation of electronic information systems.

The *Agenda for Change* highlights the cornerstones of NASA's commercial technology policy. These policies, which reflect our commercial values, include: collaboration with the private sector; equal opportunity for small, minority, and disadvantaged businesses; alliances with state and local organizations; management by metrics; electronic business practices; and others. These policies guide NASA managers to proactively promote commercialization of NASA technology. Collectively, they reflect NASA Administrator Goldin's stated intent to raise the importance of the agency's commercial technology mission to a level equal to and integral to the agency's aeronautics and space missions.

The document also describes several business practices that serve as the primary mechanisms to facilitate NASA-industry collaboration. These are referred to as: Contractor-Developed Technology Commercialization, Industry-Led Technology Development Partnerships, Dual-Use Technology Development, Commercial Technology Acquisition, Small Business Technology Development and Commercialization, Regional Alliances, and Post-Technology-Development Diffusion. The use of this flexible set of practices will enable NASA to achieve one of its key goals: to adopt commonly used private sector business practices. Each NASA program office and field center will be responsible for incorporating these practices into their program management system and ensuring that their use is broadly understood in their organization.

The *Agenda for Change* also calls for actively marketing NASA technologies to both aerospace and non-aerospace companies alike. These marketing activities will be both targeted and broadcast. Targeted efforts will be directed at industries in which there is known technical overlap. General marketing will strive to increase the overall awareness of what NASA has to offer US industry. Some of the most exciting and beneficial applications of NASA research are in such fields as health care and manufacturing. NASA presently is working with two non-aerospace organizations to identify key areas of mutually beneficial collaboration. Others are expected to unfold in the future.

On the subject of communications, electronic media are rapidly becoming an industry standard. The *Agenda for Change* outlines NASA's goals to conduct a large portion of its business electronically. Realizing this goal will mean better service to the public and better management oversight of its programs. Collection, processing, and dissemination of metrics data, for example, will become largely automated. NASA also has established the NASA Commercial Technology Home Page to provide easily accessible information to the public. This is both a cost-effective and customer-friendly way of providing needed information to potential users of NASA's resources. For those who have access to the Internet, information can be accessed with Mosaic software on the NASA Commercial Technology Home Page at URL: http://nctn.oact.hq.nasa.gov. Instructions on how to acquire the free Mosaic software can be obtained by sending an E-mail request to: innovationaoact.hq.nasa.gov. An electronic copy of the *Agenda for Change* is saved on the home page.

Broad policy statements, lofty goals, and empowered business managers do not, of course, guarantee success. The *Agenda* calls for the use of metrics to measure performance and to manage all NASA collaborations with the private sector. The metrics will be designed to quantify the benefits of NASA-industry collaborations in terms of industrial competitiveness and NASA program life cycle costs. They will address the efficiency of the day-to-day management process as well as bottom line results such as jobs, market share, productivity improvements, and the like.

The *Agenda for Change* is an outline of NASA's new way of doing business. The agency is working today to realize its potential. Successfully moving NASA toward wide acceptance of these principles, tools, and goals will benefit NASA and the nation. NASA welcomes your feedback as it implements these policies and practices. To receive a hard copy of the *Agenda for Change* or for additional information about working with NASA, contact the NASA field center commercial technology office nearest to you (see page 20).

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 in 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 20). NASA's patent-licensing program to encourage commercial development is described on page 20.

Underwing Compression Vortex-Attenuation Device

Air safety for small aircraft approaching airports behind large jetliners can be improved with a new device. Landing jetliners produce lift-induced vortex that can throw small aircraft out of control. The device attenuates the effects of this dangerous vortex.
(See page 86.)

Oligomers Terminated by Maleimide and Acetylene

These compounds can be used to make thermally stable, glassy polymers. The compounds show high or undetectable glass-transition temperatures and high thermo-oxidative stabilities.
(See page 78.)

Fluorinated Poly(Phenylene Ether Ketones)

These polymers can be used as film and coating materials in electronic and thermal-control applications units; for example, as passivant insulating coats and interlevel dielectrics in microelectronic circuits or as protective coats on solar cells and mirrors.
(See page 74.)

Improved Ferroelectric Memories With Nondestructive Readout

The average overall power demand of such a memory pack containing a 128 by 128 array of cells would be only 1 to 2 W — a level that is competitive with nonvolatile memory cells in current use.
(See page 40.)

Plasma-Spray Metal Coating on Foam

Molds, forms, and other substrates made of foams would be coated with metals by plasma spraying. One potential application might be in making thermally insulating firewalls in automobiles.
(See page 26.)

Distributed Optoelectronic Proximity Sensor

This sensor provides data on the distance, relative orientation, and curvature of a surface. It can be used in such robotic applications as noncontact probing or scanning of surfaces, localization and recognition of objects, and guiding robot hands in grasping objects.
(See page 52.)

For More Information Write In No. 401

Special Focus: Advanced Manufacturing

Plasma-Spray Metal Coating on Foam

Foam could be removed or left intact.

Marshall Space Flight Center, Alabama

Molds, forms, and other substrates made of foams would be coated with metals by plasma spraying, according to a proposal. In a given application, the foam might be ceramic, carbon, metallic, organic, or inorganic. After the coat has been applied by plasma spraying, the foam could be left intact (e.g., to serve as thermal and/or electrical insulation or as an acoustic damper) or could be removed by acid leaching, conventional machining, water-jet cutting, or another suitable technique.

Cores or vessels made of various foam materials plasma-coated with metals according to this method might be useful, for example, as thermally insulating containers for foods, liquids, or gases, or as mandrels for making composite-material (matrix/fiber) parts. A foam-filled core or vessel could be used, with the foam intact or removed depending on the specific application, as a substrate for the deposition of an additional layer or layers of the same or different metal(s).

One potential application might be in making thermally insulating firewalls in automobiles. A metal firewall provides structural integrity, but it also conducts heat from engine compartment to the passenger space. To obtain a more desirable combination of strength and thermal insulation, the main body of the firewall could be made of graphite phenolic or other high-temperature composite material, a thin layer of insulating foam could be sprayed onto the composite, and a thin coat of aluminum could be applied to the foam by plasma spraying. The aluminum coat could be machined and polished to a heat-reflective finish.

This work was done by J. Cranston of Martin Marietta Corp. for **Marshall Space Flight Center.** *For further information,* ***write in 78*** *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 20]. Refer to MFS-28904.

Fabricating Structural Stiffeners by Superplastic Forming

Strong, lightweight aluminum members are made more economically.

Langley Research Center, Hampton, Virginia

Superplastic forming (SPF) of aluminum alloys is an effective technique for making strong, lightweight structural components that conform to close dimensional tolerances. The technique was applied in experimental fabrication of prototypes of stiffening ribs for cylindrical tanks.

Heretofore, the tanks — external cryogenic-propellant tanks for the space shuttle — have been made by machining thick aluminum plates to form longitudinal T-shaped ribs (see Figure 1), then welding the plates together. The machining process reduces weight while providing the remaining thin panels with integral stiffeners. But the machining process is costly and time-consuming, and it wastes 80 percent of the plate material.

When stiffening ribs made by SPF are used in making a structural panel, the stiffening ribs are spot-welded to a metal skin (also shown in Figure 1). The use of discrete instead of integral stiffening ribs eliminates machining waste, and the use of SPF instead of conventional cold forming to fabricate the complexly shaped stiffeners eliminates the multiple steps needed in operations. The cost of fabrication is reduced correspondingly.

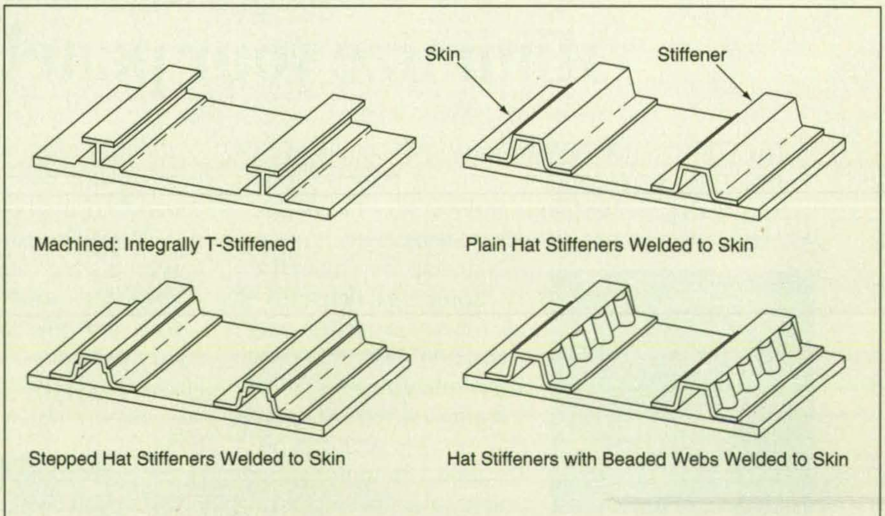


Figure 1. A **Structural Panel** made by machining (upper left) incorporates integral machined stiffeners. An alternative is a panel made with superplastic-formed ribs attached to a metal skin. A variety of rib geometries can be produced economically with SPF.

In a typical example of the SPF process, a sheet of aluminum alloy is placed between heated platens (see Figure 2) in a hydraulic press. When a compressive load is applied, a pressure seal is created around the perimeter of the sheet. The lower platen contains a die box into which die inserts of various

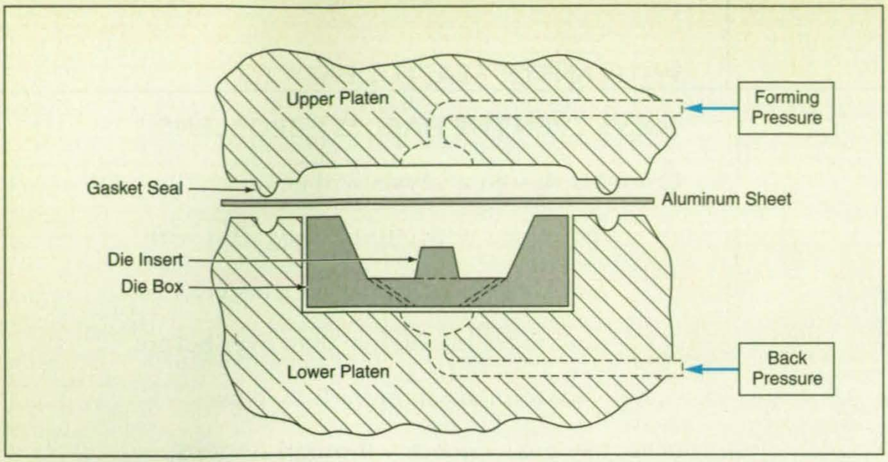


Figure 2. **Superplastic Forming** takes place between heated platens with opposing pressures. The differential pressure is varied to deform the aluminum sheet at optimum rates that maximize the strength of the formed component.

shapes can be inserted. Pressurized argon gas is applied to the sheet through the upper platen. Under influence of the pressure, the sheet gradually assumes the shape of the die. Simultaneously, pressurized argon is applied through the lower platen to generate back pressure that is needed to prevent cavitation during deformation of the sheet. Throughout the process, the pressures are varied in a series of ramps and plateaus by a computer-controlled regulator to obtain approximately the optimum strain rate for superplastic flow at each phase of deformation.

Two aluminum alloys were used in the experiments on SPF:

- Alloy 7475 was formed at a temperature of 960 °F (about 516 °C). Forming pressure was varied from 350 psi (2.41 MPa) to 500 psi (3.45 MPa) during approximately 80 minutes.
- Alloy 8090 was formed at 985 °F (about 529 °C). Forming pressure was varied from 325 psi (2.24 MPa) to 500 psi (3.45 MPa) during approximately 80 minutes.

Cavitation was suppressed by use of back pressures during forming and by including a hold, at the conclusion of forming, at the maximum pressure (500 psi) of the SPF apparatus. Increasingly complex shapes were formed, ranging in cross section from plain hat to stepped hat to hat with beaded webs.

The pressure-vs.-time profiles used in the experiments could likely be refined. Pressures and temperatures could probably be increased and forming times thus reduced to prepare for high-speed, high-quantity manufacturing.

This work was done by Thomas T. Bales and Joseph M. Shinn, Jr., of **Langley Research Center**, *Stephen J. Hales of Analytical Services and Materials, Inc., and William F. James of Lockheed Engineering and Sciences Co. For further information,* ***write in 182*** *on the TSP Request Card.*
LAR-14549

Numerical Simulation of Cutting of Gear Teeth

Computer graphics and other data products are developed from differential geometry.

Lewis Research Center, Cleveland, Ohio

The shapes of gear teeth produced by gear cutters of specified shape can be simulated computationally, according to an approach based on principles of differential geometry. The results of such a computer simulation can be displayed as computer graphics (see Figure 1) and/or used in analyses of design, manufacturing, and performance of gears. This approach is equally applicable to both standard and non-standard gear-tooth forms.

Consider the example of a gear blank rolling over a rack cutter in a standard gear-tooth-cutting procedure (see Figure 2). For the purpose of simulation, the gear-blank material is considered to be perfectly plastic in the sense that it yields wherever it is in contact with a cutter, but otherwise does not flow; the cutter produces gaps in the blank which simulate the tooth spaces between gear teeth. The surfaces between the gaps are the simulated gear tooth surfaces. By use of the principles of differential geometry, these surfaces can be computed as the enveloping surfaces traced out by the cutter when the gear blank rolls over them. This simulation procedure can also be inverted to find the shape of the cutter needed to produce gear teeth of a given shape. Clearly, this approach accelerates and facilitates analysis of alternative designs of gears and cutters.

This approach to simulation can be extended to study the generation of surfaces other than gears. For example, it can be applied to cams, bearings, and surfaces of arbitrary rolling elements as well as to gears. It should be possible to develop analogous procedures for simulating the manufacture of skin surfaces like those of automobile fenders, airfoils, and ship hulls.

This work was done by Fred B. Oswald of **Lewis Research Center**, *Ronald L. Huston of the University of Cincinnati, and Dimitrios Mavriplis of Miles Laboratories. Further information may be found in NASA TM-105392 [N92-24202], "A Basis for Solid*

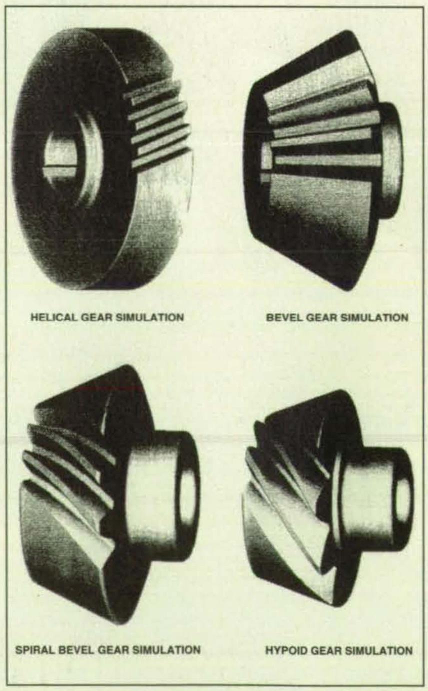


Figure 1. These **Images Were Produced in Simulations** of gear-cutting processes.

Modeling of Gear Teeth With Application in Design and Manufacture.

Copies may be purchased [prepayment required] from the NASA Center for AeroSpace Information, Linthicum Heights, Maryland, Telephone No. (301) 621-0394. Rush orders may be placed for an extra fee by calling the same number.
LEW-15841

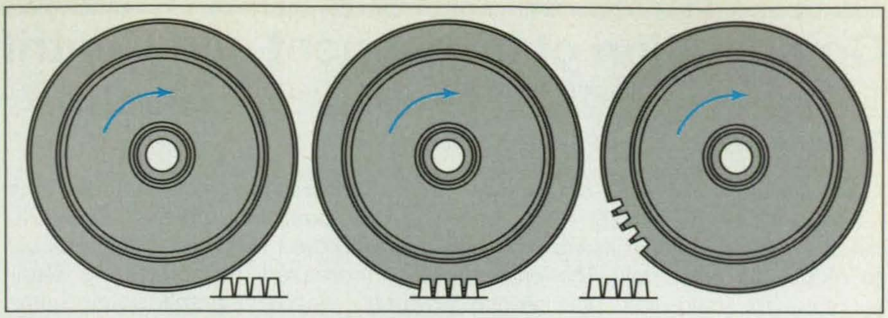


Figure 2. **Dents Are Made by a Rack Cutter** as a simulated, perfectly plastic gear blank rolls over the cutter.

Making Ceramic Components for Advanced Aircraft Engines

Silicon nitride components with internal passages have been fabricated by ceramic platelet technology.

Lewis Research Center, Cleveland, Ohio

Lightweight, oxidation-resistant silicon nitride components that contain intricate internal cooling and hydraulic passages and are capable of withstanding high operating temperatures can be made by ceramic-platelet technology. Heretofore, platelet fabrication technology has been used to make metallic components with intricate internal passages, and multilayer-ceramic-packaging technology has been available but has not been applied to fabrication of structural ceramic components nor to silicon nitride. Ceramic platelet technology incorporates features of both of the foregoing technologies. It has been demonstrated by using it to fabricate silicon nitride test articles of two types: components of a methane-cooled regenerator for an air turbo ramjet engine and components of a bipropellant injector for a rocket engine (see Figure 1).

Figure 2 illustrates a ceramic-platelet fabrication process. Ceramic tape is produced from high-purity ceramic powders that have been milled to the correct particle sizes. The formulation is optimized by addition of chemicals to obtain the desired rheological properties. The resultant slurry is cast to make tapes 0.005 to 0.030 in. (0.13 to 0.76 mm) thick. Individual platelets are punched, under numerical control, to designed patterns. The punched platelets are stacked and green bonded (that is, laminated and bonded in the "green" or unfired condition). The green laminates are then fired, yielding parts that are essentially 100 percent dense and free of leaks.

Figure 1. **Punched Platelets of Silicon Nitride** were laminated in the unfired "green" state, then fired to make this injector block containing passages.

The regenerator components were tested under realistic service conditions. They were found to be free of leaks at a pressure of 1,575 psi (10.86 MPa) and stable when exposed to propane-combustion products at a speed of 500 fps (about 150 m/s) and a temperature of 3,100 °F (about 1,700 °C). Components survived more than 100 h at 3,100 °F and endured 40 thermal cycles in excess of 2,000 °F (about 1,100 °C). The injectors passed leak tests at a pressure of 990 psi (6.8 MPa).

Thus, the feasibility of producing stable high-temperature engine components from ceramics has been demonstrated. Although the designs of the test articles are fairly simple, procedures for development of more complex and intricate components have been established. The ceramic-platelet technology may have commercial utility in the automotive, aircraft, and environmental industries for the manufacture of high-temperature components for use in regeneration of fuels, treatment of emissions, high-temperature combustion devices, and application in which other high-temperature and/or lightweight components are needed. This technology also has potential for use in the fabrication of combustors and high-temperature acoustic panels for suppression of noise in future high-speed aircraft.

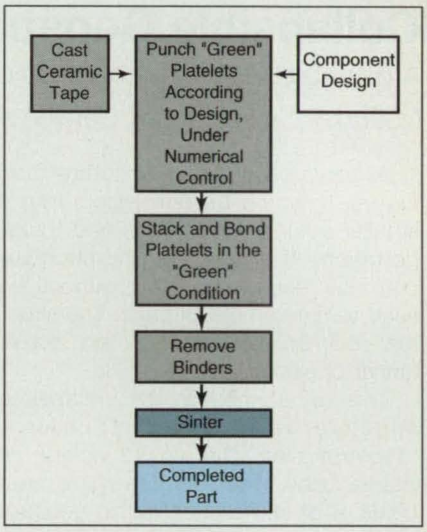


Figure 2. A **Ceramic-Platelet Fabrication Process** involves a combination of techniques from metallic-platelet fabrication and multilayer ceramic packaging.

This work was done under contract by J. E. Franklin of Aerojet Propulsion Division of Gencorp. A. Ezis of Cercom, Inc. fabricated the test articles. T. P. Herbell of **Lewis Research Center** *was the NASA program manager. For further information,* ***write in 109*** *on the TSP Request Card.*
LEW-15667

Combination of Investment and Centrifugal Casting

Thin sections are filled better, while hot tearing is reduced.

Marshall Space Flight Center, Alabama

Modifications, including the incorporation of centrifugal casting, have been made in an investment-casting process to reduce its scrap rate. The process is used to make first- and second-stage high-pressure-fuel-turbopump nozzles, which contain vanes with thin trailing edges and other thin sections. The castings from the unmodified process often had to be scrapped, mainly because of lack of fill in the thin trailing edges of the vanes or hot tears in the vane radii.

Attempts to increase the solidification time (by increasing the preheat and pour temperatures and adding mold insulation) improved filling in thin sections but also increased the hot tearing. Conversely, decreasing solidification time reduced hot tearing but also reduced filling in thin sections.

In the modified process, the investment mold is spun for a short time while it is being filled, and stopped before solidification occurs. The centrifugal force drives the molten metal into thin trailing edges, ensuring that they are filled. With improved filling, the preheat and pour temperatures can be reduced and solidification hastened so that there is less hot tearing.

This work was done by Gordon A. Creeger of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 20]. Refer to MFS-29949.

Collapsible Geostrut Structure

A portable structure could be collapsed and redeployed without disassembly and assembly.

Marshall Space Flight Center, Alabama

A conceptual truss structure (see Figure 1) would be collapsible into a smaller volume for storage and transportation. At a new site, the structure could be reerected quickly, without the need to reassemble its parts. The structure could be, for example, a tent, dome, tunnel, or platform.

The key element in the collapsible structure would be a joint, called a "geostrut joint," that would include an internal cable. The structure would be a network of struts attached to geostrut joints. Pulling the cables taut in all the joints would make the structure rigid. Releasing the cables in all the joints would relax the structure.

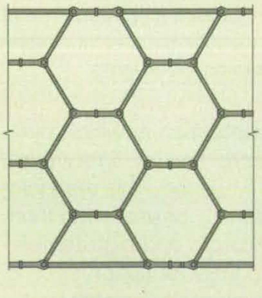


Figure 1. A Network of Joints and Legs according to the design shown in Figure 2 would constitute a rigid but collapsible structure.

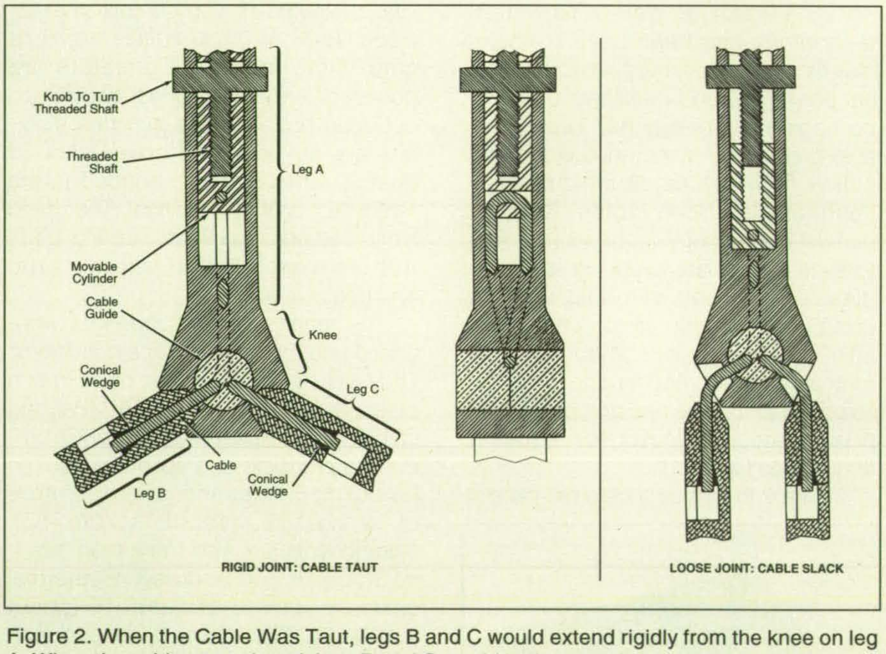


Figure 2. When the Cable Was Taut, legs B and C would extend rigidly from the knee on leg A. When the cable was relaxed, legs B and C would be loosened.

A geostrut joint would include a knee fixed to one leg, A, and two articulated legs, B and C (see Figure 2). A cable attached at its ends to legs B and C would pass through the knee to a movable cylinder inside leg A. Tension could be applied to the cable by turning a threaded shaft that would engage an internal thread in the cylinder. Conical wedges on the ends of the cable would deform when tension was applied, thereby keeping the ends of the cable from slipping out of the legs.

To loosen the geostrut joint, a technician or robot would turn the threaded shaft to drive the cylinder fully against the knee. This action would loosen the cable, and the resulting slack in the cable would then allow legs B and C to be reoriented to fold the structure into a more compact form.

This work was done by Glen A. Robertson of **Marshall Space Flight Center.** *For further information,* ***write in 20*** *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, Marshall Space Flight Center [see page 20]. Refer to MFS-28765.

Electronic Components and Circuits

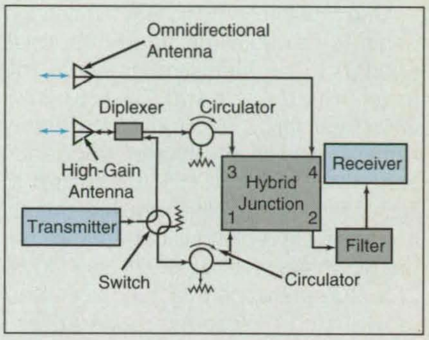
Dual-Antenna Microwave Reception Without Switching

Only the transmitter connection is switched.

NASA's Jet Propulsion Laboratory, Pasadena, California

The figure illustrates the configuration of a dual-antenna microwave communication system in which the receiver is required to remain connected to both antennas at all times, whereas the transmitter is to be switched to connect it to one antenna or the other. The combination of the hybrid junction, circulators, and filter provides the simultaneous reception paths from both antennas without significantly altering the radiation patterns of the antennas. This is one version of a communication system that is being considered for use in a spacecraft and in which a mechanical switch is permitted on the downlink (the transmission path) but not on the uplink (the reception path). The basic configuration and principle of operation would also be applicable to terrestrial microwave communication stations subject to the same dual-antenna requirements.

This work was done by Robert W. Hartop of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 18*** *on the TSP Request Card.*
NPO-18967



The **Receiver Remains Connected** to both antennas, whereas the transmitter is switched to connect it to one or the other.

Two Thick Microwave Dichroic Panels

Cross-shaped apertures would enable relatively tight packing, eliminating some grating lobes.

NASA's Jet Propulsion Laboratory, Pasadena, California

Two panels made of thin, honeycomblike metal walls constitute planar arrays of waveguidelike apertures that have been designed to satisfy special requirements with respect to microwave transmittance and reflectance. The panels are being considered for use in multiplexing signals at various frequencies in a microwave communication system. The first panel is required to be highly transmissive at frequencies of 7.165 and 8.425 GHz and highly reflective at 2.0 to 2.32 GHz. The second panel is required to be highly reflective at 31.8 to 32.3 GHz and highly transmissive at 34.2 to 34.7 GHz. Both panels are required to exhibit low insertion loss. The angle of incidence on both panels is 30°.

The requirement for high transmittance of the first panel at two frequencies conflicts with the requirement for an angle of incidence of 30° in the sense that grating lobes (which are undesired) could become significant, depending on the sizes, shapes, and spacings of apertures that could satisfy both requirements. The design that was

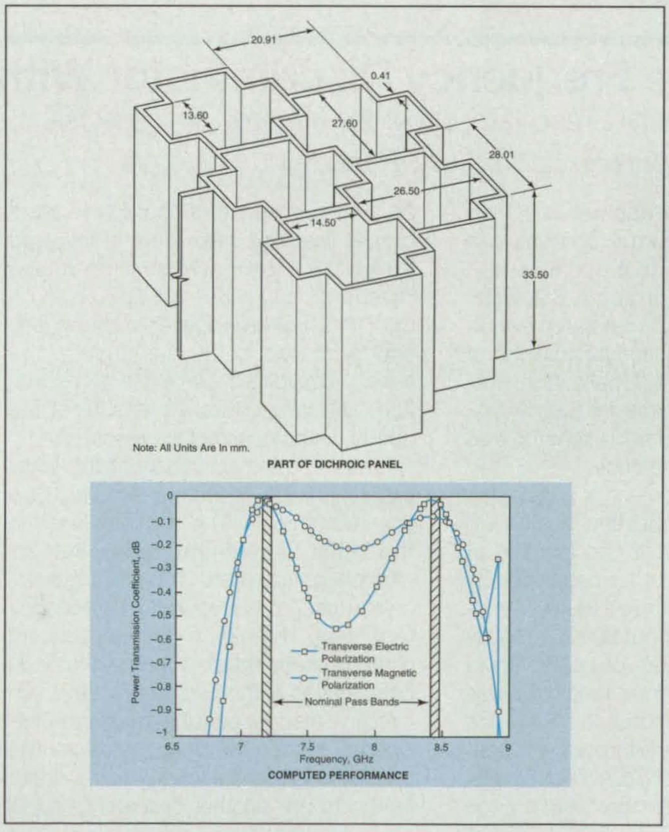


Figure 1. This **Dichroic Panel Containing Cross-Shaped Apertures** is designed to pass incident radiation at 7.165 and 8.425 GHz and to reflect incident radiation at lower frequencies (2.0 to 2.32 GHz).

chosen involves cross-shaped apertures (see Figure 1), which help to resolve the conflict by offering increased bandwidth in comparison with that of simpler rectangular apertures. In addition, cross-shaped apertures can be packed more densely than can rectangular apertures of equal overall linear dimensions. As is well known, the number of grating lobes decreases with decreasing spatial period of a grating. In this case, the packing is sufficiently dense to eliminate all grating lobes at 30°.

One problem in designing the second panel is to make the apertures small enough to be highly reflective in the lower frequency band (31.8 to 32.3 GHz), yet large enough to be highly transmissive in the higher frequency band (34.2 to 34.7 GHz). It is difficult to satisfy these competing requirements by use of simple rectangular apertures. The design chosen for this panel (see Figure 2) features stepped rectangular apertures, which provide more design flexibility to satisfy the requirements, albeit at the cost of dimensional tolerances of the order of 0.0005 in. (about 0.013 mm) or less.

This work was done by Larry W. Epp, Jacqueline C. Chen, Philip H. Stanton of Caltech and Roy E. Jorgenson of Sandia National Laboratory for **NASA's Jet Pro-pulsion Laboratory**. *For further information,* ***write in 6*** *on the TSP Request Card. NPO-18887*

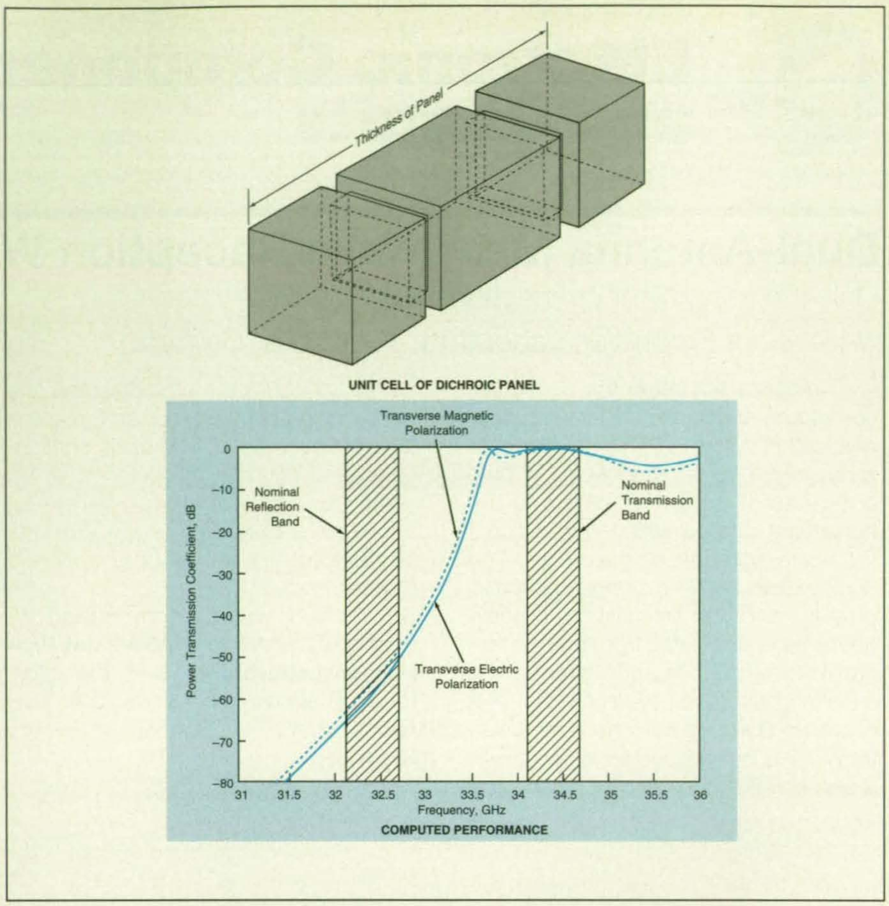


Figure 2. This **Dichroic Panel Containing Stepped Rectangular Apertures** is designed to pass incident radiation at 34.2 to 34.7 GHz and to reflect incident radiation at 31.8 to 32.3 GHz. This is not an optimized design: There is some transmission (about –50 dB) in the nominally reflected frequency band, and there is a transmission loss of about 0.5 dB in the nominally transmitted band.

Microwave Frequency Discriminator With Sapphire Resonator

The cooled sapphire resonator provides ultralow phase noise.

NASA's Jet Propulsion Laboratory, Pasadena, California

The experimental apparatus shown schematically in Figure 1 comprises a microwave oscillator that operates at a nominal frequency of about 8.1 GHz, plus a frequency-discriminator circuit that measures the phase fluctuations of the oscillator output. One of the outstanding features of the frequency discriminator is a sapphire resonator that serves as a phase reference.

The sapphire resonator is a dielectric ring resonator that operates in a "whispering-gallery" mode. It can function at room temperature, but for better performance it is typically cooled to an operating temperature of about 80 K — slightly above the temperature of boiling liquid nitrogen (77 K). [A similar resonator was described in more detail in "Sapphire Ring Resonator for Microwave Oscillator" (NPO-18082), NASA Tech Briefs, Vol. 15, No. 9 (September 1991), page 20.] In the absence of coupling to other circuits (loading), resonators of this type exhibit $Q \approx 2 \times 10^5$ at room temperature, increasing to $Q \approx 3 \times 10^7$ at 80 K. ($Q = 2\pi$ x the time-average electromagnetic energy stored in the resonator ÷ the energy dissipated per cycle of oscillation, and is used as a measure of the quality or sharpness of the resonance.)

In the loaded condition of the initial experiment, the resonator exhibited $Q = 6 \times 10^6$ at 80 K. The oscillator used in the initial experiment comprised an ultralow-phase-noise 100-MHz quartz-crystal oscillator followed by frequency multipliers. The high Q and consequent ultralow phase noise of the resonator, in combination with novel phase-detection circuitry, made it possible to use the frequency discriminator to measure the phase noise of the oscillator unit, without having to use another oscillator of equal

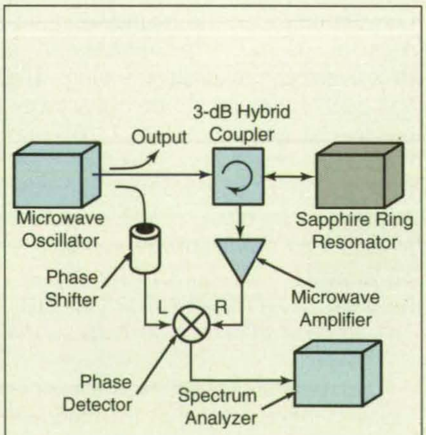


Figure 1. The **Sapphire Ring Resonator** serves as a phase stabilizer in the frequency-discriminator portion of the apparatus.

TO-5 RELAY TECHNOLOGY

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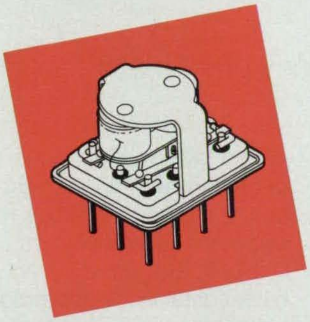

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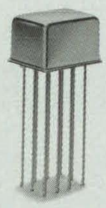

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or greater stability as phase and frequency reference. Some of the results of the initial experiment shown in Figure 2, agree closely with results obtained in previous tests of the same oscillator, while using a similar oscillator as a reference. The noise floor, however, is now much lower – showing that even lower noise oscillators could be accurately characterized.

This work was done by David G. Santiago and G. John Dick of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 53*** *on the TSP Request Card. NPO-18934.*

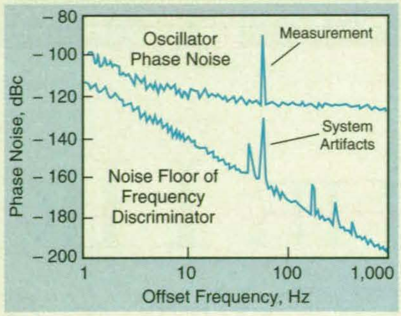


Figure 2. The **Phase Noise** of the oscillator as a function of offset frequency was measured and converted to the equivalent phase noise at the 100-MHz frequency of the crystal oscillator within the microwave oscillator. The noise floor of the frequency discriminator, converted to 100 MHz, is close to the theoretical value for the measured Q of 6 x 10^6.

Dual-Element Tunneling Accelerometer

A higher-frequency displacement transducer tracks a lower-frequency proof mass.

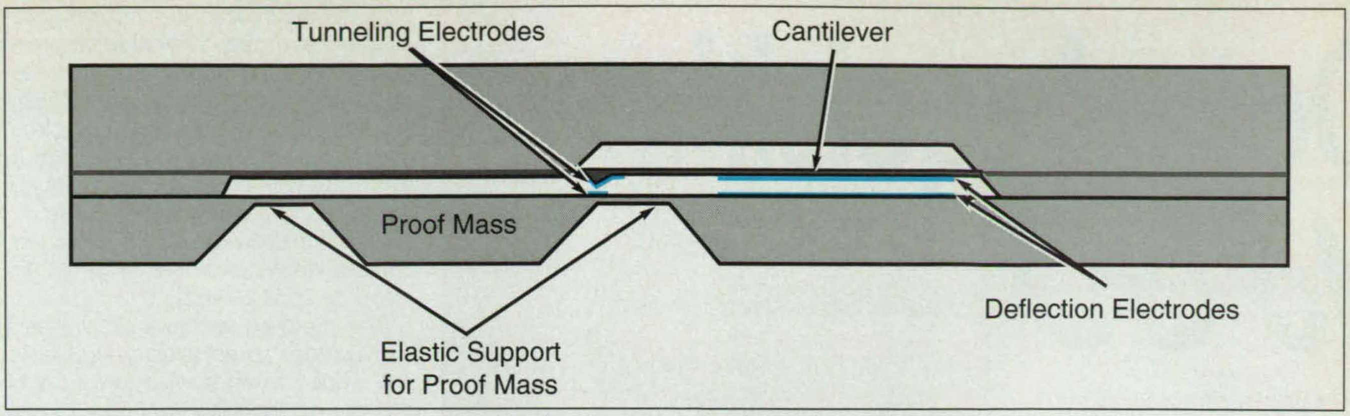
NASA's Jet Propulsion Laboratory, Pasadena, California

The improved micromachined tunneling accelerometer illustrated schematically in the figure contains two deflecting transducer elements: One of them is an elastically supported proof mass that has a relatively low resonant frequency (ª 100 Hz); the other is a cantilever tunneling transducer that tracks the displacement of the proof mass and that has a relatively high resonant frequency (ª 10 kHz). Accelerometers of this type are particularly well suited for underwater acoustic measurements, detecting vibrations that may be associated with malfunctions in vehicles, detecting seismic signals, monitoring and controlling vibrations in structures, and other applications.

Heretofore, tunneling accelerometers have contained single proof-mass/tunneling-displacement-transducer elements. The advantage of the present dual-element design is that one can select different mechanical characteristics for the proof-mass and transducer elements to optimize the overall performance of the accelerometer. In particular, the separate resonant frequencies of the two transducer elements were selected after extensive theoretical analysis of various sources of noise, to design a two-axis accelerometer with a total volume < 0.5 in.3 (< 8 cm3) and a sensitivity of 10–8 g/Hz1/2 (where g = the gravitational acceleration at the surface of the Earth).

As in other tunneling displacement transducers, an electron current is generated by quantum-mechanical tunneling between two electrodes, one of which is flat and the other of which is shaped like a pyramid. In this case, the flat tunneling electrode is attached to the elastically supported proof mass, while the pyramidal tunneling electrode is attached to the tip of the cantilever. The cantilever is deflected electrostatically by applying a suitably amplified voltage to deflection electrodes.

The deflection voltage is generated by a circuit like the one described in the following article, "Wideband Feedback Circuit for Tunneling Sensor" (NPO-18866). The circuit applies, to the tunneling electrodes, a bias voltage suf-



The **Cantilever Is Deflected** electrostatically under feedback control to maintain a constant distance between the tunneling electrodes and thus to track the deflection of the elastically supported proof mass. The frequency of mechanical resonance of the cantilever is much greater than that of the proof mass and its elastic support.

ficient to generate a quantum-mechanical-tunneling current of about 1 nA when the distance between the electrodes is about 10 Å.

The circuit effects feedback control by adjusting the deflection voltage to minimize any deviation of the tunneling current from a set point and thereby to maintain nearly constant distance between the tunneling electrodes. Thus, the cantilever is made to track the deflection of the elastically supported proof mass without touching the proof mass and interfering with its motion. The variations in the deflection voltage serve as measurements of variations in the position of the proof mass and thus also serve as measurements of acceleration along the deflection axis.

This work was done by William J. Kaiser, Thomas W. Kenny, Howard K. Rockstad, and Joseph K. Reynolds of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 114*** *on the TSP Request Card.*

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

William T. Callaghan, Manager
Technology Commercialization
JPL-301-350
4800 Oak Grove Drive
Pasadena, CA 91109

Refer to NPO-18862, volume and number of this NASA Tech Briefs issue, and the page number.

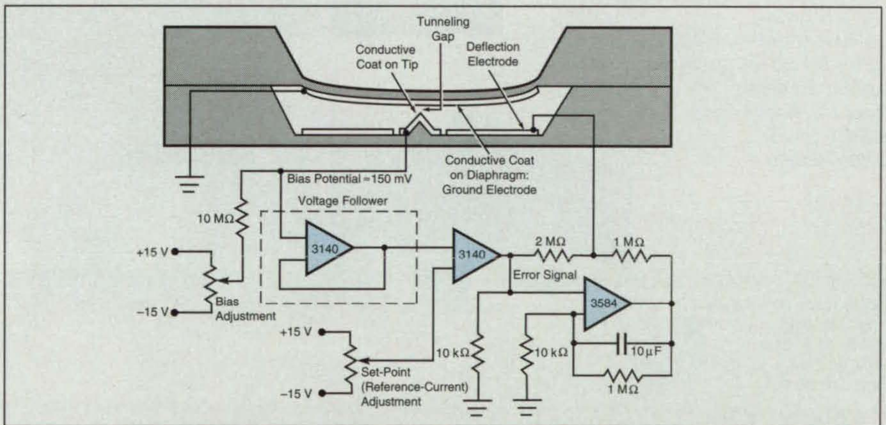
Wideband Feedback Circuit for Tunneling Sensor

Features include stability and nearly flat frequency response up to 50 kHz.

NASA's Jet Propulsion Laboratory, Pasadena, California

An improved feedback circuit is designed for use in controlling a tunneling displacement transducer. The transducer could be, for example, that in a scanning tunneling microscope, or any of the micromachined electromechanical transducers described in "Micromachined Electron-Tunneling Infrared Detectors" (NPO-18413), Laser Tech Briefs, Vol. 1, No. 1 (September, 1993), page 20; "Micromachined Tunneling Accelerometer" (NPO-18513), NASA Tech Briefs, Vol. 17, No. 11 (November, 1993), page 55; and the following article "Improved Electromechanical Infrared Sensor" (NPO-18560).

In a tunneling displacement transducer, an electron current is generated by quantum-mechanical tunneling between two electrodes, one of which is flat and the other of which is shaped like a pyramid. The electrodes are typically separated by a distance of about 10 Å. A 150 mV bias potential is applied between them, resulting in a tunneling current of the order of 1 nA. One of the electrodes is mounted on a micromechanical flexure, such as a cantilever or diaphragm, which can be used to adjust the distance between the electrodes by application of electrostatic forces between the electrodes. The feedback circuit measures the tunneling current and compares it with a reference value that represents the tunneling current at the desired separation of the electrodes. The result of this comparison is an error voltage, which is amplified and applied as a high-voltage signal to the deflection electrodes to restore the separation to the desired value.



The **Improved Feedback Circuit** for the tunneling transducer features stability and bandwidth greater than those used heretofore in scanning tunneling microscopes. This circuit has a bandwidth of 50 kHz.

Heretofore, the bandwidths of feedback circuits in scanning tunneling microscopes have been restricted to prevent oscillations of the complicated microscope structures, which have low mechanical-resonance frequencies. These circuits become electrically unstable when one attempts to extend their frequency responses to bandwidths in excess of 10 kHz. The improved circuit is designed to operate stably, with nearly flat frequency response up to 50 kHz.

The improved feedback circuit (see figure) includes an adjustable resistive voltage divider, which is used to set the bias potential at about 150 mV. The tunneling current flows through a 10-MΩ resistor, thereby developing a voltage drop, which is sensed via a 3140 operational amplifier in follower configuration. The output of this voltage follower cannot exceed the range between the bias voltage and ground: thus, the voltage-follower configuration contributes to the stability of the circuit at high frequencies in that it prevents excursions of the output voltage to supply-voltage levels, at which nonlinearities and phase shifts at high frequencies would lead to oscillations.

A simple operational-amplifier circuit compares the output of the voltage follower with a set-point voltage that represents the reference current, and generates the error signal. This low-voltage, wide-bandwidth error signal is then added to a high-voltage, narrow-bandwidth offset to produce the voltage that is applied to the deflection electrodes of the transducer. The high-voltage signal can be generated by a power supply (not shown), which is periodically adjusted to keep the error signal near zero. A simple high-voltage amplifier circuit with very low bandwidth can perform this function as well. The circuit is stable at high frequencies because the high-frequency and high-voltage circuit elements are separated.

This work was done by William J. Kaiser, Thomas W. Kenny, Howard K. Rockstad, and Joseph K. Reynolds of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 115*** *on the TSP Request Card.*

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

William T. Callaghan, Manager
Technology Commercialization
JPL-301-350
4800 Oak Grove Drive
Pasadena, CA 91109

Refer to NPO-18866, volume and number of this NASA Tech Briefs issue, and the page number.

Improved Electromechanical Infrared Sensor

Fabrication would be easier, and undesired sensitivity to acceleration would be reduced.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed electromechanical infrared detector would be an improved version of the device described in "Micromachined Electron-Tunneling Infrared Detectors" (NPO-18413), LASER Tech Briefs, Vol. 1, No. 1, September 1993, page 20. These conceptual devices are modern successors to the Golay cell, in which the infrared radiation to be detected heats a trapped gas, causing the gas to expand and displace a diaphragm. In these devices, the diaphragms and other components would be made of micromachined silicon, and the displacements of the diaphragms would be measured by an electron tunneling displacement transducer (see "Micromachined Tunneling Accelerometer" (NPO-18513) NASA Tech Briefs, Vol. 17, No. 11, November 1993, page 55.)

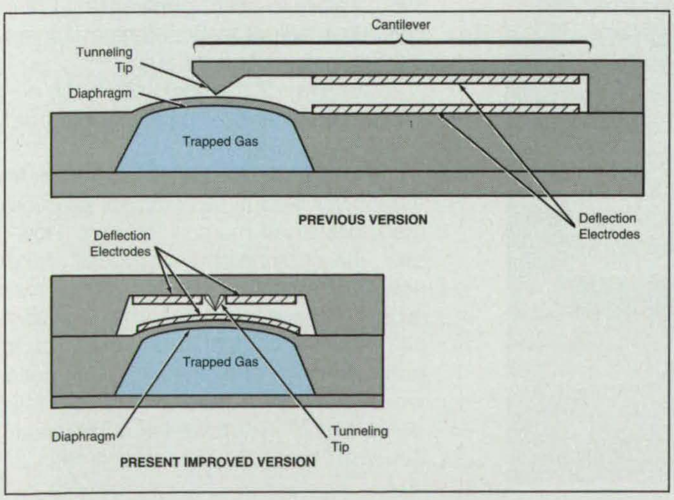
In the previous version, shown at the top of the figure, the tunneling tip would be at the end of a cantilever, the deflection of which would be adjusted electrostatically to follow the displacement of the diaphragm. In the improved version, the tunneling tip would be mounted rigidly and an electrostatic force would be applied to the diaphragm to keep it at a constant distance from the tunneling tip: this would be done by a feedback control circuit that would adjust the voltage on the electrostatic-deflection electrodes in such a way as to strive to maintain a constant quantum-mechanical-tunneling current of electrons between the tip and the diaphragm.

Initially, the control circuit would be turned on and would adjust the electrostatic-deflection voltage to deflect the diaphragm to the commanded fixed distance from the tunneling tip. Thereafter, the amount of infrared radiation absorbed in the gas would cause changes in the pressure of the gas against the diaphragm, and the control circuit would adjust the electrostatic-deflection voltage as needed to keep the diaphragm at the commanded position. The changes in the electrostatic-deflection voltage would be indicative of changes in the amount of infrared radiation.

It would be easier to fabricate the improved version because there would be no need for the complicated processes involved in micromachining the delicate cantilever. The improved version would also offer enhanced frequency response and less spurious response to acceleration, as can be understood from a comparison of vibrational resonances of the two structures: using typical dimensions, the estimated resonant frequencies of the cantilever beam and diaphragm would be 100 Hz and 50 kHz, respectively.

This work was done by Thomas W. Kenny and William J. Kaiser of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 121*** *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 20]. Refer to NPO-18560.



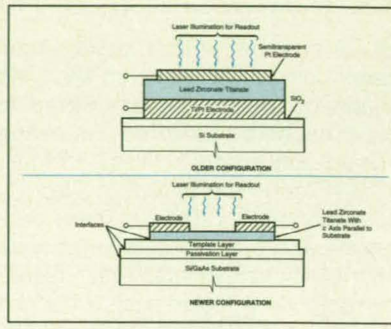
The **Diaphragm Would Be Deflected** to make it almost touch the tunneling tip in the improved version. In the previous version, the cantilever would be deflected to make the tunneling tip almost touch the diaphragm.

Improved Ferroelectric Memories With Nondestructive Readout

Photoresponse can be increased, leading to smaller power demand.

NASA's Jet Propulsion Laboratory, Pasadena, California

Ferroelectric memories with enhanced photoresponse leading to improved nondestructive optoelectronic readout and lower power demand have been proposed. These memories would be improved versions of the devices described in "Rapid, Nondestructive Readout From Ferroelectric Memory" (NPO-18551), LASER Tech Briefs, Vol. 1, No. 1 (September 1993), page 28. To recapitulate: Each memory cell is a ferroelectric capacitor, in which a datum is stored in the form of remanent polarization of the ferroelectric material. In optoelectronic nondestructive readout, a memory cell is illuminated by a laser pulse, which induces a photoresponse (photovoltage and/or photocurrent) with polarity corresponding to that of the remanent polarization; that is, the photoresponse of the cell is indicative of the stored datum.



Ferroelectric Capacitors for use as memory cells with nondestructive optoelectronic readout have been investigated. For cells of the same size, the newer configuration yields about 10 times the photoresponse of the older configuration.

The figure illustrates older and newer configurations of ferroelectric memory cells that have been tested for photoresponses. In both configurations, the electrodes are used for both writing (applying large voltages to induce remanent polarization) and reading (coupling photoresponses to external circuitry). In the older configuration, the ferroelectric layer — a film of lead zirconate titanate — is sandwiched between the two electrodes, one of which is semitransparent to the reading laser beam. The newer proposed configuration, on the other hand, is a planar configuration with the electrodes separated laterally, touching the ferroelectric film at its two ends, and the film-deposition conditions are chosen carefully to orient preferentially the c crystalline axis of lead zirconate titanate parallel to the substrate.

In an array of memory cells, each occupying an area of 20 μm^2, readout from a cell of the older configuration requires a peak optical power of about 400 mW: this power level is too high for practical mass-produced memory devices. However, the photoresponse of a cell of the newer configuration would be over two orders of magnitude larger than that of a cell of the older configuration so that readout from one of the newer cells would require a peak power of only about 4 mW — a level that is competitive with nonvolatile memory cells of

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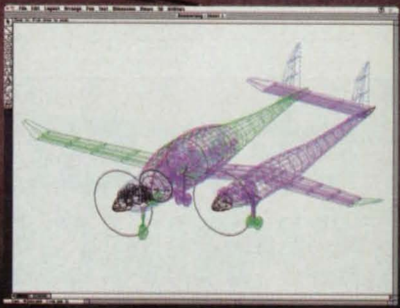

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other types that are in current use.

In a proposed application, an array of nonvolatile ferroelectric memory cells would be fabricated by standard very-large-scale integrated-circuit techniques and flip-bonded onto a similarly fabricated array of semiconductor lasers [see "Optically Addressable, Ferroelectric Memory With NDRO" (NPO-18573), NASA Tech Briefs, Vol. 18, No. 3 (March 1994), page 32] to form a memory pack. The average overall power demand of such a memory pack containing a 128 by 128 array of cells would be only 1 to 2 W.

This work was done by Sarita Thakoor and Anil P. Thakoor of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 108*** *on the TSP Request Card.*
NPO-19033

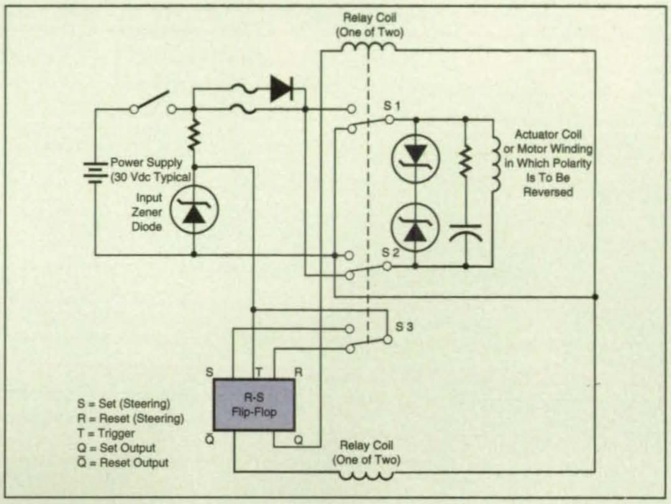
Sequential Polarity-Reversing Circuit

Polarity would be reversed each time power was turned on.

NASA's Jet Propulsion Laboratory, Pasadena, California

The figure indicates a proposed circuit that would reverse the polarity of the electric power supplied to a bidirectional dc motor, reversible electromechanical actuator, or other device that operates in a direction that depends on polarity. More specifically, this circuit would reverse the polarity each time power was turned on, without need for additional polarity-reversing or direction signals and the circuitry to process them.

Suppose that the last time power was turned on, the ganged relay switches (S1, S2, S3) were left in the position indicated in the figure. Upon application of power, the voltage across the actuator coil would begin to rise at the indicated polarity. The voltage across the input Zener diode would rise concomitantly until it reached the Zener breakdown voltage; this voltage would be transmitted through the lower left contact of S3 to the R input of the R–S flip-flop, causing the Q output to go high. This, in turn, would energize the upper relay coil, which would pull the switches to the upper position, thereby reversing the polarity of the voltage applied to the actuator coil.



This **Polarity-Reversing Circuit** would operate without additional signaling circuitry. It would reverse the polarity of the power supplied to the actuator coil each time power was turned on.

As long as the power remained on, and when it was subsequently turned off, the switches would remain in the upper position. When power was turned on again, the input Zener-diode voltage would be applied through the upper left contact of S3 to the S input of the R–S flip-flop, causing the output to go high. This would energize the lower relay coil, which would pull the switches to the lower position. When the power was subsequently turned off, the switches would remain in the lower position, completing the cycle.

This work was done by Clayton C. LaBaw of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 152*** *on the TSP Request Card.*
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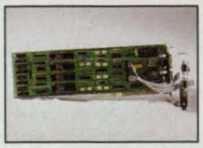

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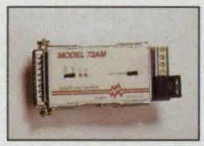

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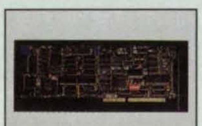

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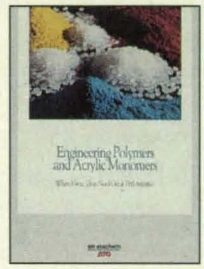

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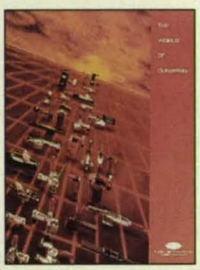

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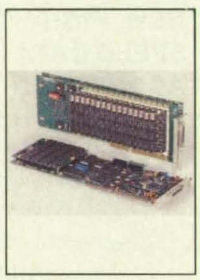

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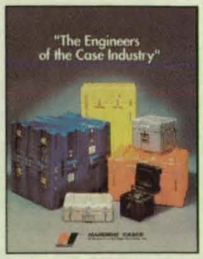

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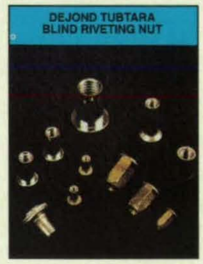

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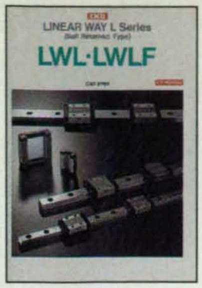

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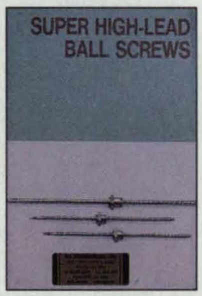

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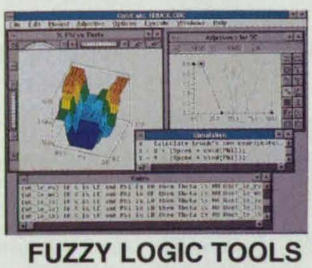

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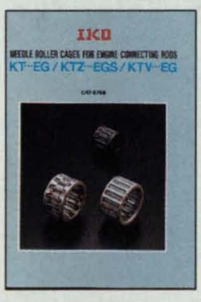

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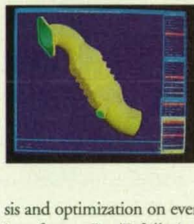

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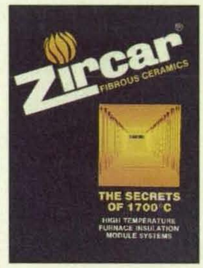

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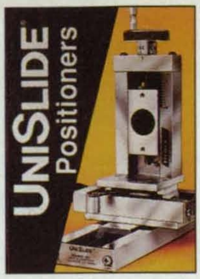

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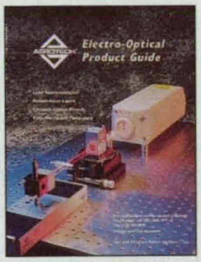

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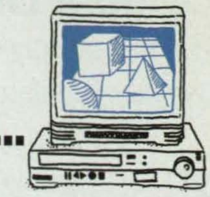

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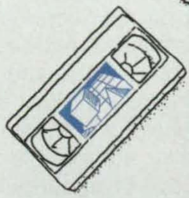

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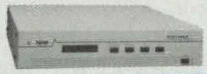

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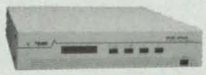

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Optical Detection of Flameout in a Combustor

The fuel supply can be shut down in time to prevent an explosion.

Langley Research Center, Hampton, Virginia

The optical flameout detector is designed to signal the control system of the facility to cut off the supply of fuel into the combustion chamber if the flame were to suddenly go out. This and other flameout detectors are important safety systems: if the flow of fuel is not stopped quickly enough after the main flame is lost, large amounts of unburned fuel would accumulate in the combustion chamber and could explode in the event of reignition.

The combustor for which the optical flameout detector was designed burns methane in air to provide hot gases for an 8-ft (2.4-m) high-temperature test chamber. To prevent the accumulation of a dangerous amount of unburned methane, it is necessary for the detection system to respond to a loss of flame in under 100 milliseconds. Commercial flameout detectors based on thermocouples and photodetectors respond too slowly, and cannot withstand the high pressures and widely varying temperatures inside the combustor. [An acoustical flameout detector for the same combustor was described in "Acoustical Detection of Flameout in a Combustor" (LAR-14900) NASA Tech Briefs, Vol. 17, No. 8 (August 1993), page 46].

In its current configuration, the optical flameout detection system can detect gross changes in the levels of ultraviolet light emitted by the flames in the combustor. The photodetector used in this device is a photomultiplier tube sensitive to light in the 200- to 400-nm region of the spectrum. The system utilizes a pair of photodetectors for redundancy, which are located outside the combustor. The detectors gain optical access to the light energy of the flame through 20-ft (6-m) fiber-optic probes designed to withstand pressures up to 5,000 psi (about 34 MPa).

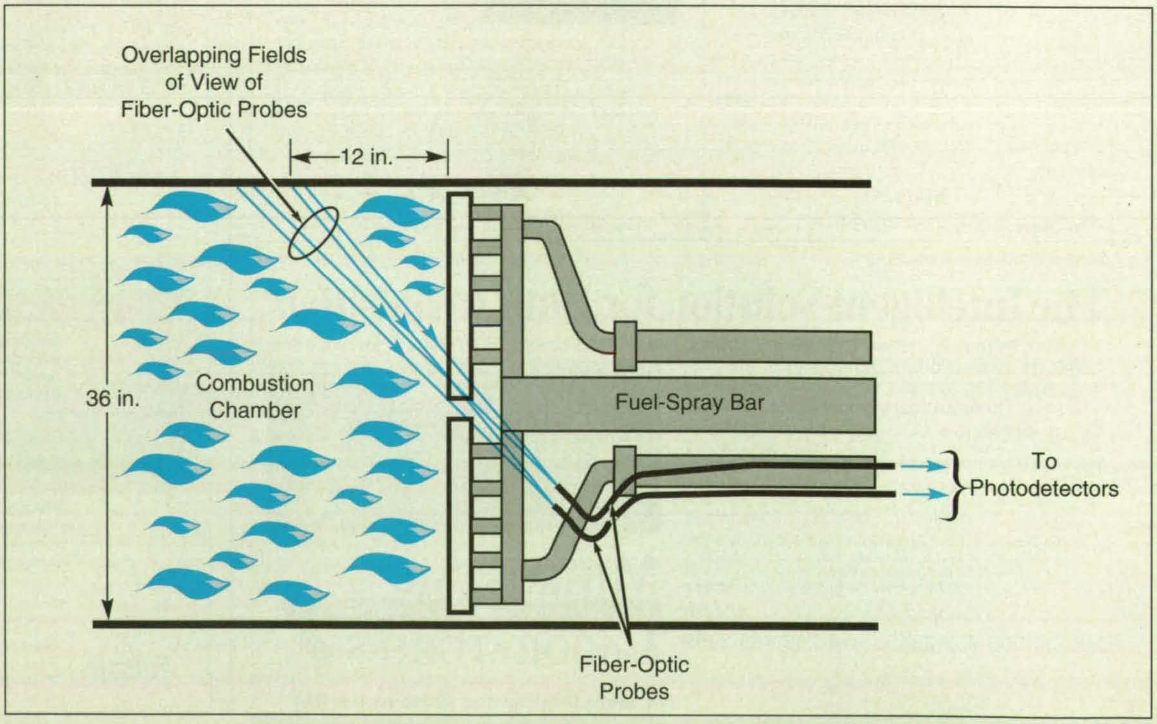
The fiber-optic probes are mounted to the fuel-spray bar upstream of the flame. No focusing optics are used, and the probes are aimed across the flow of gases at a spot on the combustion chamber wall downstream from the spray bar (see figure). This arrangement enables the flameout detection system to respond quickly to a potential loss of flame since it can detect movement of the flame front away from the spray bar face.

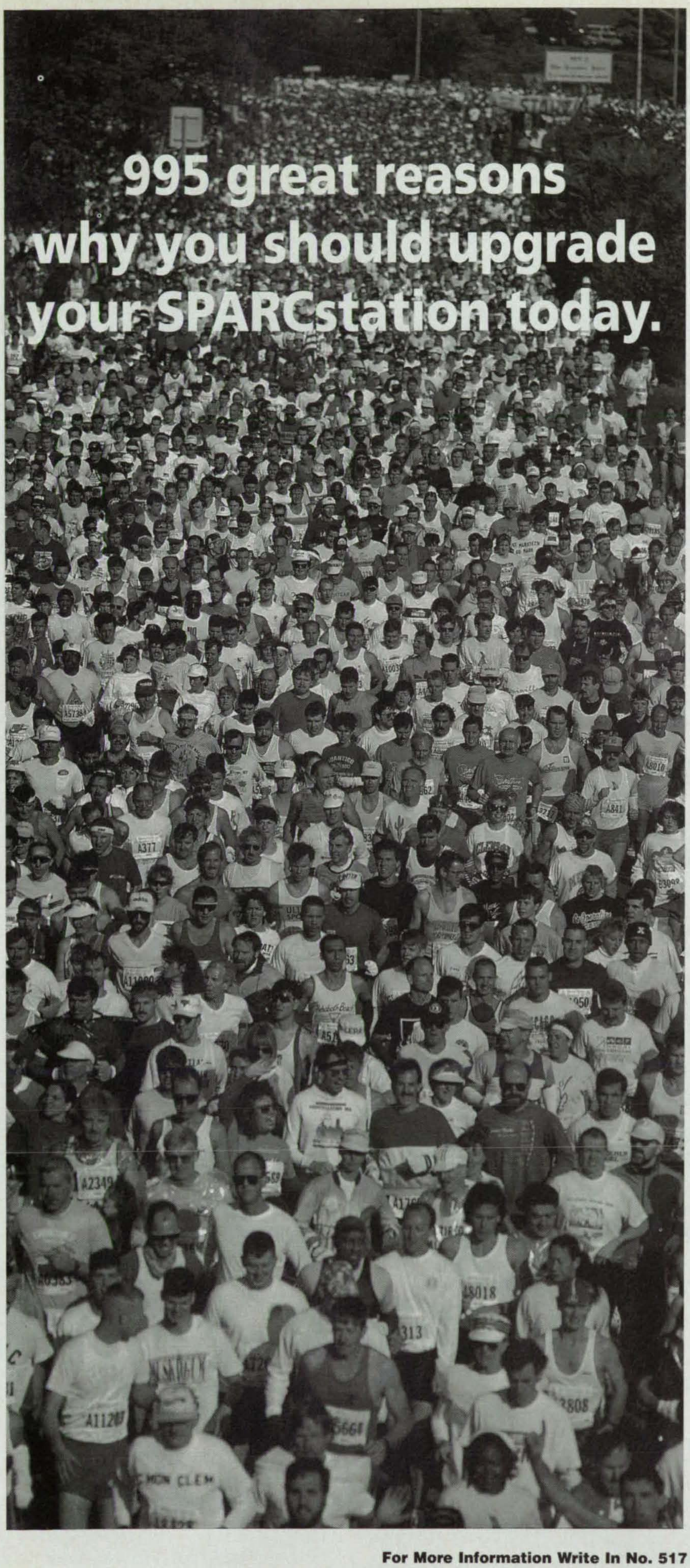
The photodetector outputs are used to activate a logic circuit that determines whether the measured combustion-chamber light intensity is indicative of a main flame. If the measured flame intensity exceeds a preset minimum output level corresponding to a low-level boost flame, the circuit will generate a signal indicating that the flame is present. Thereafter, when the outputs of the photodetectors fall below half of the preset minimum value, the logic circuit signals that the main flame has been lost. The overall response time of the optical flameout detection system is under 10 milliseconds.

This work was done by Stephen E. Borg, James W. West, Samuel E. Harper, and David W. Alderfer of **Langley Research Center** *and Robert M. Lawrence of Wyle Laboratories. For further information,* ***write in 38*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Langley Research Center [see page 20]. Refer to LAR-14997.

Fiber-Optic Probes in the combustor pick up light from the flame.





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Distributed Optoelectronic Proximity Sensor

This sensor provides data on the distance, relative orientation, and curvature of a surface.

NASA's Jet Propulsion Laboratory, Pasadena, California

An optoelectronic proximity sensor comprises seven identical units that function together to provide partially redundant data on the spatial relationship between the sensor and a nearby diffusely reflecting surface. The sensor is called the "Hexeye" because its units exhibit hexagonal symmetry when viewed along their optical axes and are mounted together in hexagonal close packing (see Figure 1). The Hexeye is being developed for use in such robotic applications as noncontact probing or scanning of surfaces, localization and recognition of objects, and guiding "smart" robot hands in grasping objects.

Older optoelectronic proximity sensors have been regarded variously as too sensitive to optical properties of surfaces (reflectance, scattering, color), insensitive and inaccurate with respect to measurements of distance, and/or too bulky for practical utilization. In addition, some older optoelectronic proximity sensors measure distance only. The Hexeye concept blends concepts of active illumination, lens action, triangulation, and multilevel fusion of sensory data into a system design that features relative insensitivity to optical properties of surfaces, enhanced sensitivity and accuracy in measurement of distance, ability to measure orientation and curvature (in addition to distance) of the nearby surface, a compact sensor package, and redundancy for continued functioning in the presence of defective sensor components.

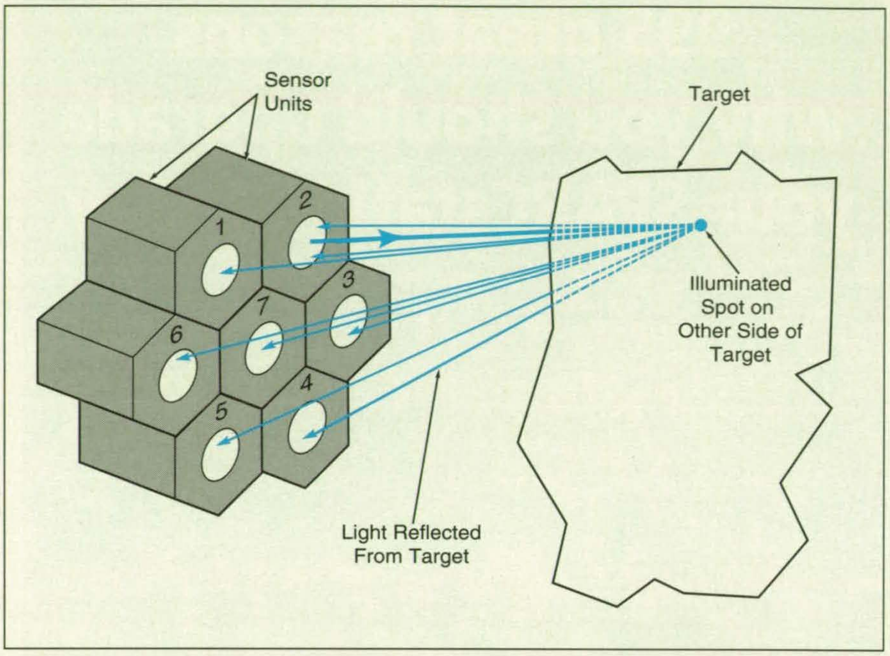

Figure 1. The **Hexeye**, so named because of its hexagonal configuration, is a compact active optoelectronic sensor composed of seven units. In the mode of operation shown here, only one sensor unit is illuminating the target.

Each unit (see Figure 2) contains a laser diode, the output of which is formed into a narrow beam by the two lenses. In a simple distance-measuring mode of operation, the laser diode is turned on, and light returned from the target (nearby surface) is partly or completely focused by lens 1, then reflected by the conical mirror onto the six linear arrays of photodetectors that constitute the sides of the hexagon. If the spot of light thus produced on each array of photodetectors were infinitesimal, then the position of the spot along the array would give a direct indication of the distance from the sensor to the target. In practice, the spots of light have finite sizes, and the distance must be computed from the distribution of light along each array; e.g., by taking weighted moments of the distribution.

Because all six arrays of photodetectors in a unit measure essentially identi-

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cal distributions of light in this operating mode, each provides redundant information that can be averaged to increase accuracy or used to verify the operation of the others. Thus, a malfunctioning photodetector can be identified, and its output ignored or replaced by an interpolated value.

Referring again to Figure 1, suppose that the laser diode in one sensor unit (only) is turned on. Then spots of light reflected from the target are also formed on the arrays of photodetectors in the neighboring units, and this makes possible another mode of operation. The distributions of light along the arrays of the neighboring units are also related to the distance of the target, though of course the relationship is more complicated than in the self-illuminating unit. Thus, the neighboring units provide redundant data that can be averaged in to increase the accuracy of the estimated distance or to continue operation in the presence of faulty sensor components.

In still another mode of operation, three contiguous units (the central unit and two adjacent units on the periphery) can be grouped together into an orientation-measurement unit (OMU). Depending on the selection of peripheral units, six different OMU's can be thus defined. The orientation of the target surface can be computed straightforwardly from the distance measurements of the three sensor units in the OMU. If the orientations determined from two OMU's are different, then the surface is curved, and/or there is a corner somewhere between the units. In either case, an average or coarse-grained curvature can be computed from the differences between the orientations determined by selected pairs of OMU's.

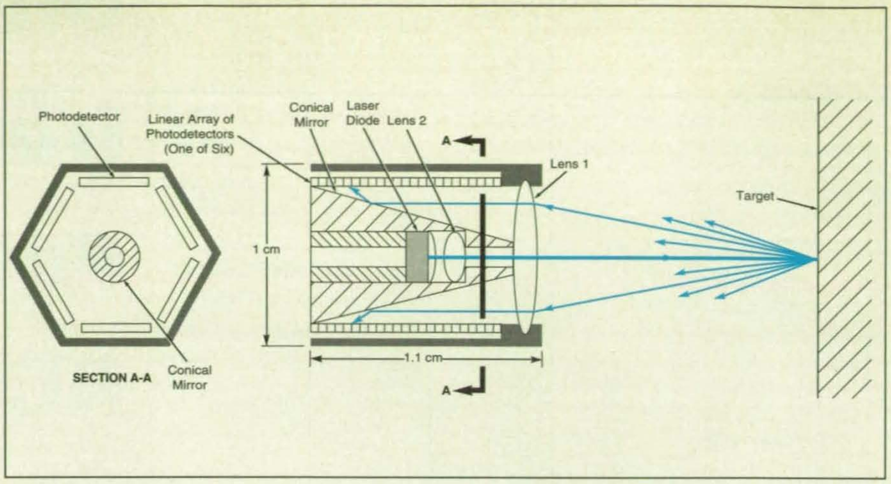

Figure 2. Each **Sensor Unit** includes a source of light and arrays of photodetectors that measure spots of light reflected from the target. The optical components are sized and shaped to obtain an optimum tradeoff among distance sensitivity, range, return of light to the photodetectors, and compactness. In the mode of operation shown here in greatly simplified form, the distance of the target is determined from the position, along any or all arrays of photodetectors, of the spot of light reflected from the target.

This work was done by Sukhan Lee of Caltech and Hernsoo Hahn of the University of Southern California for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 69*** *on the TSP Request Card.*
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Satellite Multicarrier Demodulation System

This system would convert frequency-multiplexed uplink signals to time-multiplexed downlink signals.

Lewis Research Center, Cleveland, Ohio

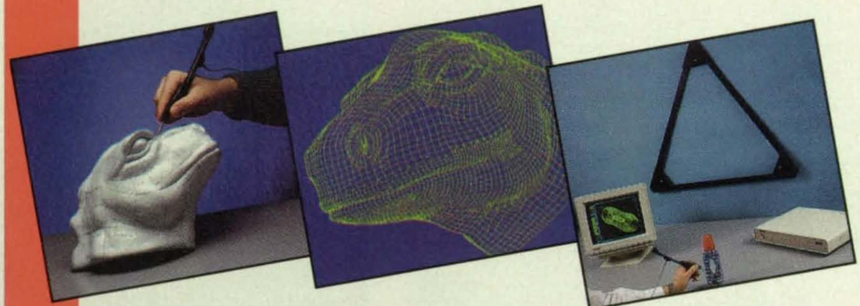
A proposed onboard signal processing system for future communications satellites would perform real-time conversion of multiple uplink (received) signals in single-channel-per-carrier, frequency-division-multiple-access (SCPC/FDMA) format to downlink (transmitted) signals in time-division-multiplexed (TDM) format. This particular conversion approach was chosen because it enhances the use of the allocated spectrum and reduces the required effective isotropic radiated power at both the transponder (satellite) and Earth stations. In addition, the equipment needed to implement this scheme can be less complex and less expensive than that needed for time-division-multiple-access (TDMA) formats. More economical future satellite communication systems would be made possible through the use of many small-capacity (64kb/s increments) multiservice Earth terminals.

The proposed system (see figure) includes a multicarrier demodulator, a baseband switch matrix, a TDM multiplexer, and an output modulator. Signals would be sampled by an analog-to-digital converter, then processed digitally using algorithms with data-dependent and data-independent components. The data-independent components would be effected in a parallel processing scheme; the data-dependent components would be effected in a pipeline processing scheme.

The key subsystem is the multicarrier demodulator, which contains a transmultiplexer that separates the FDMA signals into individual channels. The transmultiplexer would be followed by demodulators that would recover the modulation data for each channel. Both the transmultiplexer and the demodulators would be digital signal-processing subsystems that could be programmed with instructions sent from an Earth station. Each of several multicarrier demodulators in an operational system would be capable of real-time processing of data at a rate of 64kb/s from each of 800 FDMA channels spaced 45 kHz apart (total bandwidth 36 MHz). The multicarrier demodulator has been designed, simulated, and partitioned into a set of application specific integrated circuit designs to evaluate the concept and estimate operational requirements.

Separation of channels in the multicarrier demodulator design is effected by polyphase digital filters with center frequencies corresponding to the carriers in the FDMA signal, followed by a 1024-point fast-Fourier-transform (FFT) algorithm. The resulting signals in the various channels are decimated to the lowest sampling rate consistent with preservation of essential modulation data, then demodulated, then combined into a single TDM stream by interleaving of samples.

Each filter in the polyphase network is derived from a prototype low-pass filter implemented as a 9-tap finite-impulse-response filter. But instead of using a separate 9-tap filter for each of the 800 channels, hardware for a single 9-tap filter is shared among the channels by using 800 sets of filter coefficients stored in high-speed memory.



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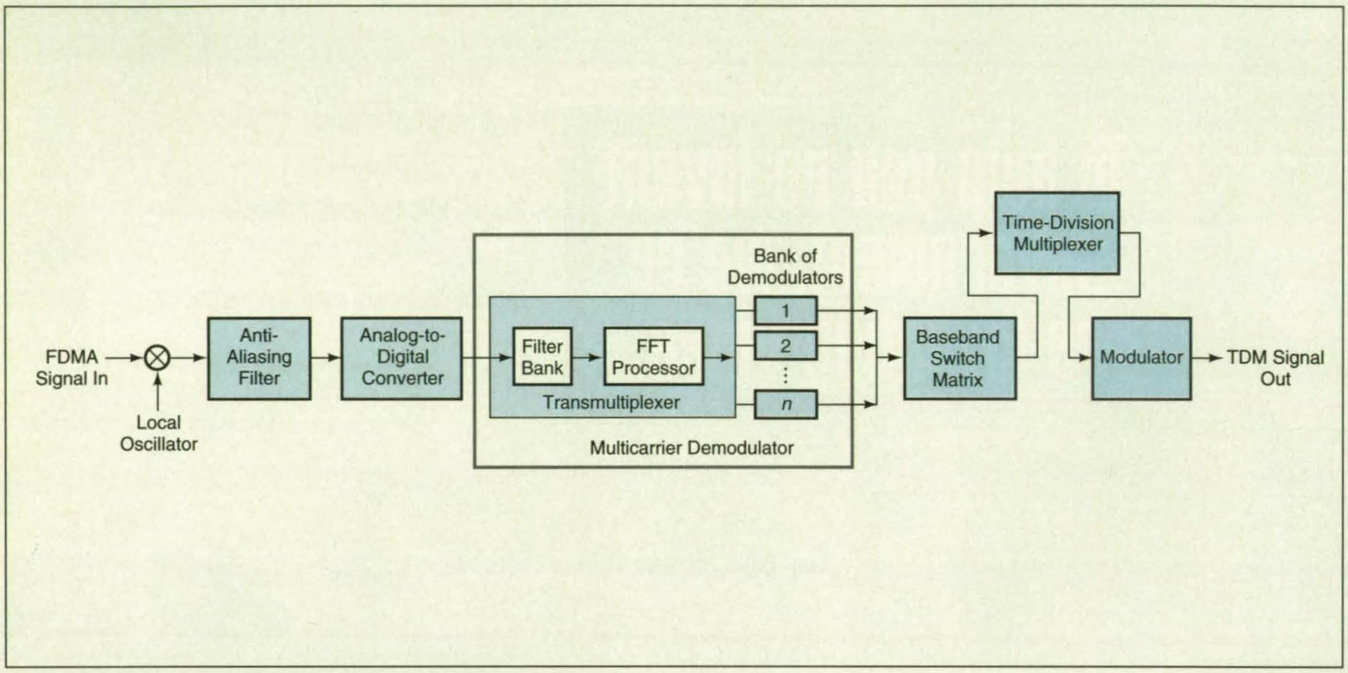
An address generator produces reading/writing addresses as it counts from 1 to 800. When the count is n, sampled data for channel n is fed to the first of nine random-access memories (RAMs). Latches between the RAMs hold the data for one read/write cycle, then each latch sends the data both to the next RAM and to a multiplier, wherein the data is multiplied by the applicable filter coefficients from high-speed memory. The outputs of the multipliers are fed to a pipelined tree adder. Once the pipeline is full, a weighted output sample is produced every clock cycle of $(36\text{ MHz})^{-1} \approx 27.8$ ns. Thus, 800 samples are made available for computation of a discrete Fourier transform every $800/(36\text{ MHz}) \approx 22.22$ µs.

The demodulator is programmable, designed for implementation with a single set of hardware that is shared among all the channels in a time-multiplexed manner. It consists mainly of carrier-recovery, clock-recovery, and data-recovery modules. Overall, the sharing of the demultiplexing and demodulating hardware among all channels yields large savings of both hardware and power over a dedicated bank of filters and demodulators.

This work was done by James Budinger of **Lewis Research Center** *and Subhash C. Kwatra, Mohsin M. Jamale, John P. Fernandez, and Linus P. Eugene of The University of Toledo. For further information,* ***write in 218*** *on the TSP Request Card.*
LEW-15346



In this **Multicarrier Demodulation System**, incoming signals would be sent through an anti-aliasing filter and an analog-to-digital converter to a transmultiplexer that would separate the incoming signals into individual channels. The signals in the channels would be demodulated, switched, then time-multiplexed into a single stream and transmitted back to Earth via a multibeam downlink antenna beam.

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Physical Sciences

System Measures Thermal Noise in a Microphone

A vacuum provides acoustic isolation from the environment.

Langley Research Center, Hampton, Virginia

Figure 1 shows the major functional blocks of a system of instrumentation that measures the thermal noise of a microphone and its associated preamplifier. As used here, "thermal noise" denotes that component of the electrical output of the preamplifier that is attributable to random impingement of air molecules on the microphone membrane plus random thermal agitation of electrical-charge carriers (Johnson noise) in the preamplifier.

To measure the thermal noise of a microphone, it is necessary to monitor the output of its preamplifier while isolating the microphone from both environmental sounds and vibrations. The advantage of the present system of instrumentation over older systems designed for the same purpose is that it includes an isolation vessel and an exterior suspension that, acting together, enable the measurement of thermal noise under realistic conditions while providing superior vibrational and acoustical isolation. Thus, the present system yields more accurate measurements of thermal noise.

The exterior suspension can be a commercial pneumatic vibration-isolation table or simply the inner tube of a tire, inflated to a pressure capable of supporting the weight of the isolation vessel. As shown in Figure 2, the isolation vessel includes a stainless steel outer vacuum vessel and a stainless steel inner vessel that contains the microphone under test and is sealed to hold air at normal atmospheric pressure. The vacuum between the outer

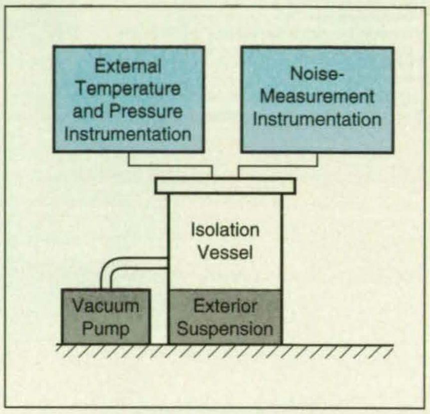

Figure 1. This **System for Measuring Thermal Noise** of a microphone and its preamplifier eliminates some of the sources of error found in older systems.

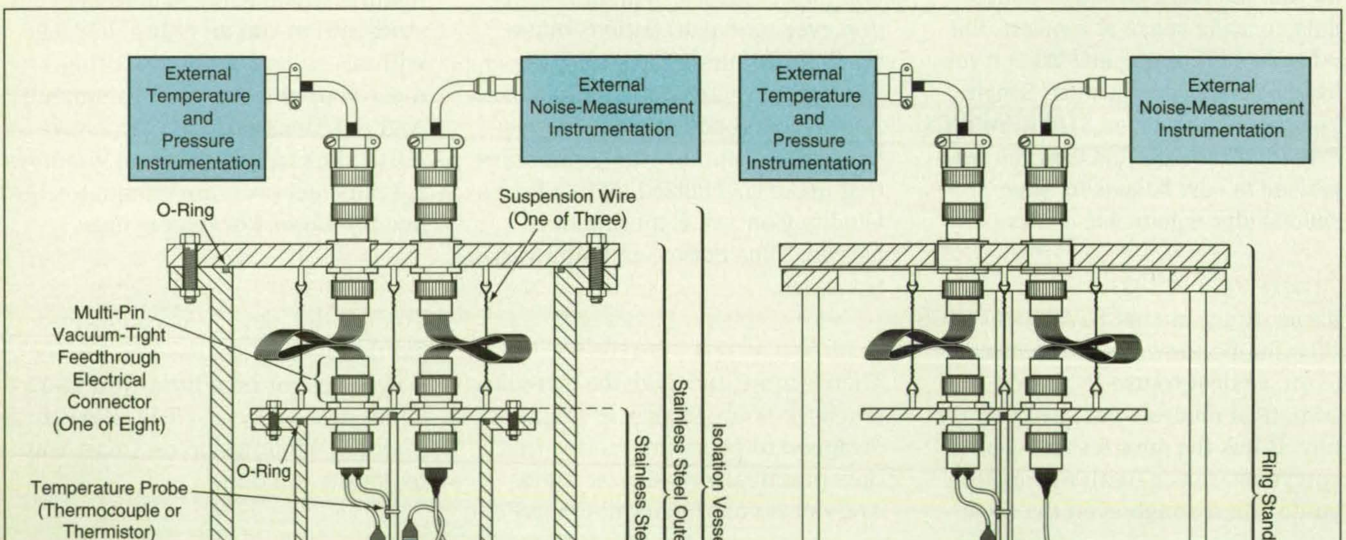

Figure 2. The **Inner and Outer Vessels** and the exterior and interior mechanical suspensions provide superior acoustical and vibrational isolation of the microphone under test.

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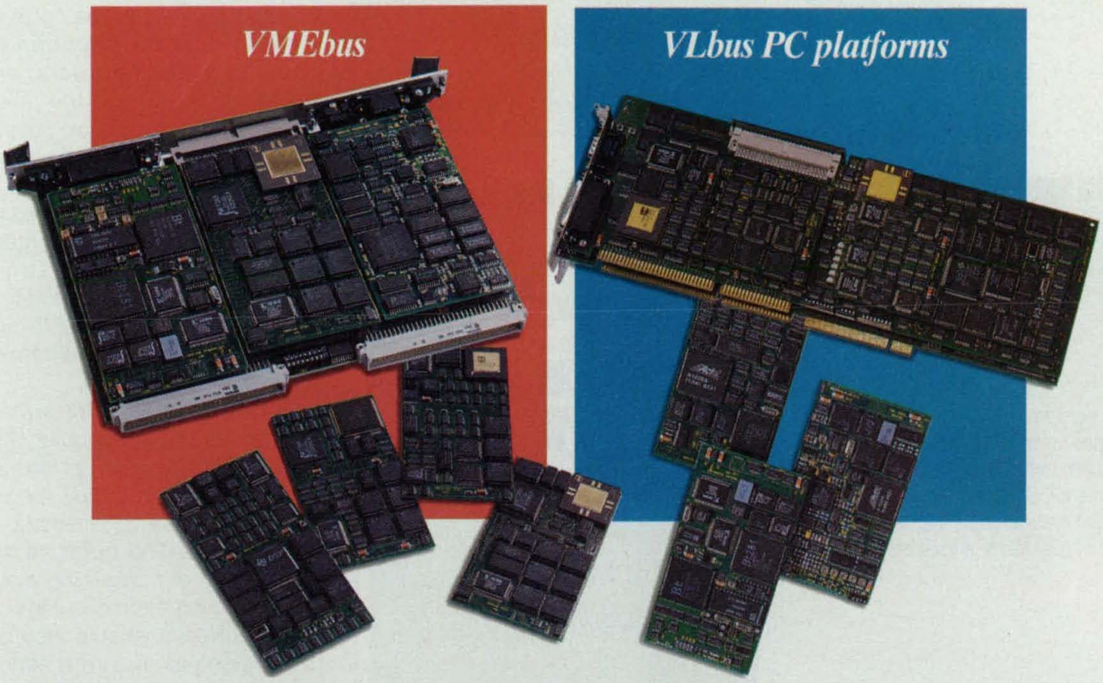

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and inner vessels provides the needed acoustical isolation. For additional vibration isolation, the inner vessel is suspended from the top of the outer vessel by three thin wires.

A static-pressure probe and a temperature probe are mounted in the inner vessel near the microphone to provide temperature and static-pressure readings ancillary to the noise readings. The electrical connections between the external instrumentation and the instrumentation inside the inner vessel are made via multiple-pin vacuum-tight electrical connectors and cables. The electrical conductivity of the inner and outer vessels helps to suppress electrostatic and electromagnetic interference with the measurements. To eliminate one source of power-line interference, the external thermocouple and pressure-transducer instrumentation is powered by a battery.

In preparation for a measurement of thermal noise, the outer vessel is evacuated to a pressure of less than 10–5 torr (1.3×10^{-3} Pa), then the vacuum pump is turned off to eliminate its noise and vibration. The outer vessel should be capable of maintaining a sufficient vacuum during the measurement interval; the inner vessel should also be capable of retaining air at normal atmospheric pressure during the measurement. A leak of air from the inner vessel to the surrounding evacuated space would be indicated by a gradually decreasing reading of the static-pressure sensor.

A measurement of thermal noise should be preceded or followed by a calibration measurement to determine the sensitivity of the microphone, so that the thermal-noise figure can be converted to an equivalent sound-pressure figure. For this purpose, the cylindrical bottom portions of both the outer and inner vessels are removed, the top plate of the outer vessel is placed on a ring stand, and the microphone is connected to a commercial microphone-calibrating acoustic source while the output of the preamplifier is measured under the same electrical conditions as in the measurement of thermal noise.

This work was done by Allan J. Zuckerwar of **Langley Research Center** *and Kim Chi T. Ngo of Old Dominion University. For further information,* ***write in 144*** *on the TSP Request Card.*

This invention has been patented by NASA (U.S. Patent No. 5,146,780). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 20]. Refer to LAR-14567.

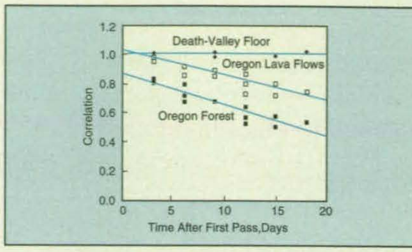
Exploiting Decorrelations in Synthetic-Aperture Radar

Temporal decorrelations reveal changes in target areas.

NASA's Jet Propulsion Laboratory, Pasadena, California

A technique for processing synthetic-aperture-radar data acquired on passes along the same or nearly the same trajectory at two different times provides data on changes that occur in the target scene during the time between the two passes. The technique is based partly on mathematical models of the statistics of correlations between the first- and second-pass radar echoes. It is also based partly on Fourier-transform relations between the (1) radar-system impulse response and (2) decorrelation functions — particularly those that express the decorrelation effects of rotation and horizontal shift of the trajectories between the two passes.

These effects are called "spatial decorrelations," while the decorrelation effects of changes in the target scene are called "temporal decorrelations." Thermal noise also contributes to decorrelation. The essence of the technique is to estimate the spatial decorrelation by use of the Fourier-transform-based models, estimate the thermal decorrelation from the signal-to-noise ratio, and correct the total observed decorrelation for these effects: what remains is the inferred temporal decorrelation, which is the quantity sought.



The **Temporal Decorrelation** (that is, the temporal contribution to the decrease in correlation) between synthetic-aperture-radar data acquired on subsequent passes along the same or nearly the same trajectory serves as a measure of change in the target scene.

The technique was tested on multiple passes, during a three week observation interval, over three target scenes: the Death-Valley floor, some lava flows in central Oregon, and a heavily forested area in Oregon. As shown in the figure, the data from Death Valley showed no significant decorrelation, those from the lava flows showed some decorrelation, while those from the forested area showed more decorrelation, which increased approximately linearly with time. The retention of correlation in the Death-Valley data is consistent with the ancillary observation that no rain or other natural effects that could have produced significant alterations in Death Valley occurred during the observation interval. The increasing decorrelation in the forested-area data is consistent with the concept of changes in radar-backscattering characteristics attributable to continuous growth of vegetation. At the time of submission of information for this article, the cause of the increase in decorrelation of the lava-flow data had not been identified, but true changes in the lava (as distinguished from other progressive sources of error or decorrelation) had not been ruled out.

This work was done by Howard A. Zebker and John D. Villasenor of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 77*** *on the TSP Request Card.*
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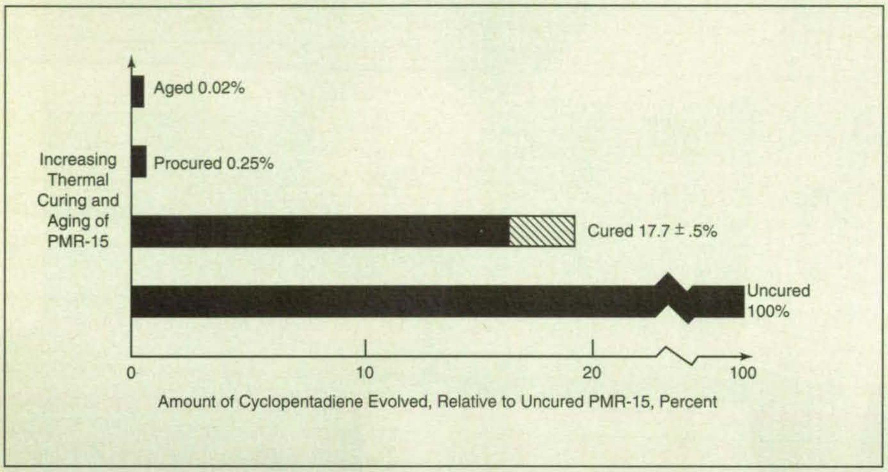
Thermal History of PMRs via Pyrolysis-Gas Chromatography

The amount of cyclopentadiene evolved in pyrolysis is related to the state of cure and postcure.

Lewis Research Center, Cleveland, Ohio

Pyrolysis-gas chromatography (PY-GC) has been demonstrated to be useful as an analytical technique to determine (1) the extents of cure or postcure of PMR-15 polyimides and to a lesser extent (2) the cumulative thermal histories of PMR-15 polyimides that have been exposed to high temperatures. PY-GC is also expected to be applicable for the same purposes to other PMR polyimides and to composite materials that contain PMR polyimides. It could be valuable in reducing costs and promoting safety in the aircraft industry by helping to identify improperly cured or postcured PMR-15 composite engine and airframe components and by helping to identify such composite parts that are nearing the ends of their useful lives.



The **Amount of Cyclopentadiene Evolved** from a specimen of PMR-15 resin in PY-GC depends on its degree of cure or postcure.

The essence of this application of PY-GC is to measure chromatographically the amount of cyclopentadiene (CPD) evolved during pyrolysis of a small specimen (in the microgram range) of PMR material. The specimen could be, for example, a piece of scrap removed from the component of interest during drilling or cutting, or it could be one of a series of small, nonfunctional tabs incorporated into the component specifically for ease of removal and sampling at intervals during use. The amount of CPD available for evolution is related to the amount of CPD that was available initially (determined by the formulated molecular weight of the PMR resin). The amount of CPD available for evolution decreases with increasing degree of cure, decreases more slowly with increasing degree of postcure, and decreases still more slowly with continued aging at elevated temperature (see figure).

The success of PY-GC as an analytical technique depends on the establishment of proper pyrolysis conditions of temperature and time, plus standardization of the mass and size of the specimens, to ensure reproducible evolution of CPD. PY-GC results have been found to be related accurately to the degree of cross linking from cure and postcure. However, they have been found to be less accurately related to long-term isothermal aging. This is because the changes in the amount of CPD evolved during long-term aging are smaller and may fall within the scatter in the data; that is, one encounters a fundamental limitation on the accuracy of the current PY-GC technique. Thus, it appears that PY-GC is a valid analytical technique for characterization of the cumulative thermal histories of PMR polyimides in the uncured, cured, and postcured conditions, but is less useful for characterization of cumulative thermal histories of long-term-aged PMR materials.

This work was done by Richard E. Gluyas of **Lewis Research Center,** *William B. Alston of the U.S. Army Aviation Systems Command, and William J. Snyder of Bucknell University. For further information,* ***write in 171*** *on the TSP Request Card.*
LEW-15725

M A T H C A D

Could this be the end of 7th row center?

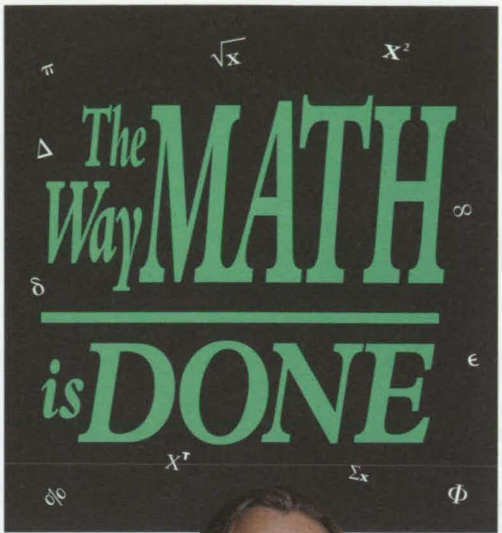
To locate the best seat in the house, two heads are better than one.

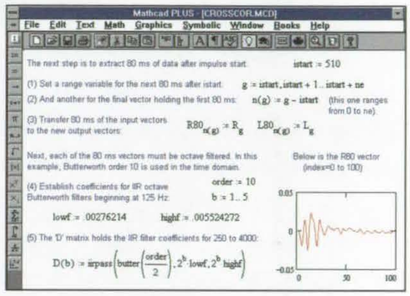
For Dick Campbell, world-class acoustics engineer, electrical engineering professor and ardent concert-goer with an "excellent ear" for music, where he sits in a concert hall can be as important as the program he sits through.

"Not seventh row center. It's too close to the source. If you care more about watching the musicians than hearing the music, it's fine. But the best seats start a quarter of the way back from the stage." And that's not just Dick's personal taste. It's a fact based on the unimpeachable impartiality of observations made by Fred (he's the one on the left, Dick's the one with a tie).

Dick, a member of the Concert Hall Research Group, employs dummies like Fred to map the acoustics of concert halls around the world, including Symphony Hall in Boston and Washington's Kennedy Center.

First, the dummy occupies various seats throughout the hall, each time listening to test sounds digitally recorded through microphones installed in its head. Then, the data is read into Mathcad® PLUS 5.0 for interaural cross correlation analysis using the Signal Processing Function Pack. This involves octave filtering of the left and right impulse reponses and picking out the maximum cross correlation of the octave-filtered pairs. It's a mildly controversial technique used for mathematical modeling of something otherwise ordained by still-quibbling critics, specifically, what makes a concert hall sound good.





Interaural cross correlation analysis using Mathcad PLUS 5.0.

But the importance of this work is not debated among his students. They study Dick's documents directly in Mathcad, revealing principles of acoustics in a way Dick calls "very much alive. They can manipulate the equations and graphs right there in front of them. They can visualize what's going on, not just do math all day long. It lets them look at a problem like it's under a magnifying glass."

Mathcad also lets Dick explore in a way that "might not be attempted otherwise." Like using a 20-term series expansion to find the first seven combined resonance frequencies for a coupled driver and standing wave tube. "You wouldn't even try this with a calculator. And the human factor of Mathcad makes it much faster than programming."

Which leaves but one probing question unanswered. Are there any bargain seats in the great halls of the world? "No, not really. But don't ever sit under the balcony. That's the worst."
Dick Campbell, EE, Professor, Worcester Polytechnic Institute, Worcester, MA.

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Heat-Pulse Measurements Reveal Fiber Volume Fractions

Nondestructive tests yield useful results in less time.

Langley Research Center, Hampton, Virginia

Measurements of thermal diffusivities by the heat-pulse method constitute the basis of a noncontact, nondestructive method of determining the fiber volume fractions (FVFs) of samples of composite (matrix/fiber) materials. Heretofore, FVFs have been determined by use of contact ultrasonic measurements and by destructive testing techniques, including acid digestion and sectioning followed by microscopic examination. Ultrasonic measurements involve several complications that make results difficult to interpret. The destructive techniques consume much time and typically yield only local data on the properties of small, possibly unrepresentative coupons or sacrificial areas on the surfaces of samples to be characterized. Testing by the heat-pulse method takes less time, provides data to characterize a sample through its thickness, and is amenable to scanning for a global determination of gradual spatial variations in FVF along the sample.

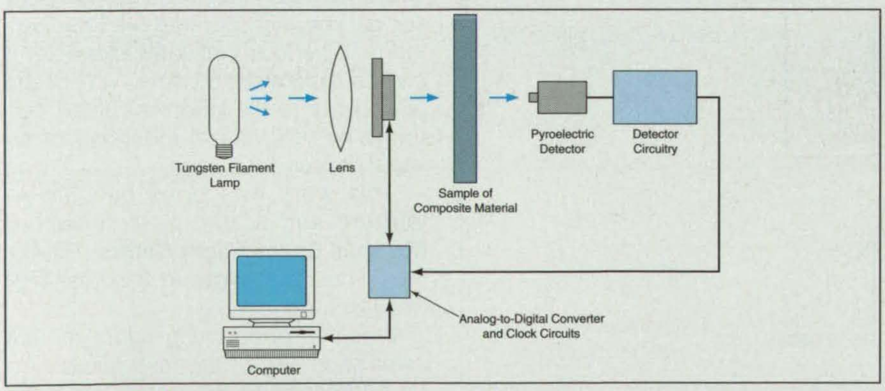
The FVF of a composite material is the fraction of the total volume occupied by the fibers. The FVF is a subject of continuing experimental and theoretical investigation because it is related to the tensile strength of the material. Thermal diffusivity serves as a convenient measure of FVF because it varies strongly with FVF in a known way. The strong variation is caused by the large ratio (typically hundreds or thousands) between the thermal conductivity of the fibers and that of the matrix.

In the present version of the heat-pulse method (see figure), light from a lamp is focused by a lens onto a small spot on the sample of material. The light is modulated by an electromechanical or electronic shutter under computer control, so that the illuminated spot is subjected to periodic heating. The heat diffuses through the sample and some of it is emitted on the opposite side as modulated infrared radiation. A polyvinylidene fluoride pyroelectric detector measures this radiation.

The shutter-control and detector-output signals are digitized at the rate of 256 samples per shutter period for four periods. The relative phases of these two signals are computed from fast Fourier transforms of the signals, with corrections derived from independent measurements of the phases of the shutter, detector, and detector circuitry; this calculation yields that part of the phase shift that is attributable to the delay in propagation of the modulated heat through the sample.

The thermal diffusivity of the composite material can then be calculated from the theoretical relationship among the propagation phase shift, the thickness of the sample, the modulation frequency, and the thermal diffusivity. Finally, the FVF can be calculated by inverting the equation that expresses the thermal diffusivity of the composite as a function of the FVF and the thermal conductivities, specific heats, and densities of the fiber and matrix materials. The measured FVF was to within +/– 3.6% of the destructive test results.

This work was done by William P. Winfree of **Langley Research Center** *and Joseph N. Zalameda of the Army Research Laboratory at Langley. For further information,* ***write in 92*** *on the TSP Request Card. LAR-15126*



Modulated Radiant Heat is applied to the left face of the sample, while the resulting modulated infrared emitted by the left face is monitored. The phase shift between the two modulations is indicative of the thermal diffusivity and the fiber volume fraction of the sample.

Sensor Detects Semiconductor Escaping From Ampoule

Electrical resistance and temperature change upon exposure to semiconductors

Marshall Space Flight Center, Alabama

Figure 1 illustrates an electrochemical sensor that detects semiconductor materials escaping from a broken fused-silica ampoule. The ampoule contains such materials in a crystal-growth furnace. The sensor is small enough to be placed inside a metal cartridge that surrounds the ampoule in the furnace. Typically, the ampoule is charged with toxic semiconductor materials like PbSnTe, HgZnTe, and GaAs. This sensor can be used to shut down the furnace automatically if the ampoule breaks and thereby prevent the further release of molten semiconductor, which could quickly breach the surrounding thin wall [0.010 to 0.020 in. (0.25 to 0.50 mm) thick] of the cartridge, damage the furnace, and/or release toxic vapors into the surrounding area.

The sensor capitalizes on the chemical reactions that occur between semiconductors and metals at the melting temperatures of the semiconductors. The sensor contains two wires made of dissimilar metals with a junction between them to form a closed electrical circuit. The chemical reactions between the two dissimilar metals and the semiconductor materials increase the electrical resistance of the sensor in a step of the order of megohms. The use of two dissimilar metals in the sensor also enables it to measure temperature via the voltage produced by the Seebeck effect. Therefore, resistance and voltage measurements can be taken alternately at a frequency of approximately 1 Hz.

The sensor was tested with HgCdTe and GaAs semiconductor materials. In each case, the material was placed in a boron nitride crucible, which was placed inside a quartz liner in a crystal-growth furnace. The sensor was placed through a groove in the crucible into the volume containing the semiconductor material. (This setup simulated the case in which the ampoule was already ruptured before processing.) The temperature was increased, and the resistance and temperature of the sensor were recorded until step increases of resistance (see Figure 2) indicated that the sensor was exposed to the vaporous or molten semiconductor material.

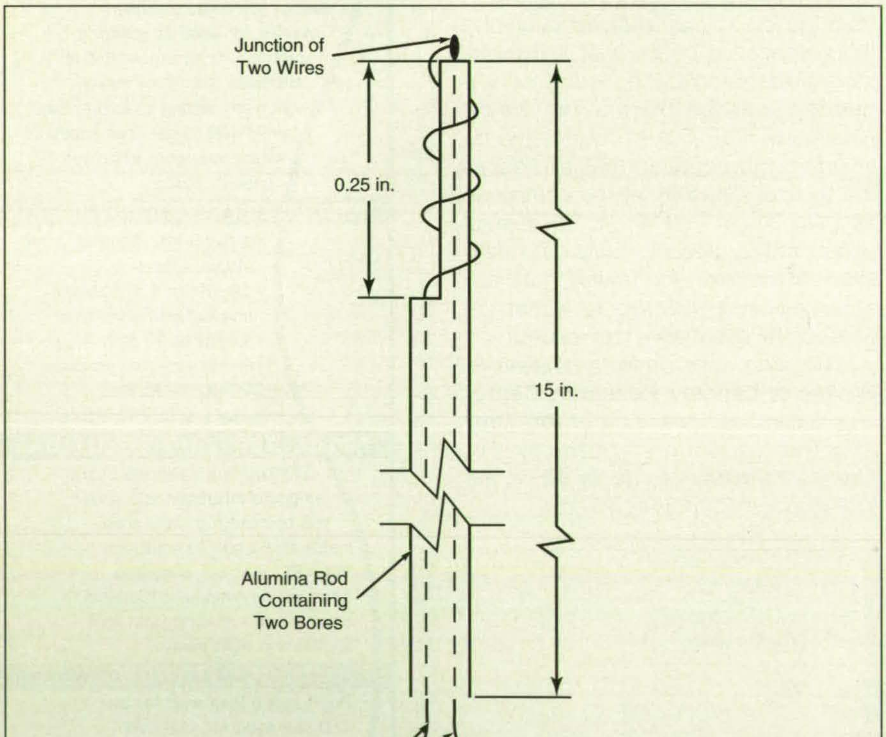


Figure 1. This **Sensor Detects the Breakage** of an ampoule that contains molten semiconductor. The chemical reaction between the hot semiconductor material and the wire causes a step increase in the electrical resistance and temperature of the wire.

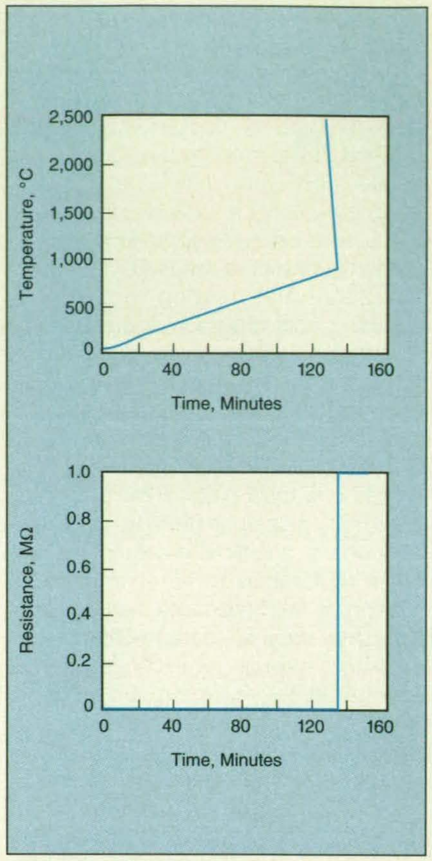


Figure 2. This **Step Increase in Temperature and Resistance** of a prototype sensor indicates the presence of hot GaAs.

Because of the step increase in resistance, the sensor can be regarded as operating in a simple on/off mode that can be used to shut down the crystal-growth furnaces automatically. The sensor can be incorporated into the cartridge in various ways; for example, it can be affixed to the outer wall of the ampoule or to the inner wall of the cartridge by mechanical mounting or by vapor deposition.

This work was done by Dale A. Watring and Martin L. Johnson of **Marshall Space Flight Center**. *For further information,* ***write in 5*** *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 20]. Refer to MFS-28852.

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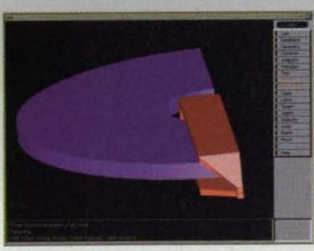

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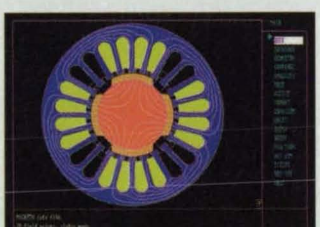

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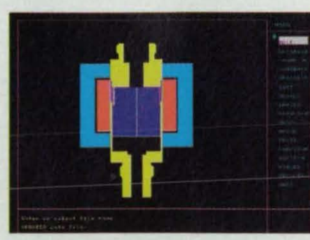

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Using Si Diodes To Detect H2 Liquid/Vapor Interfaces

Rakes of diodes can serve as liquid-level indicators.

Lewis Research Center, Cleveland, Ohio

Commercially available silicon-diode temperature sensors can be used to detect interfaces between hydrogen liquid and hydrogen vapor at steady-state saturation conditions. In a practical application, sensors of this type would be mounted at short intervals along a rod to form a rake-like array. The array would be inserted in a tank with the rod oriented vertically, where it would sense the level of liquid hydrogen to a resolution equal to the interval between sensors.

The basic idea is to measure the voltage across a sensor (as an indication of its temperature) while supplying a small electric current that heats the sensor. Because the vapor cools the sensor less effectively than the liquid does, the sensor's steady-state temperature is greater when the sensor is surrounded by vapor than when it is immersed in liquid. It should be noted that voltage output decreases as temperature increases for silicon diodes. Thus, the temperature (voltage) reading can be used to determine whether the liquid level is above or below the sensor.

The principle of detecting a liquid/gas interface by use of a combination of electrical heating and measurement of a quantity related to temperature is not new; what is new is the choice of silicon diodes over such other transducers as hot-wire sensors, thermopiles, carbon resistors, thermistors, and germanium diodes. Silicon diodes were chosen over the other transducers because in the hydrogen-liquid/hydrogen-vapor application, they come the closest to satisfying the following design criteria:

- The sensors should affect the measured quantity minimally; that is, they should dissipate minimal heat into the liquid.
- The sensors should be easy to operate and calibrate.
- Changes in tank pressure, rates of flow of liquid, and temperature of the liquid should exert minimal effects on the accuracy of the sensors.

Additional advantages of silicon diodes include relatively low cost and compatibility with relatively simple signal-conditioning circuitry.

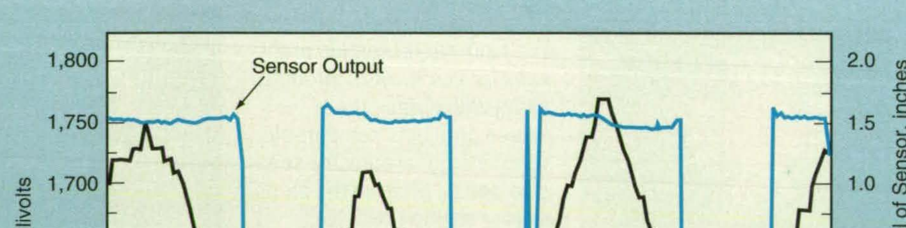
The concept was tested in experiments in which silicon-diode temperature sensors were placed in an insulated tank, which was then partly filled with liquid hydrogen. A steady current was supplied to each sensor and the voltage across the sensor produced by the current was measured as the level of the liquid was varied several times between slightly below and slightly above the sensors and the pressure in the tank fluctuated between 20 psi (≈ 140 kPa) and 27 psi (≈ 190 kPa).

Of several different current levels tried, 30 mA was found to produce sufficient self-heating of the sensors to (1) give a clear voltage indication from which one can distinguish between liquid and vapor and (2) vaporize any liquid remaining on a sensor that has risen above the surface of the liquid. At the same time, this current level results in a sensor-self-heating rate of no more than about 53 mW, which is within the safety limit for the use of these sensors in hydrogen and was less than 0.5 percent of the parasitic leakage of heat into the tank used in the experiments.

The figure presents data from measurements on one of the silicon-diode sensors at a current of 30 mA. If the data is above 0.0 on the level axis, the diode is in liquid. These data show that it is possible to set a switchpoint voltage about midway between a vapor- and a liquid-indicating voltage (in this case, about 1.6 V): Above the switching voltage, the sensor can be assumed to be in liquid; below the switchpoint voltage, the sensor can be assumed to be in vapor. In a practical application, a sensor rake would be alternately taken above and below the surface of liquid hydrogen, each of the diodes on the rake would be calibrated with respect to its liquid/vapor switchpoint voltage, and the calibration would be programmed into a data-acquisition system.

This work was done by Paula Jean Dempsey and Richard Fabik of **Lewis Research Center.** *For further information,* ***write in 237*** *on the TSP Request Card.*

LEW-15860



The **Output Voltage** of a silicon-diode temperature sensor supplied with a current of 30 mA varied between two clearly distinguishable values when the level of liquid hydrogen was alternated between slightly above and slightly below the sensor.

Fluorinated Poly(Phenylene Ether Ketones)

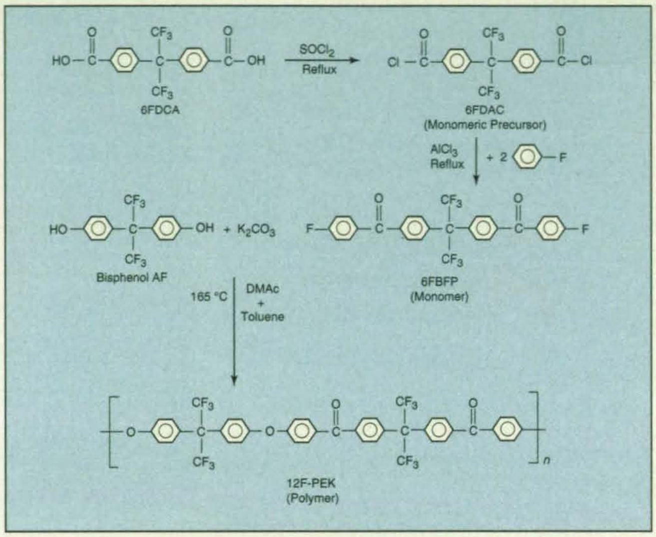
These polymers could be used to coat solar cells.

Langley Research Center, Hampton, Virginia

Fluorinated poly(phenylene ether ketones) are colorless, transparent, low-dielectric-constant, highly thermally stable polymers. They are particularly suitable for use as film and coating materials in electronic and thermal-control applications; for example, as passivant insulating coats and interlevel dielectrics in microelectronic circuits, or as protective transparent coats on solar cells or mirrors.

The poly(phenylene ether ketones) that have been commercially available until now have not been the materials of choice for such applications because it is too difficult to process them: they are insoluble and so cannot be solution-cast into thin films. For example, the only known film form of the commercial product poly(phenylene ether ether ketone) (PEEK®) must be extruded. Furthermore, the color of PEEK® varies from pale to dark amber, depending on thickness, so that it is not sufficiently transparent at solar wavelengths for use as a solar-cell cover.

The figure illustrates the sequence of chemical reactions in an experimental synthesis of a fluorinated poly(phenylene ether ketone) called "12F-PEK." In the first step, 1,1,1,3,3,3-hexafluoro2,2-bis(p-carboxyphenyl)propane, (6FDCA) was re-fluxed in the presence of thionyl chloride (SOCl2) to produce the monomeric precursor 1,1,1,3,3,3-hexafluoro2,2-b is(p-chloroformylphenyl) propane (6FDAC). The 6FDAC was then refluxed with fluorobenzene in the presence of aluminum chloride to produce the monomer 1,1,1,3,3,3-hexafluoro-2,2-bis[4-(4fluorobenzoyl) phenyl] propane (6FBFP).



The **Fluorinated Poly(phenylene ether ketone) 12F-PEK** was synthesized in this sequence of reactions.

Property	12F-PEK	PEEK®
Glass-Transition Temperature	180 °C	143 °C
Melting Temperature	*	343 °C
Dielectric Constant at 10 GHz	2.40	2.85
Temperature of 10-percent Weight Loss in Air During Dynamic Thermogravimetric Analysis	537 °C	540 °C
Percent Weight Loss in Thermogravimetric Analysis		
After 100 h at 350 °C	14	34
After 200 h at 350 °C	20	96
Film Former (From Cast Solution)	Yes	No
Soluble in Common Organic Solvents	Yes	No
Transparent at Wavelengths From 400 to 500 nm	Yes	No

* Semicrystalline structure from x-ray diffraction but no observable melt.

The **Solubility and Transparency of 12-PEK,** along with its lower dielectric constant and its other properties make it more useful (in comparison with PEEK®) as a dielectric film and coating material in many applications.

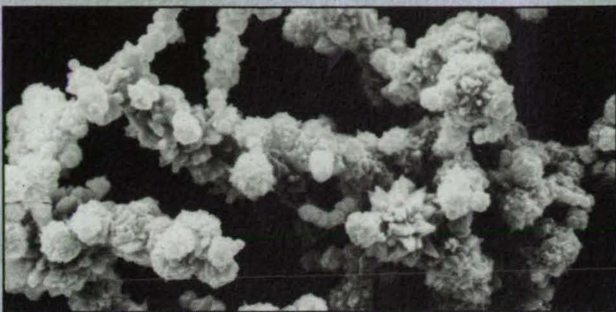
Setting aside the monomer for the moment, bisphenol AF was reacted with potassium carbonate by heating it in a mixture of toluene and dimethylacetamide (DMAc). Water was azeotroped off with toluene as the potassium salt of bisphenol AF formed. This salt was then mixed with the 6FBFP monomer in DMAc and heated to reflux at a temperature of 165 °C. The reaction between the salt and the monomer yielded the 12F-PEK polymer, which was precipitated by dripping the reaction mixture into stirred water. The polymer was purified by filtration, redissolution, reprecipitation, refiltering, and vacuum drying.

The table compares the properties of 12F-PEK with those of PEEK®. 12F-PEK has the higher glass-transition temperature, as determined by differential scanning calorimetry. The dielectric constant of 12F-PEK is decidedly lower than that of PEEK®. Although the data from dynamic thermogravimetric analyses show the two polymers to behave nearly identically, 12F-PEK exhibits superior long-term thermal stability upon isothermal aging in air at 350 °C. Unlike PEEK®, 12F-PEK can be dissolved in a solvent (e.g., chloroform, methylene chloride, or methyl ethyl ketone) and applied to form a transparent film or coating to a desired substrate. 12F-PEK can also be solution-cast to produce a self-supporting polymer film (as opposed to extrusion in the case of PEEK®).

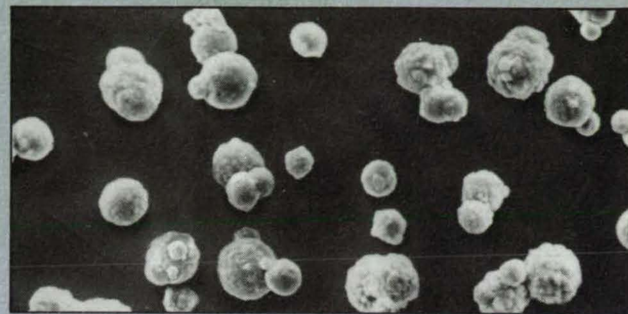
This work was done by Anne K. St. Clair of **Langley Research Center** *and Patrick E. Cassidy and Gordon L. Tullos of Southwestern Texas State University. For further information,* ***write in 1*** *on the TSP Request Card.*

This invention has been patented by NASA (U.S. Patent 4,902,769). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 20]. Refer to LAR-13992.

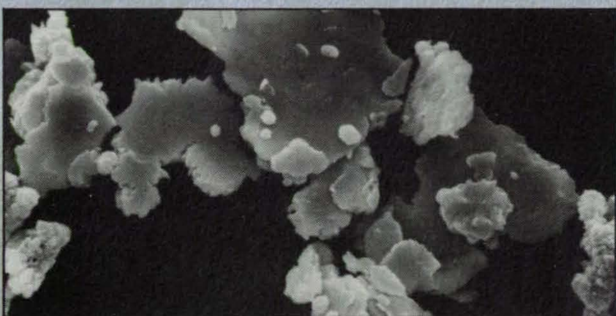
SPECIFY INCO SPECIALTY POWDERS FOR WIDE RANGE OF ELECTRONIC APPLICATIONS



Inco Type T 287 Filamentary Powder, particle size (FSSS) 2.6-3.3 microns, apparent density 0.75-0.95 g/cc, relative surface resistivity 0.30 ohms per square (□).



Novamet Silver Coated Nickel Spheres, 15% Ag, 2.5 g/cc apparent density, particle size 10 microns, screen mesh 99%-250, surface resistivity 0.03 Ω/□.



Novamet HCA-1 Flake, screen mesh 98% minus 400, apparent density 0.90 g/cc, thickness 1.0-1.1 microns, surface resistivity 0.25 Ω/□.

Novamet Nickel Coated Graphite, 60% fully encapsulated Ni, apparent density 1.6 g/cc, particle size (FSSS) 100 microns, screen mesh 63% −150/+250, surface resistivity 0.3 Ω/□.

Inco Specialty Powder Products now has a wide range of nickel and coated powders with exceptional conductive and magnetic properties. These properties make them ideal for a spectrum of electronic applications such as conducting film technology, coatings, adhesives, gaskets and EMI shielding.

EXTENSIVE PRODUCT RANGE

The development of computer processed control coupled with the continuous powder production improvements enables us to meet your most stringent powder specifications for electronic applications.

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Magnetic ferrites and surge arrestor applications also use our specialized range of nickel oxides. High Purity Black Nickel Oxide, 77.2% Ni, BET 75 (m^2/g) particle size (FSSS) 5.2 microns, minus 325 mesh 99% plus. Green Nickel Oxide, 78.5% Ni, BET 3 (m^2/g) particle size 1.6 microns, −325 mesh 100%.

Inco Specialty Powder Products is your unique source for custom fitting high performance powders into electronic applications. Our customer focused, worldwide marketing service group is ready to help you with your current and future needs.

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For More Information Write In No. 535

Making Fuel-Cell Electrodes by Electrodeposition

Platinum-alloy catalyst is deposited on high-surface-area carbon.

NASA's Jet Propulsion Laboratory, Pasadena, California

Electrodes for the direct oxidation of methanol in fuel cells can be fabricated, more quickly than before, in a process that involves room-temperature electrochemical deposition of platinum-alloy catalysts on commercially available high-surface-area carbon support structures that contain polytetrafluoroethylene (PTFE). The process takes only 30 to 50 minutes and results in electrodes that are catalytically active as prepared; that is, there is no need for an additional activation step as there is in the previous method of fabricating such electrodes. The composition of the catalytic platinum alloy and the sizes of particles in the catalytic layers on the electrodes can be varied by changing the operating conditions during electrodeposition; thus, the process affords additional flexibility in the design of electrocatalysts.

The commercial support structures used in experiments to demonstrate the process consisted of carbon with a specific surface area of 200 m^2/g, containing 15 percent PTFE as a binder, applied to a fiber-based carbon paper. The electrodeposition bath used in each experiment was a solution that contained ions of the metals to be deposited. For example, the solution for the deposition of Pt/Ru contained hydrogen hexachloroplatinate(IV) and potassium pentachloroaquoruthenium(III). The solution for the deposition of tin contained stannic chloride.

The concentration of metal ions in each electrodeposition bath lay in the range of 0.01 to 0.05 M. The salts were dissolved in 1 N sulfuric acid to prevent hydrolysis. In the case of ruthenium, the bath was deaerated to prevent formation of higher oxidation states. High-purity perfluorooctanesulfonic acid (C-8 acid) was added at a concentration of 0.1 to 1.0 g/L, as a wetting agent: Because of the PTFE in the electrode, complete wetting of the carbon particles cannot be achieved without C-8 acid. C-8 acid is electroinactive and is not specifically absorbed on the metal sites, and therefore does not affect the electrodeposition process.

In each experiment, the electrodeposition was carried out in a three-electrode cell (see Figure 1) in which the anodes consisted of pure platinum wire. To prevent the oxidation products of the anode from diffusing into the cathode compartment, the anode and cathode were separated by fine glass frits. A mercury/mercurous sulfate reference electrode was used to monitor and control the potential of the carbon electrode (the working electrode) during electrodeposition. Both potentiostatic and galvanostatic methods were used. The composition of the alloy deposit was controlled by choosing a bath composition (normalized for the electrochemical equivalents for the metals) and operating well above the limiting current densities for deposition of the metal(s). The quantity of charge passed during the deposition (minus the amount that caused evolution of hydrogen) was used to monitor the quantity of material deposited. The electrodeposition usually took 5 to 10 minutes, the exact time in each experiment depending on the operating conditions and the catalyst loading desired. Following electrodepo-

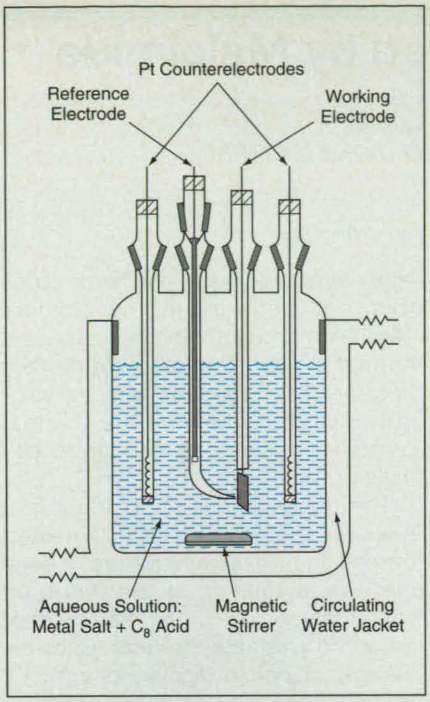


Figure 1. This **Electrochemical Cell** was used to deposit platinum-alloy catalysts on carbon-supported electrodes.

sition, the electrodes were washed at least three times, for 15 minutes each time, in circulating deionized water to rid the surface of adsorbed chloride and sulfate ions.

As indicated by scanning electron microscopy, the surfaces of the resulting electrodes are very uniformly coated with particles, shaped like cotton balls, that have significant fine structures. The average particle size is of the order of 0.1 μm.

The performances of the electrodes in the oxidation of methanol were studied in half cells. Figure 2 shows galvanostatic polarization curves obtained in two such cells, which contained Pt/Ru electrodes at two different loadings and were operated at a temperature of 60 °C with a solution of 1 M methanol and 0.5 M sulfuric acid. The electrode with the loading of 5 mg/cm^2 sustained continuous current at a density of 100 mA/cm^2 at 0.45 V vs. NHE. The electrocatalytic activity of these electrodes was found to be comparable to that of commercially available electrodes. By optimization of the composition of the alloy and of the electrodeposition conditions, further improvement in performance is attainable.

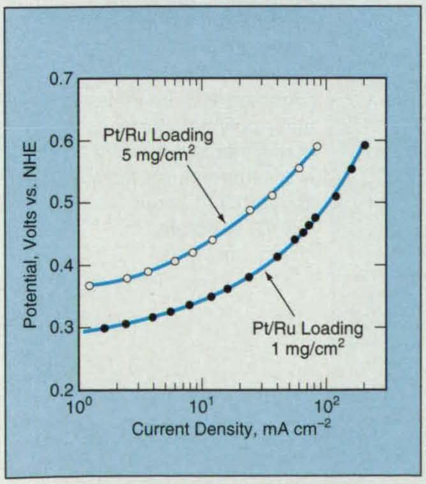


Figure 2. These **Galvanostatic Polarization Curves** were obtained in experiments on the oxidation of methanol in half cells.

This work was done by Sekharipuram R. Narayanan, Subbarao Surampudi, and Gerald Halpert of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 197*** *on the TSP Request Card.*

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

William T. Callaghan, Manager
Technology Commercialization
JPL-301-350
4800 Oak Grove Drive
Pasadena, CA 91109

Refer to NPO-19185, volume and number of this NASA Tech Briefs issue, and the page number.

Oligomers Terminated by Maleimide and Acetylene

These compounds can be used to make thermally stable, glassy polymers.

Langley Research Center, Hampton, Virginia

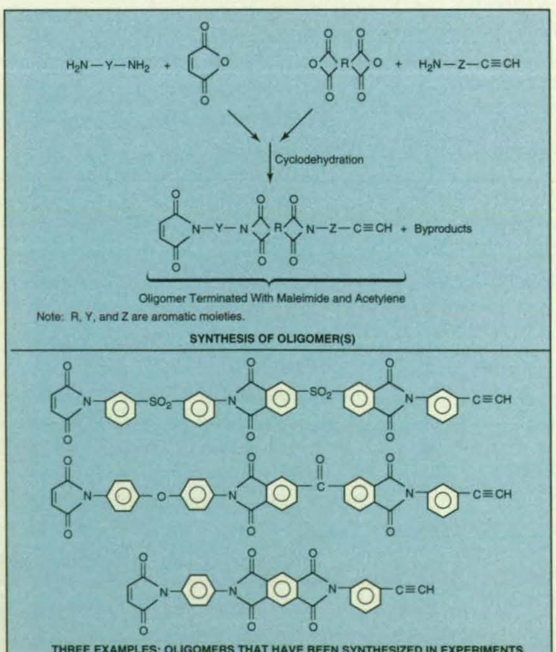
Oligomeric molecules terminated with maleimide and acetylene groups can be synthesized and thermally treated to form cross-linked polymers that exhibit high or undetectable glass-transition temperatures and high thermo-oxidative stabilities. Synthesis of an oligomer of this type (see figure) begins with the preparation of two mixtures: (1) stoichiometric amounts of maleic anhydride and an aromatic or substituted aromatic diamine monomer in a suitable organic solvent, which is typically dimethyl acetamide (DMAc); and (2) stoichiometric amounts of an aminophenylacetylene monomer and an aromatic or substituted aromatic dianhydride monomer in an organic solvent. These two mixtures are poured together and stirred for several hours at room temperature. Then the intermediate product is cyclodehydrated by adding acetic anhydride and a small amount of nickelous acetate and stirring for several more hours.

The reaction mixture is blended into ice water to precipitate the oligomeric product, which is then washed with deionized water, filtered, and dried in vacuum. The desired oligomer terminated with maleimide at one end and acetylene at the other is the primary product, but it is accompanied by other products that include bismaleimides, bisethnyls, and oligomers that have either ethynyl or maleimide terminations (but not both as in the primary oligomeric product). These byproducts are left in the product because they decrease its melting temperature without adversely affecting the thermal properties of the polymers that will ultimately be formed from it.

The dried oligomeric product is a powdery material. When it is heated beyond its melting temperature, it polymerizes, exhibiting an exotherm so strong that active cooling may be necessary to dissipate the heat. Because the reactivity of an oligomer of this type is very strong and because it contains doubly and triply bonded carbon atoms, it can be copolymerized, in any proportion(s), with one or more other compound(s) that contain acetylene or maleimide groups.

This work was done by Terry L. St. Clair and Ruth H. Pater of **Langley Research Center** *and Margaret K. Gerber of Lockheed Engineering & Sciences Corp. For further information,* ***write in 140*** *on the TSP Request Card.*

This invention has been patented by NASA (U.S. Patent No. 5,189,129). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 20]. Refer to LAR-14475.



Oligomers Terminated by Maleimide and Acetylene Groups are synthesized in this three-part reaction sequence. These oligomers can be thermally polymerized or copolymerized (typically at temperatures from about 225 to about 320°C) to obtain glassy polymers.

Computer Programs

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Computer Programs

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Electronic Components and Circuits

Program Simulates Spacecraft Communication Scenarios

DECAT computes effects of motion, antenna radiation patterns, noise, interference, and other phenomena.

The Dynamic Environment Communications Analysis Testbed (DECAT) computer program is a modular simulation program developed by Lockheed Engineering & Sciences Co. in support of the Tracking and Communications Division at NASA/Johnson Space Center. The flexibility of the DECAT simulation environment enables users to analyze many communications scenarios quickly and easily, eliminating much or all need for users to create specific computer programs. Users can create simulations that involve any number of vehicles, receivers, transmitters, and antennas via a graphical user interface (GUI).

Motions of vehicles (that is, spacecraft) and planets are defined hierarchically. The motion of any vehicle or planet can be described in reference to any other vehicle or planet. This allows different vehicles to be referenced in different coordinate systems. The antenna and the rest of the structure of a vehicle can be moved dynamically. The dynamics of the structure of the vehicle and of the antenna boresight are updated at each simulation time step, producing radio-frequency-coverage results more accurate than those obtainable from static simulated structures.

The modular design of DECAT makes it adaptable to any specific simulation analysis with modules, called "control functions," that are written by the user. These functions enable the user to perform specific analyses easily, without changes to the core DECAT source code. Control functions include the calculation of structural or planetary blockage of communication links by use of antenna-boresight lines of sight or antenna cones, determination of Doppler effects on communication links, and calculation of signal-to-noise or signal-to-interferer ratios.

The DECAT GUI was implemented by use of a software tool called the "Transportable Applications Environment Plus" (TAE Plus), developed at Goddard Space Flight Center, which enables users to create and set up complex simulations quickly and easily. TAE Plus runs on a VAX VMS computer under a Motif X Window System. This setup enables the execution of the DECAT GUI from any compatible terminal connected to the same network.

DECAT puts out ASCII files when signal probes are activated in the DECAT GUI. Utility subprograms in DECAT postprocess the DECAT output files to produce radio-frequency-coverage statistics and files for plotting.

DECAT is written in C language for use on DEC VAX-series computers running VMS 5.3 or higher. Both a menu-driven interface and a graphical user interface are included. The graphical user interface requires the TAE Plus, Version 5.1 package available from COSMIC (GSC-13463), DECWindows Version 5.3 or higher, DECWindows Programming Environment, and the DECWindows Developer Kit for OSF/Motif Version 1.1. Both versions require VAX C, Version 3.0 or higher. The standard distribution medium for DECAT is a 1,600-bit/in. (630-bit/cm), 9-track magnetic tape in DEC VAX BACKUP format. It is also available on a TK50 in DEC VAX BACKUP format. This version of DECAT was developed in 1992.

This program was written by Kenneth P. Land, Robert E. Best, Douglas J. Steel, and William C. Gadd of Lockheed Engineering & Sciences Co. for **Johnson Space Center**. *For further information,* ***write in 49*** *on the TSP Request Card.*
MSC-21900

Electronic Systems

Program Helps Generate and Manage Graphics

LCFM facilitates generation of graphics for real-time applications.

Computer graphics are often applied for better understanding and interpretation of data under observation. These graphics become more complicated when animation is required during "run-time," as found in many typical modern artificial-intelligence and expert systems. The Living Color Frame Maker (LCFM) computer program solves many of the problems involved in the generation of such "real-time" graphics.

LCFM is a software tool for generation and management of graphics on IBM or IBM-compatible personal computers. To eliminate custom graphical programming, a designer can use LCFM to generate computer-graphics frames. These graphical frames are then saved as text files, in a readable and disclosed format, which can be easily retrieved and manipulated by user programs for a wide range of real-time visual information applications.

For example, LCFM can be implemented in a frame-based expert system for visual aids in management of systems. For purposes of monitoring, diagnosis, and/or control, diagrams of circuits or systems can be brought to "life" by use of designated video colors and intensities to symbolize the status of hardware components (via real-time feedback from sensors). Thus, the status of systems can be displayed.

LCFM is easy to use with graphical interfaces and provides on-line help instructions. All options are executed by use of mouse commands and are displayed on a single menu for fast and easy operation. LCFM is written in C++ using the Borland C++ 2.0 compiler for IBM PC-series computers and compatible computers running MS-DOS. The program requires a mouse and an EGA/VGA display. A minimum of 77K of random-access memory is also required for execution. The documentation is provided in electronic form on the distribution medium in WordPerfect format. A sample MS-DOS executable code is provided on the distribution medium. The standard distribution medium for this program is one 5.25-in. (13.335-cm), 360K diskette in MS-DOS format. The contents of the diskette are compressed by use of the PKWARE archiving software tools. The utility program to unarchive the files, PKUNZIP.EXE, is included. The Living Color Frame Maker program was developed in 1992.

This program was written by L. V. Truong of **Lewis Research Center**. *For further information,* ***write in 169*** *on the TSP Request Card. LEW-15554*

Computing Plasma Interactions of a Spacecraft

NASCAP/LEO computes a variety of electrostatic, plasma, and flow effects.

NASCAP/LEO (NASA Spacecraft Charging Analyzer Program for Low Earth Orbit) implements a collection of

mathematical models and algorithms designed to study the electrostatic interaction between a cold, dense plasma and spacecraft surfaces. NASCAP/LEO examines the penetration of potentials into the ambient plasma, the collection of current by the spacecraft surfaces due to applied biases, the potentials of insulating spacecraft surfaces, the floating potential of the spacecraft relative to plasma ground, the degradation of solar-array performances by parasitic currents, and the hydrodynamic flow of spacecraft-generated plasma around the spacecraft. Spacecraft surfaces can be conductive or coated with thin dielectric materials.

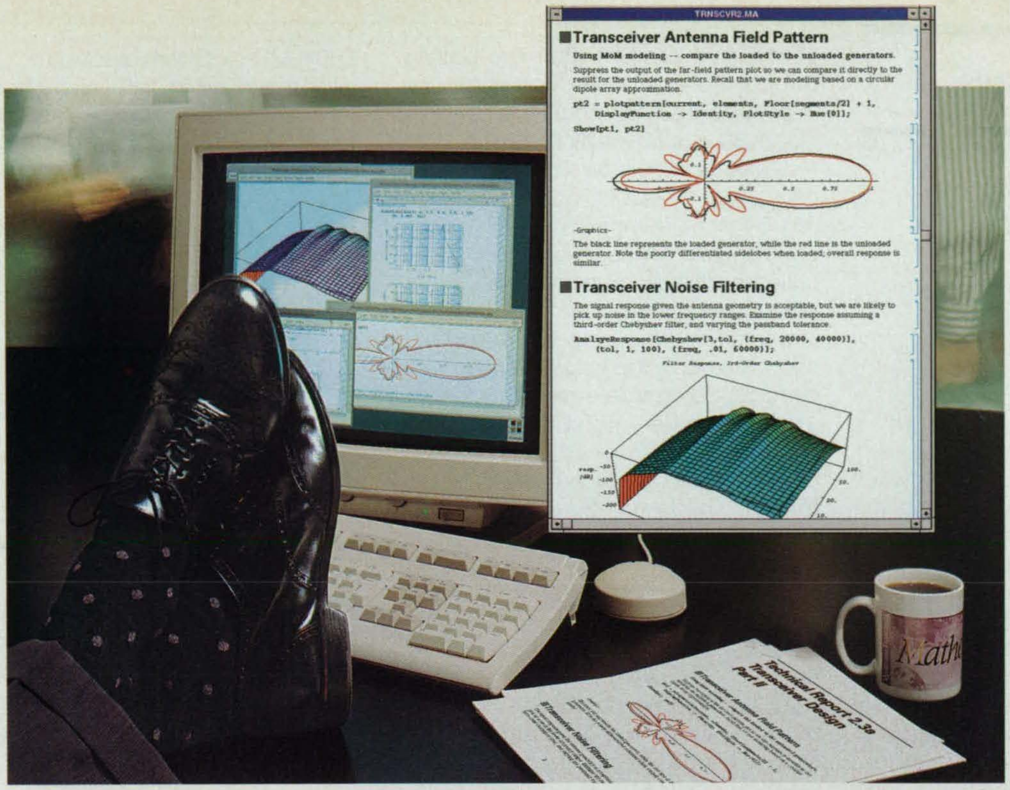
NASCAP/LEO is appropriate for conditions in which (1) the temperature of the plasma (typically 0.1 to 1.0 eV in low orbit around the Earth) is small in comparison with spacecraft-generated potentials and (2) the Debye screening length (typically 1 cm in low orbit around the Earth) is short in comparison with the dimensions of the spacecraft. The related NASCAP/GEO (LEW-12973) code (NASA Charging Analyzer Program for Geosynchronous Orbit, usually denoted simply as NASCAP) is appropriate for conditions under which spacecraft differential potentials result from interactions with a hot (1 to 20 keV) plasma and the Debye screening length is much larger than the dimensions of the spacecraft.

NASCAP/LEO features an advanced geometrical capability. While retaining, for computational efficiency, a cubic grid structure throughout most of space, NASCAP/LEO provides for the definition of objects as surface models by use of such standard finite-element software as PATRAN and EMRC DISPLAY II. Thus, the geometry of an object is not forced to conform to the cubic grid structure. Interface routines are provided to embed the object in the NASCAP/LEO cubic grid. A subdivision capability is provided to obtain enhanced resolution near critical parts of a spacecraft. Modeling capability is further enhanced by the availability of mirror planes. For users who do not have access to appropriate finite-element software, the object-definition portion of the related NASCAP/GEO code is provided as part of the NASCAP/LEO package. Auxiliary programs enable the user to view the object and the gridding of the space around it.

Electrostatic potentials are computed three-dimensionally. Space charge is taken into account in a simple analytic formulation that includes the effects of particle acceleration and convergence. Boundary conditions can be either fixed potentials or fixed electric fields and can be specified independently at each surface cell. Auxiliary programs enable the user to plot electrostatic potentials in the space around an object or on the surface of the object.

NASCAP/LEO is written in FORTRAN 77 and C language for Sun4-series computers running SunOS and for Silicon Graphics computers running IRIX 4.0 or higher. Approximately 6.1 Mb of random-access memory are required for execution. Graphical support is provided for MIT's X Window System (including Sun OpenWindows and Silicon Graphics Xsgi), for Silicon Graphics GL, for Tektronix 41xx- and 42xx-series terminals, and for color and gray-scale PostScript printers. The standard distribution medium for this package is a 0.25-in. (6.35-mm) streaming-magnetic-tape cartridge in UNIX tar format. NASCAP/LEO was developed during 1980–1990.

This program was written by M. J. Mandell and V. A. Davis of Maxwell Laboratories, Inc., for **Lewis Research Center's** *Power Technology Division. For further information,* ***write in 39*** *on the TSP Request Card.*
LEW-15641



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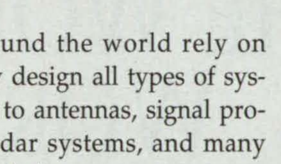

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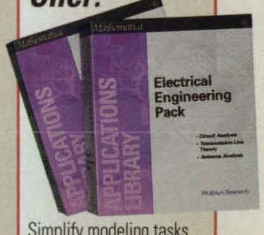

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For More Information Write In No. 526

Physical Sciences

Program for Joule-Thomson Analysis of Mixed Cryogens

JTMIX predicts Joule-Thomson cooling capacities and boiling-point depressions.

The JTMIX computer program was written to enable the prediction of both ideal and realistic properties of mixed gases at temperatures between 65 and 80 K. JTMIX can be used to perform Joule-Thomson analysis of any gaseous mixture of neon, nitrogen, various hydrocarbons, argon, oxygen, carbon monoxide, carbon dioxide, and hydrogen sulfide. When used in conjunction with the DDMIX computer program of the National Institute of Standards and Technology (NIST), JTMIX has accurately predicted the order-of-magnitude increases in Joule-Thomson cooling capacities that occur when various hydrocarbons are added to nitrogen. JTMIX also predicts that the boiling temperature of nitrogen can be depressed from the normal value to as low as 60 K upon addition of neon.

JTMIX searches the length of a heat exchanger for "pinch points" that can result from the immiscibility of various components. These points yield physically unrealistic numerical solutions. When pinch points are found, the user is warned and the temperature and the effectiveness of the heat exchanger are corrected to provide a realistic solution. JTMIX gives very good correlation — within the accuracy of experimental data on mixed gases published by the former Union of Soviet Socialist Republics and published by APD for the United States Naval Weapons Laboratory. Data taken at NASA's Jet Propulsion Laboratory also confirm the predictions of JTMIX for all cases tested.

JTMIX is written in Turbo C for IBM PC-compatible computers running MS-DOS. DDMIX [available from NIST, Gaithersburg, MD, telephone: (301) 975-2208] is necessary for obtaining data on the enthalpies of mixed fluids; these data are fed as input data to JTMIX. The standard distribution medium for JTMIX is a 5.25-in. (13.335-cm), 360K MS-DOS-format diskette. JTMIX was developed in 1991 and is a copyrighted work with all copyright vested in NASA.

This program was written by Jack A. Jones and Alan Lund of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 177*** *on the TSP Request Card.*
NPO-19097

Mathematics and Information Sciences

Program for Systematic Documentation of Tasks

This program assists a programmer in developing expert-system software for specific tasks.

The Task Analysis Report Generation Tool (TARGET) computer program is a graphical-interface software tool used

to capture procedural knowledge and translate that knowledge into a hierarchical report. TARGET is based on VISTA, a knowledge-acquisition software tool developed by the Naval Systems Training Center. TARGET helps a programmer and/or a task expert to organize and understand the steps involved in accomplishing a task. The user can label individual steps in the task through a dialogue box and get immediate graphical feedback for analysis.

By use of TARGET, one can decompose a task into basic action kernels or minimal steps to obtain a clear picture of all basic actions needed to accomplish the task. The TARGET method enables the user to go back and critically examine the overall flow and makeup of the task process. The user can switch between graphical (box flow diagrams) and text (task hierarchy) versions to make it easier to study the process being documented. As the practice of decomposition continues, tasks and their subtasks can be repeatedly modified to reflect the user's procedures and rationale more accurately.

This program is designed to help a programmer document an expert's task, thus enabling the programmer to build an expert-system computer program that can help others perform the task. Flexibility is a key element of the design of this software system and of the knowledge-acquisition session. If the expert cannot find time to work with the programmer on the knowledge-acquisition process, the programmer and the expert can work in iterative sessions. TARGET is easy to use and is tailored to accommodate users ranging from the novice to the experienced builder of expert systems.

TARGET is written in C language for IBM PC-series and compatible computers running MS-DOS and Microsoft Windows version 3.0 or 3.1. No source code is supplied. The executable code requires 2Mb of random-access memory, a Microsoft-compatible mouse, a VGA display, and a computer that contains an 80286, 386, or 486 processor. The standard medium for distribution of TARGET is one 5.25-in.(13.335 cm), 360K, MS-DOS-format diskette. TARGET was developed in 1991.

This program was written by Christopher John Ortiz and Robert T. Savely of **Marshall Space Flight Center**, *Bowen Loftin of the University of Houston, and Tim Saito of Computer Science Corp. For further information,* ***write in 192*** *on the TSP Request Card. MSC-22129*

Software for Computer-Aided Design of Control Systems

CAESY incorporates features of both Ada and MATLAB.

The Computer Aided Engineering System (CAESY) software was developed to provide means to evaluate methods for dealing with users' needs in the computer-aided design of control systems. Many developers of software and other algorithms for the design of control systems have recognized that the software tools heretofore available have been limited in both flexibility and efficiency. Many requirements influence the development of new software tools; these requirements include the desire to facilitate mathematical modeling, design, and analysis of complex systems and the need to shorten the time spent on analysis and design. Other considerations include the desire to use advanced computer architecture to help in designing control systems, adopt new methodologies in control, and integrate such design processes as those that pertain to structures and optics with those that pertain to control.

CAESY is an interpreter program for performing engineering calculations. It incorporates features of both Ada and MATLAB. It is designed to be reasonably flexible and powerful. CAESY includes internally defined functions and procedures and provides for definition of functions and procedures by the user.

CAESY supports matrix calculations in the same manner as that of MATLAB. However, CAESY is an intermediate product of a continuing research project, and while it provides some features that are not found in commercially sold software tools, it does not exhibit the robustness of many commercially developed software tools.

CAESY is written in C language for use on Sun4-series computers running SunOS 4.1.1 and later. The program is designed to optionally use the LAPACK math software library. The LAPACK math routines are available through anonymous ftp from research.att.com. CAESY requires 4Mb of random-access memory for execution. The standard distribution medium is a 0.25-in. (6.35-mm) streaming-magnetic-tape cartridge (QIC-24) in UNIX tar format. CAESY was developed in 1993 and is a copyrighted work with all copyright vested in NASA.

This program was written by Matthew Wette of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 156*** *on the TSP Request Card. NPO-19155*

Mechanics

Dynamic Imbalance Would Counter Offcenter Thrust

Offset of a mass would be adjusted to eliminate net dynamic imbalance.

Lyndon B. Johnson Space Center, Houston, Texas

Dynamic imbalance generated by an offcenter thrust on a rotating body would be eliminated, according to a proposal, by shifting some of the mass of the body to generate an opposing dynamic imbalance. This dynamic-balancing technique was proposed originally for a spacecraft that includes a massive crew module connected via a long, lightweight intermediate structure to a massive engine module, such that artificial gravitation in the crew module can be generated by rotating the spacecraft around an axis that is parallel to the thrust generated by the engine. Of course, the technique is also applicable to dynamic balancing of rotating terrestrial equipment to which offcenter forces are applied.

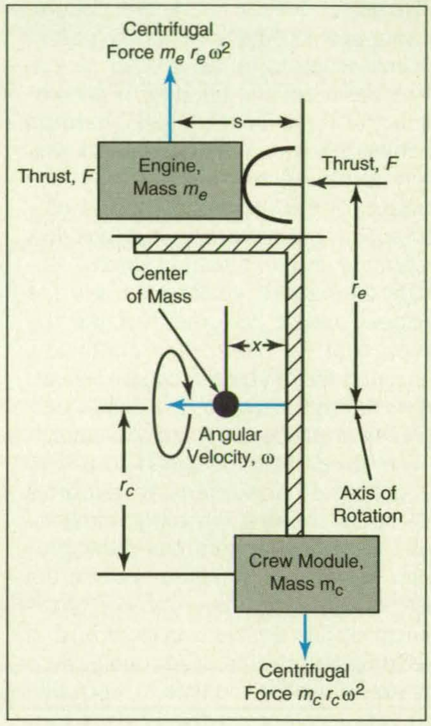
In one version of the technique (see figure), the opposing dynamic imbalance would be adjusted by displacing the engine module a distance s forward along a line parallel to the axis of rotation. The required value of s would be that value for which the centrifugal forces and the engine thrust acting through their respective moment arms produced zero net torque about the center of mass. Using the quantities indicated in the figure, and assuming that all other masses (truss, fuel) are distributed more or less symmetrically about any point on the axis of rotation (and no thrust is applied), it can be shown that the required value of s is given by

$$s \sim \frac{F}{m_e w^2}$$

In a second version of the technique, more suitable for a lightweight engine module, the crew module would be displaced backward by an amount given by the same equation. In yet another version, the masses would be mounted on hinged arms, and the hinge angles would be adjusted to obtain zero net dynamic imbalance.

This work was done by Jason McCanna of **Johnson Space Center.** *For further information,* ***write in 19*** *on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center [see page 20]. Refer to MSC-22021.



Axial Offset of the Engine Mass would introduce a dynamic imbalance that would compensate for the imbalance caused by the thrust.

Underwing Compression Vortex-Attenuation Device

A panel attenuates the total vortex system of an aircraft and increases wing lift.

Langley Research Center, Hampton, Virginia

The lift-induced vortex system associated with a large jet airplane has become a major problem to the air-traffic controller in that it constitutes an unseen hazard to smaller following aircraft. The rotational airflow or vortex developed at or near each wingtip of an aircraft remains essentially stationary in space and induces a rolling moment on a smaller following aircraft that encounters it. This rolling moment has proved to be so strong that loss of control in a smaller aircraft has occurred as far as 4 mi (6 km) behind a large airplane. The vortex problem is particularly severe in flightpaths around major airports, where smaller aircraft are most likely to follow large airplanes, and during landing, when small aircraft have little altitude in which to regain control after an encounter. The underwing compression vortex-attenuation device has been designed to provide a method for attenuating the lift-induced vortex generated by the wings of an airplane.

The device includes a compression panel attached to the lower surface of the wing, facing perpendicular to the streamwise airflow, as shown in the figure. The panel should be located between the midpoint of the local wing cord and the trailing edge in the chordwise direction and at approximately 55 percent of the wingspan as measured from the centerline of the fuselage in the spanwise direction. The panel is hinged so that it can be deployed during landing and can be retracted when not in use. This device does not provide elevational

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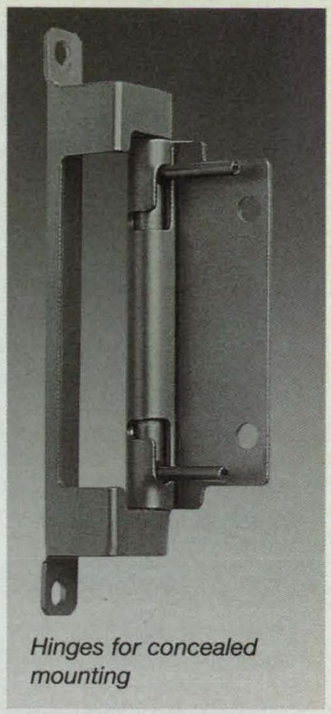

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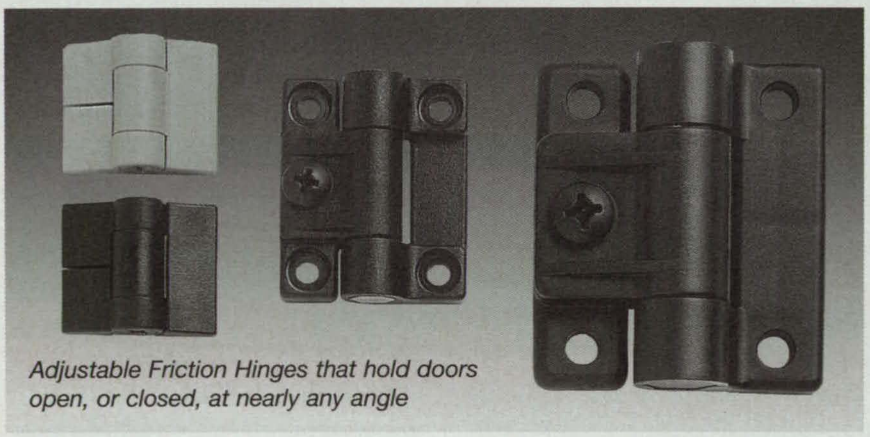
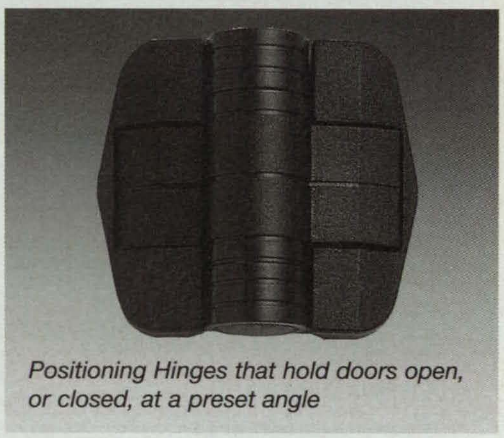


Adjustable Friction Hinges that hold doors open, or closed, at nearly any angle



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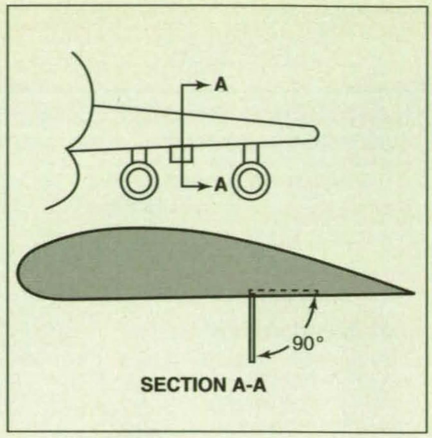
control; its purpose is to dissipate the total vortex system of an aircraft. The area of the panel is approximately one-half of 1 percent of the total wing area. The ideal shape for the panel would be rectangular, the width being two to three times the height. The size, shape, and position of the panel can vary, depending on the airplane and its flap system. The panel should be located such that it produces a positive pressure gradient, aligned with the final downstream rollup of the total vortex system. This will interrupt the axial flow in the core of the vortex, causing the vortex to collapse.

The underwing compression attenuation device attenuates the total vortex system produced by an airplane, and the concept can be effective on all types of aircraft. In addition, it causes an increase in wing lift rather than a reduction when deployed. This device may prove of specific interest to aircraft designers and could enhance air safety in general.

This work was done by James C. Patterson, Jr., of **Langley Research Center**. *No further documentation is available.*

This invention has been patented by NASA (U.S. Patent No. 5,230,486). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center *[see page 20]*. *Refer to LAR-14744.*



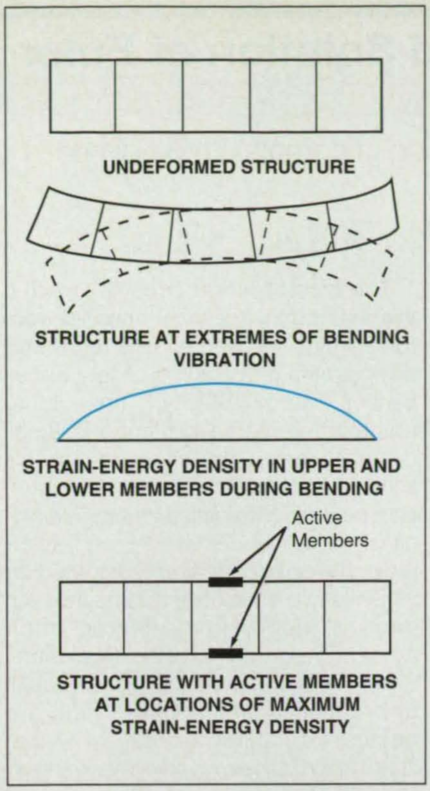
The **Compression Panel Is Hinged** so that it can be retracted when not in use.

Guideline for Design of Adaptive Structures

Active members should be located at positions of maximum strain energy.

NASA's Jet Propulsion Laboratory, Pasadena, California

A recently developed guideline for the design of adaptive structures specifies that active members should be located at positions of maximum strain energy (see figure). Although the term "adaptive structures" has not been used explicitly in previous articles in NASA Tech Briefs, several articles have discussed aspects of the emerging adaptive-structure concept. According to the current definition, one example of an adaptive structure is a truss or trusslike structure that includes (1) active members (which contain piezoelectric or other actuators to control their lengths and/or exert lengthwise forces on other members), (2) sensors (e.g., strain sensors, accelerometers, and/or displacement



A Structure Subject to Bending Vibrations could be made adaptive by use of active members at the locations of maximum strain energy — in this case, at the middle.

sensors that may or may not be collocated with the active members), and (3) local electronic feedback control subsystems and/or a global electronic feedback control system that control(s) the actuators in response to sensor outputs to suppress vibrations by introducing opposing vibrations, to introduce and measure test vibrations, to compensate for thermal or other slowly varying distortions in the structure, and/or introduce deliberate distortions into the structure (e.g., to bend a truss that supports a telescope mirror to bring the mirror into focus).

The present guideline to locate the active members of an adaptive structure at the locations of maximum strain energy was developed by following an alternative to the traditional approach to analysis of the statics and dynamics of flexible structures. In the traditional approach, one attempts to analyze the loads in structural members by a process that involves, among other things, correlation of computed vibrational modes with accelerometer test data. In the alternative approach, the equations of motion of flexible structures are formulated in terms of kinetic energies, strain energies, and direct measurements of forces.

In one scenario, a structure would be designed to maintain a precise specified shape even while it was being assembled or deployed in space. Maintaining precise dimensional control during assembly could be essential to assembly without large external loads or to prevent jamming of a substructure preventing a successful deployment. In this scenario, one would analyze the anticipated loads in the adaptive structures and substructures during every step of the assembly or deployment sequence to determine locations where strain energy could be concentrated due to hardware tolerances. Then in the final design of the structure, active members would be assigned to those locations, and during assembly or deployment, they would be used to relieve the internal loads (or strain energy) allowing for assembly of structures without a requirement for large external loads. The active members could also be used to prevent "binding" during the deployment of the structure. Then the structure can be adjusted to the precision shape requirement and adjusted during its operation as required.

This work was done by Senol Utku of Duke University and Ben K. Wada of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 29*** *on the TSP Request Card.* *NPO-18820*

Multiblock, Multigrid Solution of Euler Equations

This method provides for simulation of complex three-dimensional supersonic flows.

Langley Research Center, Hampton, Virginia

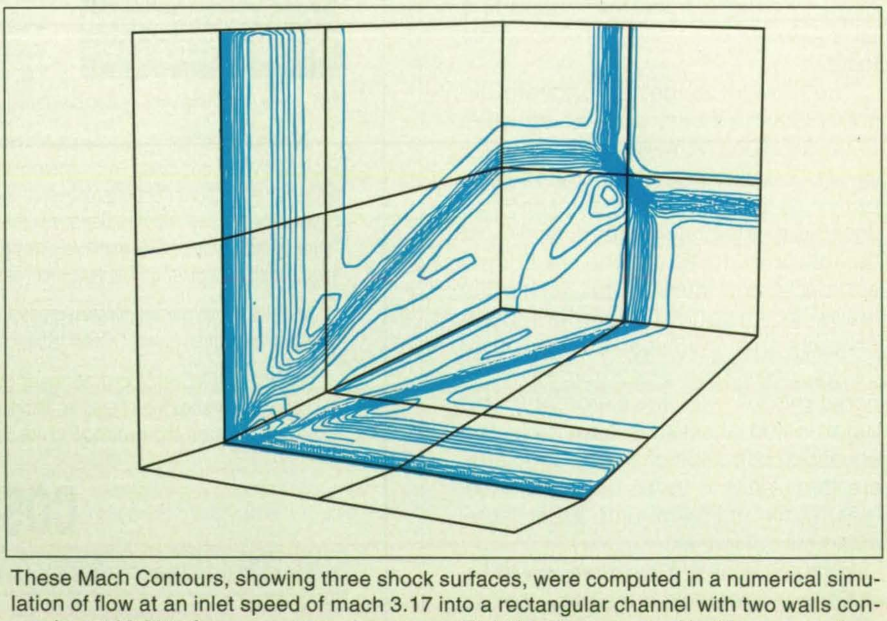
A method of numerical solution of the Euler equations of three-dimensional flow of a compressible fluid involves a combination of multiblock and multigrid strategies. In a multiblock strategy, the flow field is divided, into multiple smaller, more computationally-convenient zones (blocks) and a computational grid fitted to the applicable flow boundaries is generated in each block. In the particular multigrid strategy used here, different quantities are computed, variously, on finer or coarser grids [coarser grids are obtained by skipping over 2n (where n is an integer) grid intervals along each coordinate axis of the finest grid in each block]. The purpose of this multigrid strategy is to minimize the cost of computation by using the fewest grid points that yield acceptably accurate values of the affected variable.

The particular form of the Euler equations that constitutes the physical basis of the present method is the nondimensionalized strong-conservation-law form, specialized to flow of an ideal gas under isenthalpic conditions. An important advantage of the assumption of isenthalpy is that it enables replacement of the differential equation for the conservation of energy with a simple algebraic equation, thereby reducing the computational burden by reducing the number of differential equations that have to be solved simultaneously.

The discretization scheme used in this method involves van Leer flux-vector splitting (related to upstream and downstream propagation of flow disturbances) with MUSCL-type (monotone-upstream-centered-schemes-for-conservative-laws-type) differencing. This scheme is chosen because it offers an acceptable compromise among robustness, numerical complexity, and accuracy. The solution is then computed by either of two alternative approaches: an implicit approximate-factorization approach or an explicit Warming-Beam two-step (predictor/corrector) approach, in which both steps are accurate to second order in space. Both approaches involve marching in pseudotime to advance the numerical solution.

The method was tested on several three-dimensional flows that were successively more complex (see figure). The multigrid strategy was found to be very effective in accelerating convergence to the steady state, while the multiblock strategy provided geometric flexibility.

This work was done by N. Duane Melson of **Langley Research Center** *and Frank E. Cannizzaro and E. von Lavante of Old Dominion University. For further information,* ***write in 141*** *on the TSP Request Card.*
LAR-14411



These Mach Contours, showing three shock surfaces, were computed in a numerical simulation of flow at an inlet speed of mach 3.17 into a rectangular channel with two walls converging at 12.2° to form a compression corner. Eight blocks were used in this computation.

System Would Regulate Low Gas Pressure

The system is intended to maintain gases in containers at pressures near atmospheric.

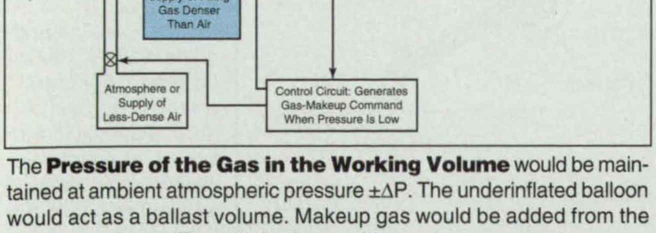
NASA's Jet Propulsion Laboratory, Pasadena, California

The proposed system shown schematically in the figure would maintain a filling gas denser than air in an enclosed working volume at a constant pressure at or near the pressure of the ambient atmosphere. The system would also use the filling gas conservatively. In the original intended application, the working volume would be a microwave waveguide or an enclosed high-voltage system, and the filling gas would be sulfur hexafluoride. The system is needed because internal heating during operation of a waveguide or other apparatus causes fluctuations in the temperature and, thus, in the pressure of the filling gas. Extreme fluctuations in pressure could harm delicate components like dielectric membrane windows that confine the gas but are nearly transparent to the microwave radiation that is intended to pass through them.

The system would include a ballast volume in the form of an underinflated balloon that would communicate with the working volume. The balloon would be housed in a rigid chamber that would not be subject to the extremes of temperature of the working volume. The pressure in the rigid chamber surrounding the balloon would be regulated at ambient atmospheric pressure or at a constant small differential pressure above or below ambient ($+\Delta P$ or $-\Delta P$, respectively). When the working volume was filled with the dense gas, the partial inflation of the balloon would allow margin for expansion and contraction to maintain pressure equilibrium between the filling gas and the regulated gas in the rigid chamber surrounding the balloon. Thus, the expansion and contraction of the balloon would accommodate expansion or contraction of the gas during operational heating or cooling in the working volume, maintaining the pressure in the working volume at ambient or at a constant differential above or below ambient.

If gas were lost from the system due to leakage or diffusion, a low-pressure sensor would respond, signaling valve actuators to supply more gas to the working volume. If pressure should rise too high, an overpressure relief valve would open before the excessive pressure could damage the system.

This work was done by Robert E. Frazer of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 10*** *on the TSP Request Card. NPO-18994*



The **Pressure of the Gas in the Working Volume** would be maintained at ambient atmospheric pressure $\pm\Delta P$. The underinflated balloon would act as a ballast volume. Makeup gas would be added from the supply as needed. The relief valve would prevent overpressure.

Low-Noise Rotorcraft Blades

The planform would feature a combination of rearward and forward sweep.

Langley Research Center, Hampton, Virginia

The blades of helicopter rotors, tilt rotors, and the like could be reshaped to reduce noise, according to a proposal. The planform of such a blade would be changed from the customary straight configuration to one with a straight inboard section, a midlength section with aft sweep, and an outboard section with forward sweep (see figure).

The forward sweep of the planform over a large outer portion of the blade would constitute the primary noise-reduction feature. Although the forward-swept shape has not yet been defined precisely, it has been estimated that the forward-sweep angle could lie in the range of about 30° to 45° (35° nominal) and the spanwise extent of the forward sweep could lie between 25 and 55 percent (40 percent nominal) of the radius of the blade.

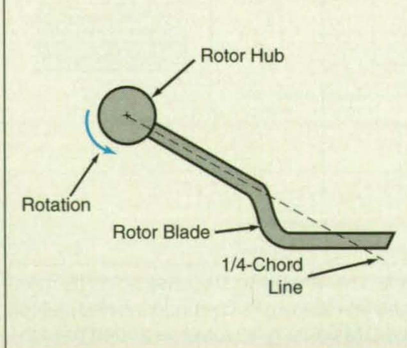
The component of noise generated by blade/vortex interaction is the one that would be reduced the most. This is because the forward-swept portion of the blade would intercept the most troublesome advancing-side tip vortices at skew angles to the blade rather than nearly parallel: the blade/vortex interactions would lose much of their impulse character, with consequent reduction of noise.

High-speed thickness noise would be reduced by favorable blade-surface thickness gradients over the modified planform. The forward sweep would also relieve some of the compressive effect in the tip region, with consequent reduction of noise from compressive sources. For the same reason, performance at high advance ratio could be improved. Finally, cabin vibration and loading noise could be reduced by a load-averaging effect of the double-sweep planform.

The aft-swept section provides for balancing of aerodynamic and other dynamic forces on the blade along the 1/4-chord line of the straight inboard section and along the projection of this line to the outermost blade radius. This feature would make it possible for hub-hinge forces and moments to remain within practical bounds. The aft-swept section would also provide the stabilizing blade forces and moments to counteract any instability caused by the forward sweep.

This work was done by Thomas F. Brooks of **Langley Research Center.** *For further information,* ***write in 145*** *on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 20]. Refer to LAR-14569.



The Swept Planform would make the advancing side of the blade cut across tip vortices at an angle rather than parallel. This would reduce noise generated by blade/vortex interaction. For clarity, only one blade is shown here; a practical rotor would, of course, include multiple blades in a balanced configuration.

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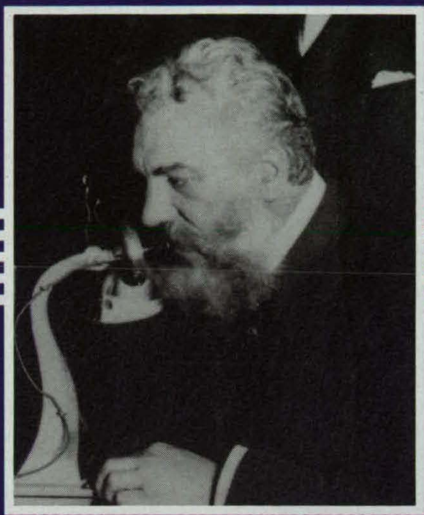

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Predicting Flow-Induced Vibrations in a Convoluted Hose

A composite model was constructed from two less accurate models.

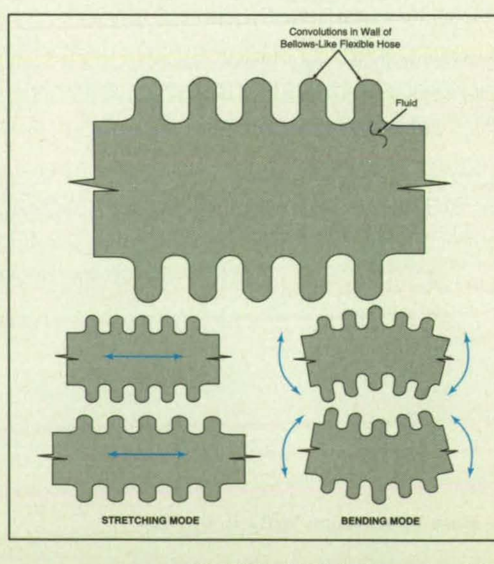
Marshall Space Flight Center, Alabama

A composite mathematical model predicts approximately the frequencies and modes of vibrations induced by flows of various fluids in a convoluted hose (see figure). This model was constructed from two older approximate models that were complementary to each other. One of the older models did not adequately account for interactions between the hose structures and the fluids and therefore gave accurate predictions only in cases in which the fluids had little effect or in which the fluids acted as simple additional mass loads that were parts of the hose structures. The other older model accounted for fluid/structure interactions but was applicable only to hoses made of steel.

Like the second-mentioned older model, the composite model is based partly on a spring-and-lumped-mass representation of dynamics that involve the springiness and mass of a convolution of the hose and the density of the fluid in the hose. The Laplace-transformed equations of coupled motion of the lumped masses and springs lead to the following fourth-order equation for the complex frequencies of the vibrational modes:

In this equation, s is the Laplace-transform complex frequency, K is the spring stiffness of a convolution, rf is the mass density of the fluid, A is a cross-sectional area of a convolution, C is called the "fluid capacitance" (analogous to electrical capacitance) and is a measure of the energy and momentum associated with the change in the amount of fluid in a convolution during flexing of the hose, and L is called "fluid inertance" (analogous to both inertia and electrical inductance) and is a function of the dimensions of a convolution. The solution of this equation consists of two sets of complex roots associated with two frequencies. The resonant frequencies predicted by this model are generally lower than those observed in experiments.

This work was done by Stuart A. Harvey of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information,* ***write in 101*** *on the TSP Request Card.*
MFS-29969



Vibrations in Both Stretching and Bending modes can occur when the flow of fluid in the hose interacts with the convolutions.

Fixture for Calibrating Pressure Probe

It is not necessary to remove the probe from the wind tunnel.

Langley Research Center, Hampton, Virginia

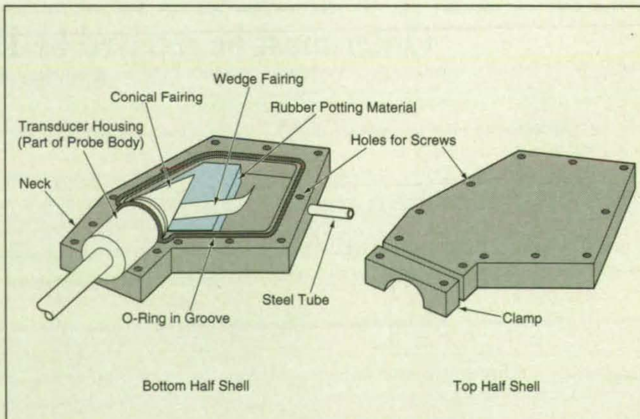
A fixture in the form of a specially designed clamshell housing enables the in situ calibration of a pressure transducer mounted in the body of a pressure probe in a wind tunnel. Without such a fixture, one would have to remove the probe from the wind tunnel to calibrate the transducer, thereby losing considerable running time.

The fixture (see figure) includes two metal half shells machined with necks and matching cavities that, when put together, define a larger neck and cavity that accommodate the probe. The half shells, along with a clamp that is essentially a sawed-off portion of the upper (in the figure) half shell, are assembled to cover the probe and are held in place by screws. The probe is secured to the bottom half shell by use of the clamp before installing the top half shell: it is necessary to follow this sequence to protect the probe during assembly.

The forward part of the probe, containing conical and wedge fairings, is supported within the cavity in a rubber potting material, which also serves to keep the probe from rotating. A continuous O-ring is formed to fit around the transducer housing and between the half shells in a groove cut around the periphery of the cavity. The O-ring seals the cavity to form an air-tight chamber around the probe and its transducer. Controlled pressure for calibration of the probe is sent into the chamber via a steel tube in the lower (in the figure) half shell.

The clamshell calibration fixture can be attached to a pressure probe in a few minutes, making it possible to calibrate the pressure transducer at convenient times. For example, calibrations can be performed before and after wind-tunnel runs each day, between runs in the event of delays or suspected malfunctions, and at essentially any other time, without having to remove the probe from the wind tunnel.

This work was done by George C. Ashby, Jr., Peter Vasquez, Lewis A. Horsley, John T. Bowman, Henry N. Zumbrun, and John W. Eves of **Langley Research Center.** *No further documentation is available.*
LAR-14660



The **Clamshell Fixture** encloses the pressure probe, making it possible to calibrate the probe *in situ.*

Improved Flat Specimens for Tensile and Fatigue Testing of Composites

A transition contour radius of 41.9 cm appears most promising.

Lewis Research Center, Cleveland, Ohio

An improved shape has been proposed for flat, reduced-gauge-section specimens for tensile and fatigue testing of advanced composite materials at ambient and high temperatures. A typical current specimen (see figure) consists of a flat bar 15.2 cm long, 1.27 cm wide, and 0.318 cm thick, with full-width tab regions at the ends, a 3.81-cm-long gauge section of reduced width (0.795 cm) in the middle, and two transition regions where the width tapers between the tab and gauge widths along a 6.35-cm-radius circular arc tangent to the edge of the gauge section. The specimen is gripped by squeezing it between tabs in the tab regions, and the tensile test load is applied via the tab grips.

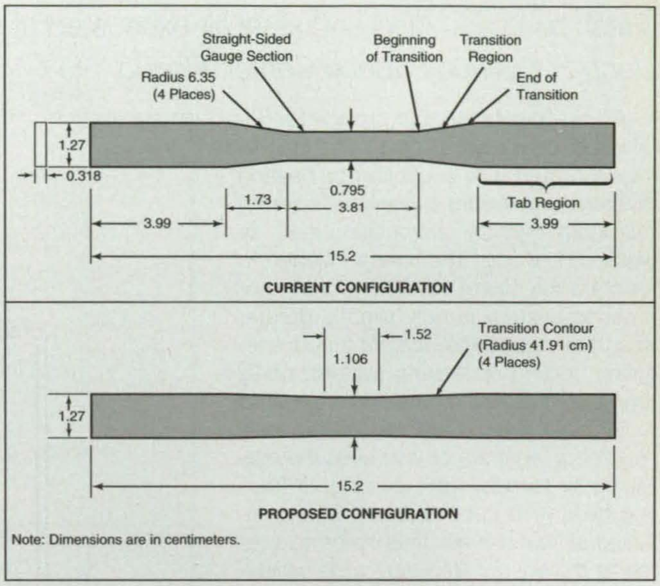
Alternative shapes of specimens have been considered during the past few years because of a need to obtain more-consistent and more-accurate results from tensile and fatigue tests of advanced composite materials. Specimens of the configuration described above are subject to concentrations and combinations of stresses that frequently lead to failures in the transition and tab regions (instead of in the gauge sections as desired). These premature failures yield low values of ultimate strength and short fatigue lives. An improved configuration would minimize concentrations of stress and local damage in a specimen, forcing tensile and fatigue failure to occur consistently in the more nearly homogeneously stressed and more nearly isothermal volume of the gauge section.

The improved shape, with a transition-contour radius of 41.91 cm and a gauge width of 1.106 cm, was chosen from among several alternative shapes in a computer simulation of stresses and strains. The simulation was based on a three-dimensional finite-element linear-elastic mathematical model of stresses and strains in homogeneous specimen and tab materials. Of the shapes analyzed, this one was found to have the lowest stresses in the transition region and the largest separation between the locations of maximum tensile and maximum shear stresses.

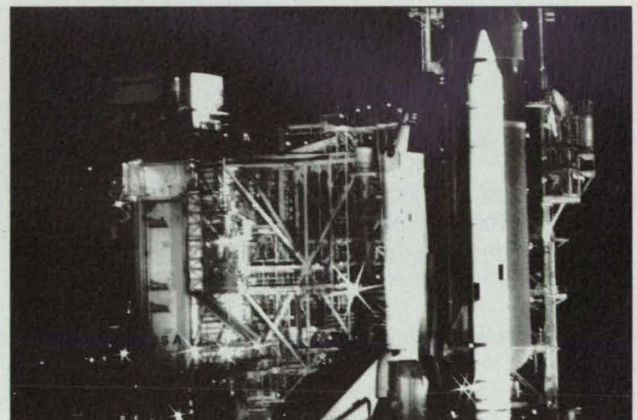
The computer simulation also led to the following conclusions, among others:

- The stresses in the transition region are relatively insensitive to the properties of the specimen materials analyzed.
- The use of the 41.91-cm-radius specimen design may require a uniform heat zone beyond the straight-sided gauge section. This would ensure failure in the uniformly heated zone by accounting for statistical variations of strength within the specimen and for differences in strength influenced by temperature.
- The material should be selected by considering the entire deformation behavior, including any nonlinearity of the tab and specimen materials as well as the machinability and the directional strength characteristics of the tab material.
- The tabs should be made as long as possible to reduce the clamping pressure and shear stress applied by the grips.

This work was done by Dennis W. Worthem of Sverdrup Technology, Inc., for **Lewis Research Center.** *For further information,* ***write in 3*** *on the TSP Request Card.*
LEW-15687



The **Proposed Tensile-Specimen Configuration** would reduce undesired concentrations of stresses in the transition and tab regions, forcing tensile failure to occur in the gauge section and thereby ensuring more-consistent results in tensile tests.

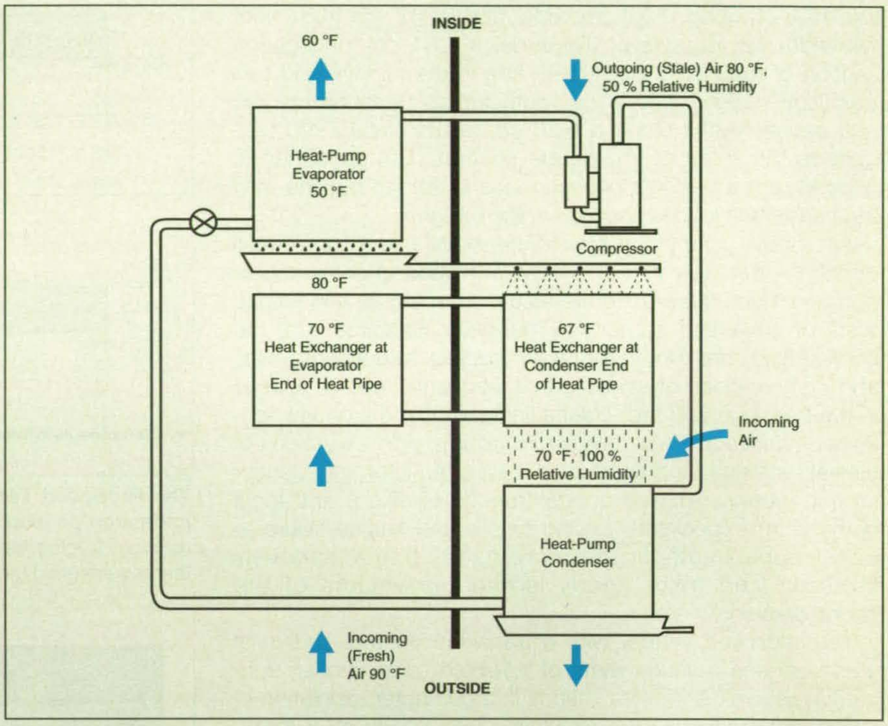


Ventilating Air-Conditioner

Fresh air is admitted and stale air exhausted at relatively low energy cost.

John F. Kennedy Space Center, Florida

An air-conditioner that provides ventilation is designed to be used alone or incorporated into a cooling or heating system that could otherwise operate efficiently only by recirculating stale air within a building. The energy needed to operate the overall ventilating cooling or heating system is only slightly greater than that needed to operate a nonventilating cooling or heating system, partly because it uses the outgoing stale air to cool the incoming fresh air (during cooling in hot weather) or else uses the outgoing air to heat the incoming air (during heating in cold weather). The ventilating air-conditioner thus helps to preserve the energy efficiency while satisfying the need for increased forced ventilation to prevent the accumulation of undesired gases like radon and formaldehyde in modern tightly sealed buildings.



On the Inlet Side, fresh incoming air passes over the evaporator end of a heat pipe, which cools it, then over the heat-pump evaporator, which cools it further and dehumidifies it. Meanwhile, on the outlet side, inside air flows over the opposite end of the heat pipe, removing heat from it, then over the heat-pump condenser, removing heat from it as well. Condensed water from the inlet air further cools the condenser end of the heat pipe. Temperatures shown are for summer conditions; in winter, the system would heat the incoming air instead of cooling it.

The figure illustrates the ventilating air-conditioner operating in the hot-weather cooling mode. One major subsystem of the ventilating air-conditioner comprises a heat pipe and the heat exchangers at its evaporator and condenser ends. This subsystem transfers heat between the incoming and outgoing airstreams and recovers about 50 percent of the energy for heating the incoming air in winter or cooling it in summer.

Another major subsystem of the ventilating air-conditioner comprises evaporator and condenser heat exchangers and a compressor. This subsystem constitutes a heat pump that recovers heat that the other subsystem cannot. This subsystem condenses moisture from the incoming air and reevaporates it into the outgoing air. In so doing, it cools the outgoing air to its wet-bulb temperature, further increasing the effectiveness of the heat-pipe subsystem.

The heat-pump subsystem is especially helpful in summer, when the difference between the heat contents of the incoming and outgoing airstreams is more latent than it is sensible. The heat pipe alone depends on the difference between the temperatures of the airstreams, which difference can be small on summer days, even though humid outdoor air can contain more heat than dry indoor air does. The combination of passive transfer of heat by the heat pipe and active assistance by the heat pump results in the transfer of the entire differential thermal energy content between the incoming and outgoing airstreams; that is, there is a neutral thermal balance between the streams.

The ventilating air-conditioner can provide fresh treated air to a variety of confined spaces: hospital surgeries, laboratories, clean rooms, and printing shops and other places where solvents are used, for example. In mobile homes and portable classrooms, the ventilating air-conditioner can eliminate irritant chemicals (and their smells) exuded by carpets, panels, and other materials, ensuring a healthy indoor environment for the occupants — without consuming excess energy.

This work was done by Khanh Dinh of Heat Pipe Technology, Inc., for **Kennedy Space Center**. *For further information,* ***write in 161*** *on the TSP Request Card.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention (U.S. Patent No. 4,938,135). Inquiries concerning rights for its commercial use should be addressed to

Khanh Dinh
Heat Pipe Technology, Inc.
P.O. Box 999
803 NE 1st Street
Alachua, FL 32615

Refer to KSC-11619, volume and number of this NASA Tech Briefs *issue, and the page number.*

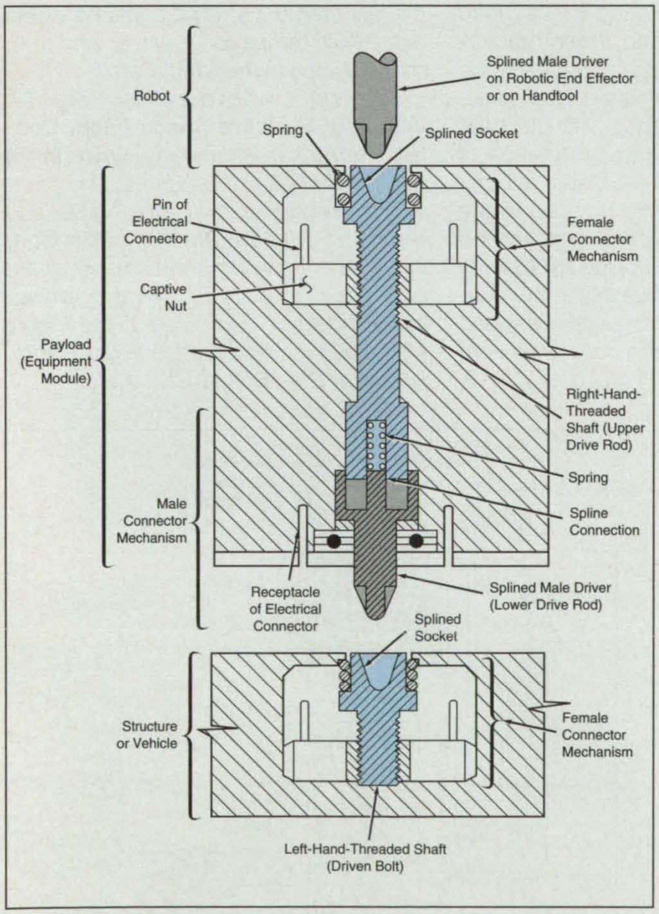
Spline-Screw Payload-Fastening System

A payload is handed off securely between a robot and a vehicle or structure.

Goddard Space Flight Center, Greenbelt, Maryland

The figure presents a simplified cross-sectional side view of a payload-fastening system that effects secure handoff of a payload or other equipment module between (1) a robot that installs or removes the module and (2) the vehicle or structure on which the module is to be installed or from which it is to be removed. The system was designed for use in outer space but may also be useful on Earth in applications in which there is a need for secure handling and secure mounting of equipment modules during storage, transport, and/or operation. It is particularly useful in machine or robotic applications because it cannot be cross-threaded.

The payload-fastening system includes mechanisms like those described in "Tool-Changing Mechanism for Robot" (GSC-13435), NASA Tech Briefs, Vol. 18, No. 2 (February 1994), page 84; and "Self-Aligning Mechanical and Electrical Coupling" (GSC-13430), NASA Tech Briefs, Vol. 17, No. 3 (March 1993), page 92. Of particular importance are the mating female and male connector mechanisms. These mechanisms constitute partly self-aligning docking/undocking subsystems that can provide soft and hard docking and undocking and electrical connection/disconnection between the structures and/or modules in which these mechanisms are mounted.



The **Spline-Screw Payload-Fastening System** includes mating female and male connector mechanisms. Clockwise (or counterclockwise) rotation of the splined male driver on the robotic end effector causes the connection between the robot and payload to tighten (or loosen, respectively) and simultaneously causes the connection between the payload and the structure to loosen (or tighten, respectively).

To recapitulate from the noted prior articles: the rotary splined male driver of each male connector mechanism fits in a splined socket in a threaded shaft in its mating female connector mechanism. Depending on the direction of rotation of the male driver and the sense of the threads, the mechanical connection between the male and female connector mechanisms is tightened or loosened. Simultaneously, the rotation of the threaded shaft causes a captive nut in the female connector mechanism to move up (during tightening) or down (during loosening) so that electrical connector pins mounted on the captive nut move into (or out of) contact with mating receptacles in the male connector mechanism. The male and female connector mechanisms include springs that set various preloads during the soft and hard phases of docking and undocking.

In the secure-handoff scheme of this payload-fastening system, the payload is always attached securely to the robot, to both the robot and the structure, or to the structure only. The male connector mechanism on the robotic end effector and the mating female connector mechanism in the payload are designed so that clockwise (or counterclockwise) rotation of the splined male driver on the robotic end effector tightens (or loosens, respectively) the mechanical and electrical connection between them.

The right-hand-threaded shaft in the female connector

mechanism in the payload drives the splined male driver that protrudes from the male connector mechanism at the bottom of the payload, and this driver, in turn, actuates the left-hand-threaded shaft in the female connector mechanism in the structure. Because of the opposite threading and other details of the mating connector mechanisms in the payload and the structure, the same clockwise (or counterclockwise) rotation that tightens (or loosens, respectively) the mechanical and electrical connections between the robot and the payload loosens (or tightens, respectively) the connections between the payload and the structure. At an intermediate point in the overall range of rotation, the payload is connected securely to both the robot and the structure.

This work was done by John M. Vranish of **Goddard Space Flight Center.** *For further information,* ***write in 126*** *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 20]. Refer to GSC-13454.

Spline-Screw Multiple-Rotation Mechanism

This mechanism functions like a combined robotic gripper and nut runner.

Goddard Space Flight Center, Greenbelt, Maryland

The spline-screw multiple-rotation mechanism is related to the spline-screw payload-fastening system described in the accompanying article (GSC-13454), and can be incorporated as a subsystem in an alternative version of the system. This mechanism functions somewhat like a combination of a robotic gripper and a nut runner; it provides both a secure grip and rotary actuation of other parts of the system.

The figure shows a version of this mechanism that can be used in a system in which there is no need to make or break electrical connections to the payload during robotic installation or removal of the payload. (A more complicated version would be needed to make and break electrical connections, but this simpler version suffices to illustrate the basic principle of operation.) This mechanism is mounted in the payload.

Suppose that the payload is initially fastened to the structure (not shown) and that the robot has been moved into soft dock in the payload. The splined driver (part of the end effector of the robot) is rotated clockwise, causing the bolt to turn clockwise and move downward via right-handed-thread engagement with the torque gear. Continuation of this motion removes the initial clearance between the mating tension-transmitting surfaces of the splined driver and the splined receptacle in the bolthead, so that the robot and payload go into hard dock, with spring preload transmitted as tension in the bolt and splined driver.

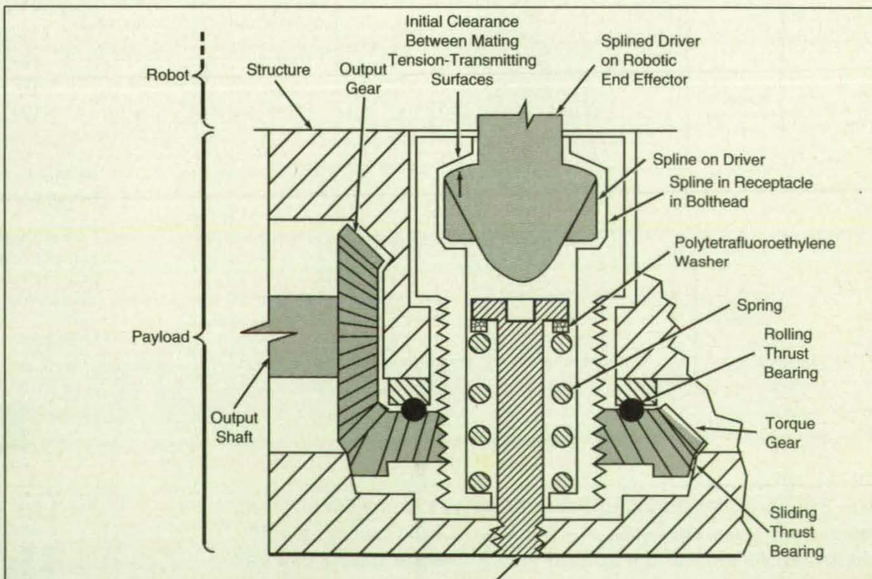
The bolt cannot translate downward further; instead, continued clockwise rotation of the driver and bolt causes the torque gear to translate upward until its upward motion is stopped by the rolling thrust bearing and it engages the output gear. Further clockwise rotation builds up friction resulting in forces and torques in the thread engagement, so that torque is transmitted from the driver, through the threads, through the engaged gears to the output shaft. The output shaft can thus be rotated continuously until and unless it is restrained.

Suppose that the output shaft is connected to other, partly similar mechanisms (not shown) that attach the payload to, or detach it from, a structure. Further clockwise rotation would actuate those mechanisms to disengage the payload from the structure, and those mechanisms would impose a hard stop on the output shaft at the moment of disengagement. Once the output shaft is thus restrained, further clockwise rotation of the driver would cause the bolt to attempt to translate downward, increasing the tension beyond the spring preload and applying some of the gripping force to the payload via the thrust bearing. In this condition, the robot would grip the payload firmly, and can pull the payload away from the structure.

Of course, the sequence of motions can be reversed to attach the payload to the structure, then detach it from the robot. During the detachment sequence, the counterclockwise motion of the driver takes the system through stages in which at first the payload is connected securely to the robot only, then to the robot and structure, then to the structure only. After the last stage, the robot could be pulled away from the payload, which would remain secured to the structure.

This work was done by John M. Vranish of **Goddard Space Flight Center.** *For further information,* ***write in 74*** *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 20]. Refer to GSC-13452.



The **Spline-Screw Multiple-Rotation Mechanism** can be part of a modified version of the spline-screw payload-fastening mechanism described in the accompanying article.

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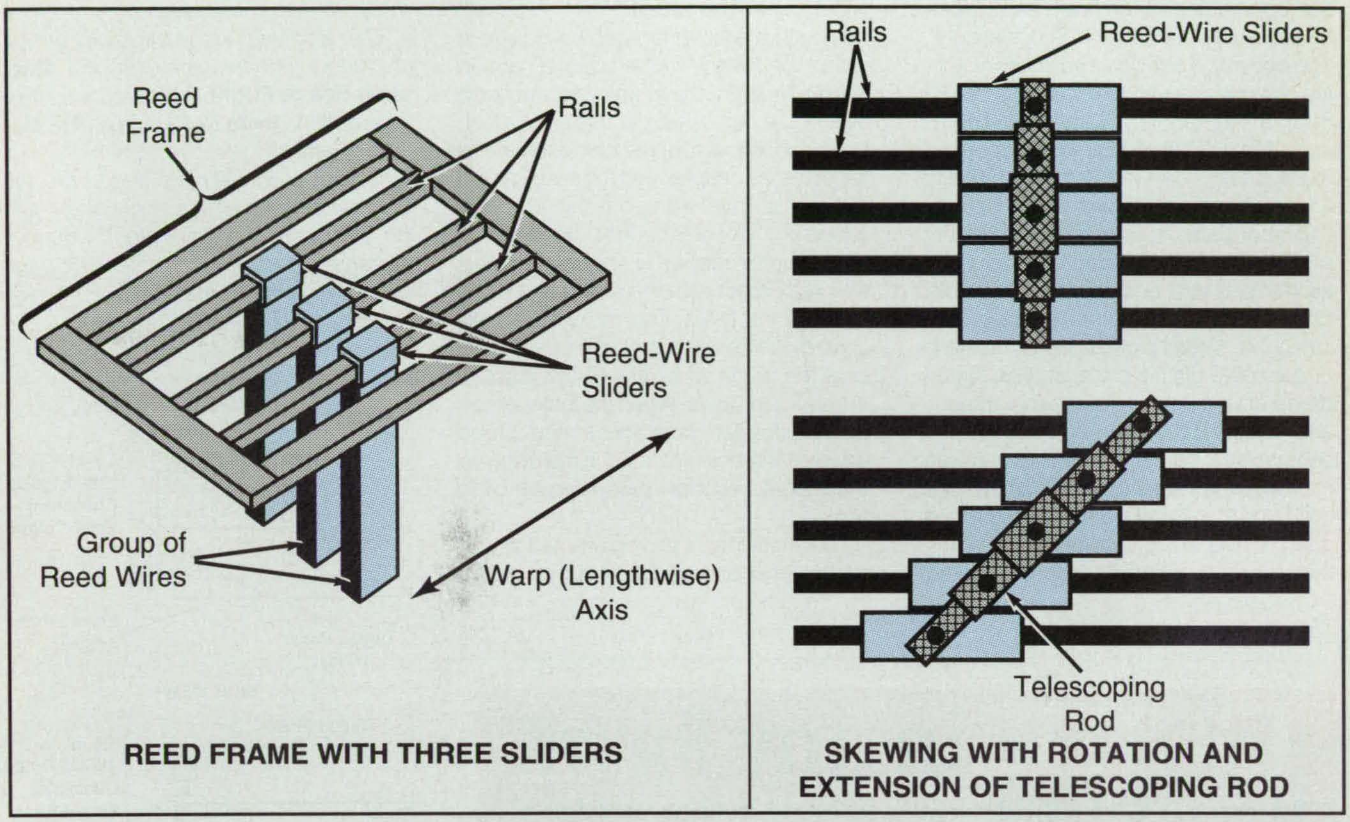
Adjustable Reeds for Weaving

Local characteristics of fabrics would be varied to suit special applications.

Langley Research Center, Hampton, Virginia



Selected Aspects of the Adjustable-Reed Machinery concept are shown here in greatly simplified schematic form. Many more reed wires and sliders, plus mechanisms to move them, would be included in a practical version.

Adjustable reed machinery has been proposed for use in weaving fabrics in various net shapes, widths, yarn spacings, and yarn angles. By use of this machinery, the locations of the edges of a fabric and the configuration of warp (lengthwise) and filling (crosswise) yarns could be varied along the fabric to obtain specified properties. Such a specially designed fabric might be needed, for example, as the fiber reinforcement in a highly stressed matrix/fiber composite-material structural component.

"Reed" in weaving denotes a movable, comblike device that holds the warp yarns apart in the desired lateral spacing and "beats up" each filling yarn into place in the fabric; that is, the reed pushes each new filling yarn against the last previously woven filling yarn. Heretofore, reeds have been made in various fixed geometries or with limited capability for adjustment. The proposed machinery would offer an expanded capability of adjustment that would provide for gradual or abrupt variation of the geometric relationships among the yarns, as needed, during the weaving process.

The parts that are inserted between the warp yarns are called "reed wires" (although they are not wires and are more like a group of long rectangular plates wherein the warp yarns slide between the plates). In the proposed machinery, reed wires would be mounted in groups on sliders, which in turn would be mounted on lengthwise rails in a reed frame (see figure). Mechanisms would be incorporated to (1) move the sliders lengthwise, parallel to the warp yarns, by sliding them along the rails, (2) move the sliders crosswise by translating the reed frame rails perpendicular to the warp yarns, and (3) crosswise by spreading the reed rails within a group. The profile of the reed wires in a group on each slider can be changed. Changing the profile of the reed wires alters the angle between the warp and fill yarns. A rotary actuator with a telescoping shaft attached to all the sliders in a group skews the sliders as shown at the bottom right of the figure.

The crosswise spreading of the reed rails would be accomplished by a pair of scissorlike motor-driven mechanisms (not shown in the figure) connected to the parts of the reed frame that support the rails. The entire reed frame would be translated by a rack-gear mechanism. Beatup of the fill yarns could be accomplished by the traditional method in which the entire reed frame is moved; alternatively, the reed frame could be held fixed and sliders could be moved lengthwise individually to push the yarns into place. In some cases, a combination of the two methods might be used.

This work was done by Gary L. Farley of the U.S. Army Vehicle Structures Directorate for **Langley Research Center.** *For further information,* ***write in 98*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Langley Research Center [see page 24]. Refer to LAR-15072.

Apparatus for Eddy-Current Inspection of Bolts

Threads, shanks, and fillets can be inspected for small flaws.

Marshall Space Flight Center, Alabama

An eddy-current apparatus for the inspection of bolts, studs, and other threaded fasteners detects flaws in threads, shanks, and head fillets. With the help of this apparatus, a technician can quickly inspect fasteners of various dimensions. The apparatus can accommodate fasteners with diameters from 0.190 in. (about 4.83 mm) to 1 in. (25.4 mm) and with lengths up to 5 in. (127 mm). The basic design of the apparatus can readily be modified to accommodate fasteners of other sizes.

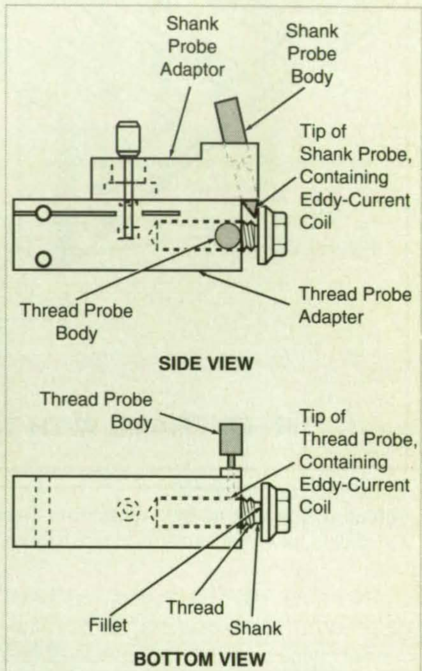
The apparatus includes eddy-current probes in two probe adapters specific to each thread size, and an inspection table. One of the adapters for each thread size, called the "thread probe adapter," is made of a durable plastic material. The thread probe adapter contains internal threads and holds a side-mounted eddy-current sensor (see figure). As a motor-driven chuck on the inspection table screws the bolt to be inspected into the thread probe adapter, the eddy-current probe in the thread probe adapter scans the thread, including the thread root, which is the most critical region. In tests, the apparatus detected artificial flaws as small as 0.015 in. (0.38 mm) by 0.030 in. (0.76 mm) in the root of a bolt.

The other adapter for each thread size is called the "shank probe adapter" and is used to inspect the shank and the head fillet of the bolt. After the thread of a bolt has been inspected, the bolt is left in the thread probe adapter, and the shank probe adapter is attached to the thread probe adapter. The eddy-current probe in the shank probe adapter is spring-loaded to ensure contact with the shank at a point close to the head. The fastener is then unscrewed from the thread probe adapter as the shank eddy-current probe scans the shank for flaws. When the fastener has been extracted from the thread probe adapter, the bolt is rotated in the open so that the eddy-current probe can scan the fillet.

The chuck motor is programmed to turn the fastener at a constant speed based on the fastener serial number and the area to be scanned, both of which are keyed into the system by the operator. The adapters are mounted on a free ball slide, collinear with the chuck axis.

This work was done by Jay M. Amos of United Technologies Corp. for **Marshall Space Flight Center**. *For further information,* ***write in 93*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 24]. Refer to MFS-28900.



Adapters Hold Eddy-Current Probes that scan selected surface regions of a fastener. The thread probe adapter is used to inspect the thread. The shank probe adapter, which is mounted on the thread probe adapter, is used to inspect the shank and the head fillet.

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Furnace Tubes for Depositing Parylene-N™ on HgI_2 Crystals

Molecules acquire greater kinetic energy on zigzag paths.

NASA's Jet Propulsion Laboratory, Pasadena, California

The shapes of quartz pyrolysis tubes used to deposit Parylene-N on HgI_2 crystals have been modified to improve the quality of the coating. (In this application, the HgI_2 crystals are intended for use as x-ray detectors and must be coated for protection against moisture and other contaminants.)

The parylenes are thermoplastic polymers derived from paraxylene; they are used to make pore-free coatings and thin dielectric films in capacitors. Parylene-N is a commercial parylene, the deposition of which involves cracking of a parylene dimer by heating it in a pyrolysis tube to obtain the parylene monomer.

To improve the quality of the polymeric Parylene-N deposit, it is necessary to crack the dimer more nearly completely and to give greater kinetic energy to the dimer molecules. This can be done by increasing the pyrolysis temperature and adding some barriers or baffles to the path taken by the dimer as it travels through the pyrolysis tube so that dimer molecules have greater probability of striking the hot tube surfaces and acquiring greater kinetic energy. In addition, the longer path taken by the dimer in passing by the baffles increases the time spent in the high-temperature region, thereby increasing the degree of cracking even more.

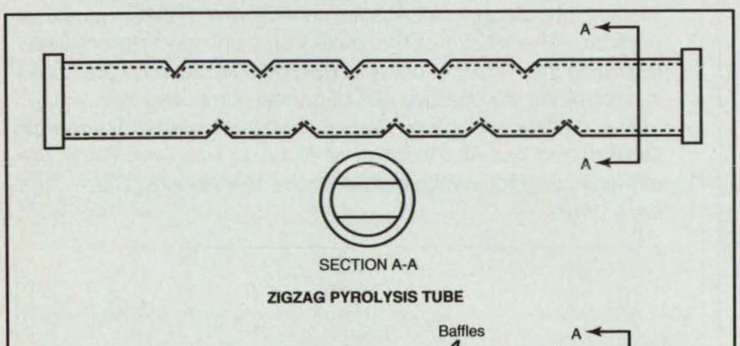
The figure illustrates two pyrolysis tubes that were tested as replacements for the original pyrolysis tubes, which did not contain baffles. The use of the zigzag tube, along with the higher processing temperature, resulted in a coating of better quality, including greater transparency and more uniformity of appearance. The second tube contained baffles arranged at various angles about its axis so that there was no direct path from the inlet to the outlet and molecules were forced to bounce from baffle to baffle on the way through. The parylene coatings formed on HgI_2 crystals with this tube were very clear and transparent; they were also free of pinholes, as shown by an absence of etching of the coated HgI_2 crystals during immersion in an aqueous solution of KI.

This work was done by Jan S. Iwanczyk and Yuzhong J. Wang of Xsirius, Inc., for **NASA's Jet Propulsion Laboratory.** *No further documentation is available.*

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

Dr. Yuzhong J. Wang
Xsirius, Inc.
Marina Towers North
4640 Admiralty Way, Suite 214
Marina Del Rey, CA 90292

Refer to NPO-18949, volume and number of this NASA Tech Briefs *issue, and the page number.*



Zigzag Paths in modified pyrolysis tubes result in improved deposits of parylene polymers.

Graph-Based Dynamic Assignment of Multiple Processors

Time needed to execute an application algorithm is minimized, subject to a set of rules.

Langley Research Center, Hampton, Virginia

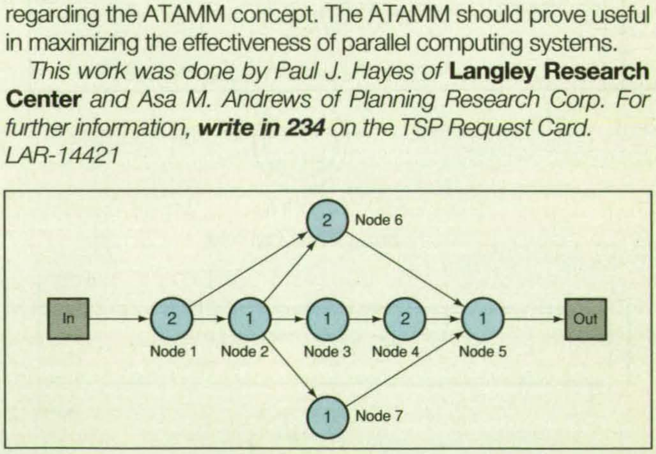
The algorithm-to-architecture mapping model (ATAMM) is a strategy that minimizes the time needed to periodically execute a graphically described, data-driven application algorithm on multiple data processors. "Graphically described" as used here means that (1) the application algorithm is divided into blocks represented as nodes of a graph, (2) the computer code that implements each block is executed on a single processor, and (3) the flow of data between blocks of the application algorithm (and between corresponding processors) is represented by arcs drawn between corresponding nodes of the graph (see figure).

The ATAMM can be implemented as an operating system that manages the flow of data and dynamically assigns nodes of the graph to processors. It also predicts throughput versus the number of processors available to execute a given application algorithm. The ATAMM includes rules that ensure that the application algorithm represented by the graph will be executed periodically without deadlock and in the shortest possible repetition time.

All of the processors are assumed to be identical, to be interconnected on a bus, and to contain identical codes, so that each processor can execute any node of the graph. Each node of the graph is assigned to a processor that is available and idle at the time data are available for execution of the node: This approach provides for graceful degradation of the computing system when processors fail, and eliminates the need for reconfiguration.

The performance of the ATAMM in the case of a 7-node graph like the one in the figure was tested in a simulation by use of the Architecture Design and Assessment System (ADAS) computer program. The results of the simulation confirmed expectations regarding the ATAMM concept. The ATAMM should prove useful in maximizing the effectiveness of parallel computing systems.

This work was done by Paul J. Hayes of **Langley Research Center** *and Asa M. Andrews of Planning Research Corp. For further information,* ***write in 234*** *on the TSP Request Card.*
LAR-14421



Blocks of Computer Code executed on individual processors are represented as nodes of the graph, while the arcs of the graph represent flows of data. The ATAMM places available processors at the nodes, according to need and availability, subject to rules that minimize execution time and prevent deadlock.

Root-Contact/Pressure-Plate Assembly for Hydroponic System

The assembly applies pressure to stimulate growth while moving to accommodate growth.

John F. Kennedy Space Center, Florida

Figure 1 illustrates a hydroponic system for growing sweetpotatoes and possibly other tuber and root crops. The design of the growth channels in this system exploits the discovery that the storage roots of sweetpotato plants grow faster and larger when stimulated by contact pressure: the growth channels are equipped with root-contact/pressure-plate assemblies that apply gentle pressure to the roots to stimulate growth while moving to accommodate the growth.

Figure 2 shows one of the channels in more detail. The root-contact/pressure-plate assembly includes a rigid flat plate suspended loosely in the channel by thin, flexible vinyl sheets, which are opaque to prevent light from stimulating the growth of algae in the nutrient liquid at the bottom of the channel. The stems of the growing plants pass through holes in the flat plate, so that their roots will be below the flat plate in the nutrient liquid and the foliage above. The plate provides support for the stem and the foliage. For vining plants like sweetpotato, strings can be vertically attached and tied from above for additional support.

The upper edges of the vinyl sheets are secured to the tops of the side walls of the channel by frictional connectors. The lower edges of the vinyl sheets are secured to opposite edges of the flat plate by two plate connectors, which thereby become extensions of the plate. The combined weight of the flat plate, plate connectors, vinyl sheets, and foliage supported by the plate press down on the roots below. Thus, the roots are stimulated by the pressure of contact with the flat plate and plate connectors and with the bottom of the channel; when the roots grow into contact with the sides of the channel, they receive additional stimulation from there.

As the roots grow, they lift the flat plate and plate connectors. This continued lifting slackens the vinyl sheets. To take up some or all of the slack, the sheets can be pulled over the tops of the channel side walls and secured there by the friction fit of connectors.

This work was done by Carlton E. Morris, Philip A. Loretan, Conrad K. Bonsi, and Walter A. Hill of Tuskegee University for **Kennedy Space Center**. *For further information,* ***write in 89*** *on the TSP Request Card.*

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

Dr. Philip A. Loretan
Tuskegee University
School of Agriculture and Home Economics
Experiment Station
Farm Mechanization Building
Tuskegee, Alabama 36083

Refer to KSC-11603, volume and number of this NASA Tech Briefs *issue, and the page number.*

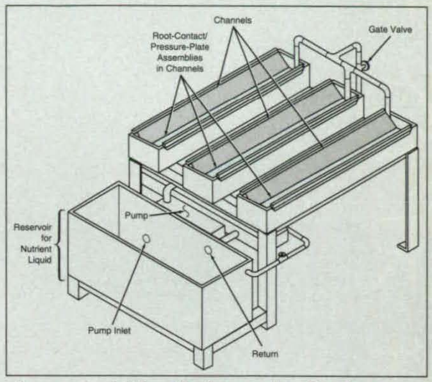


Figure 1. **This Hydroponic System** includes growth channels equipped with rootcontact/pressure-plate assemblies. The pump and associated plumbing circulate the nutrient liquid from the reservoir, along the bottom of the growth channels, and back to the reservoir.

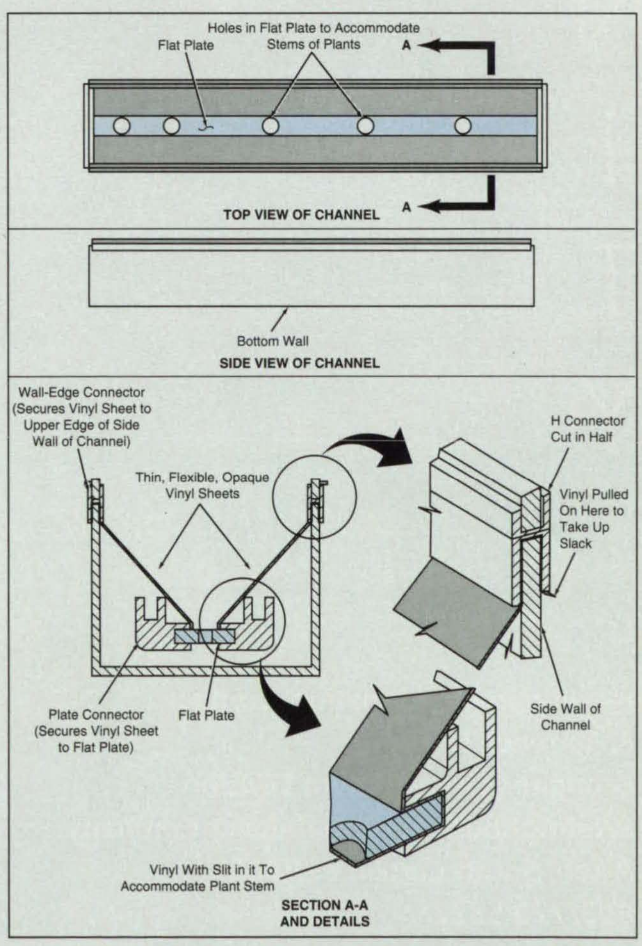


Figure 2. The **Root-Contact/Pressure-Plate Assembly** in each growth channel stimulates the growth of sweetpotato storage roots by applying mild contact pressure. The flat plate and plate connectors, which together constitute the pressure plate, are free to move upward to accommodate the growth of the roots.

Books & Reports

These reports, studies, and handbooks are available from NASA as Technical Support Packages (TSPs) when a Request Card number is cited; otherwise they are available from the NASA Center for Aerospace Information.

Machinery

Improved Composite Fabrication Process Minimizes Damage to Fibers

A document describes an improved process for making fiber/matrix composite materials — especially SiC-fiber/metal-matrix materials that would fail gradually when overstressed, instead of failing suddenly and catastrophically as do many fiber/matrix composite materials. The gradual-failure characteristic is imparted by coating the fibers with a relatively soft material (e.g., Nb or Cu) that yields in compliance with deformations of the matrix.

This work was done by Don Petrasek, Len Westfall, and Steve Arnold of **Lewis Research Center** *and Richard Krutenat and William Glenn of Textron Specialty Materials. To obtain a copy of the document "Fiber Reinforced Composite, Composite Preform and Method of Manufacturing Fiber Reinforced Composite,"* ***write in 241*** *on the TSP Request Card.*
LEW-15620

Physical Sciences

Study of Heating of the Base Region of a Rocket

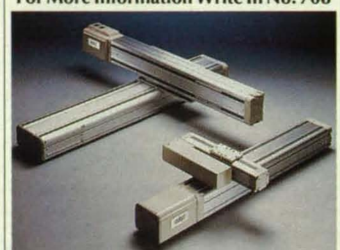
A report describes a theoretical study of heating in the base region of a proposed rocket called the "NLS 1.5 stage reference vehicle." The study was prompted by concern that some surfaces in the base region (the region in and near the engine) may be subject to excessive heating caused by recirculation and combustion of fuel rich exhaust gases, the flows of which were poorly understood. Previous studies of this type had involved empirically developed heat-transfer correlations that were valid within only limited ranges of geometries and flow conditions. This study employed a more sophisticated approach based on computational fluid dynamics (CFD). The study involved numerical simulations of the flow field in the base region and in the main exhaust plume of a cluster of six engines with heat shields.

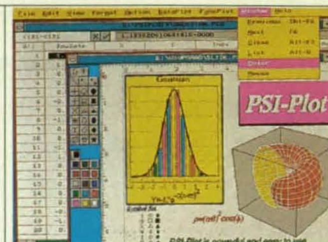
This work was done by Edward P. Ascoli, Adel A. Heiba, Yann-Fu Hsu, Ronald R. Lagnado, Edward D. Lynch, and Ronald J. Ungewitter of Rockwell International Corp. for **Marshall Space Flight Center**. *To obtain a copy of the report, "CFD Base Heating Analysis of the NLS 1.5 Stage Reference Vehicle,"* ***write in 250*** *on the TSP Request Card.*
MFS-29973

New on the Market

The PCM-UIO48, a PC/104 bus universal 48-point **digital I/O interface** from WinSystems, Arlington, TX, features an interruptible event sense that improves system performance for real-time monitoring and control. The card monitors rising and falling digital edge transitions, latches them, and signals the host processor of a change in input, enabling the card to sense event-related inputs without polling its input status channel by channel.
For More Information Write In No. 707

Adept Technology Inc., San Jose, CA, has unveiled the Adept Molecules™ **cartesian-style robot**, a modular, scalable complement to the company's robot family, with 15 standard configurations. The modules can serve as add-ons to Adept's robot, motion control, or vision systems using its integrated VME control platform or in stand-alone mode.
For More Information Write In No. 708





Version 3.0 of PSI-Plot **technical plotting and data processing software** from Poly Software International, Salt Lake City, UT, offers ordinary differential equation solvers, customized desktop color control, on-screen rulers, and EMS and XMS usage control. Its data sheet performs statistical analysis, data transformation, digital signal processing, nonlinear parameter fitting, and model development.
For More Information Write In No. 702

Teknor Microsystems Inc., Montreal, Quebec, has introduced the VIPer-804, a 386SX/486SLC half-size PC/AT industrial **single-board computer** designed to form the base for various compact and rugged embedded systems. Through the modularity of PC/104 compatible cards, OEMs can integrate fax/modems, PCMCIA, and GPS cards.
For More Information Write In No. 706

A **global positioning system (GPS) video-based mapping system** for condition surveys from Infrared Technologies Corp., Columbia, MD, combines GPS satellite data, GIS, digital mapping, video, and audio on one platform. The portable system includes a DX4 75-Hz laptop with an 8.4" active matrix color display, a 340 MB hard drive, a Toshiba 2X CD-ROM, a 6-channel GPS receiver, aviation mapping software, a terrain map, and a high-resolution, infrared CCD camera.
For More Information Write In No. 712

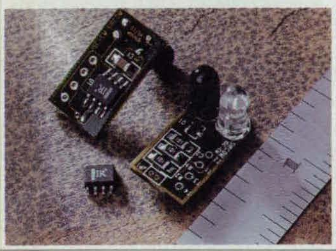
TeleRobotics Inc., Knoxville, TN, has unveiled Omniview™, a **digital video imaging system** that pans, tilts, magnifies, and rotates a video image with no pointing mechanism. Producing a real-time display from anywhere in a wide-angle field-of-view eliminates the need for conventional pan-and-tilt mechanisms in remote viewing applications. The system produces up to four independent views and can be installed with existing video cameras.
For More Information Write In No. 703

The Digi-Field, a **digital field-strength meter** from IC Engineering, Encino, CA, features a frequency response of DC to 12 GHz for use in preliminary susceptibility compliance measurements. The compact Model C combines the sensitivities of existing models A (150 nanowatts at 100 MHz) and B (2 nanowatts). All models feature a 3½-digit display.
For More Information Write In No. 713

New on the Market

Engineering samples of the new SIRComm™ **infrared wireless communications integrated circuit chip** are available from Irvine Sensors Corp., Costa Mesa, CA. The chip permits mobile units such as notebook computers and cellular phones to communicate with modems, printers, or other stationary peripherals by using IR signals rather than cables or radio transmissions. The circuitry's low-power operation (15 μA, at either 3 or 5 V) offers a 115.2 kbaud data rate, 8-12 times faster than current high-speed PC modems.

For More Information Write In No. 705

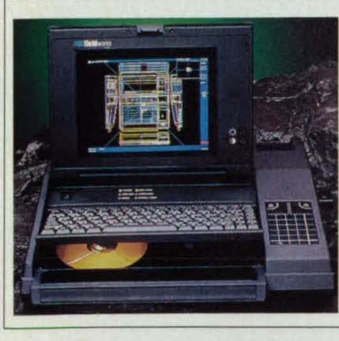


Knowledge Revolution, San Mateo, CA, has released a Microsoft Windows™ version of its Working Model™ **motion simulation software**—a cross platform, desktop engineering solution for motion analysis. Users can create mechanical systems on a computer screen by graphically building objects or importing them from a CAD program. The software assigns objects physical properties such as mass, friction, and elasticity, then the dynamic simulation engine mathematically calculates the accurate motion of the objects and displays their movement in smooth animation.

For More Information Write In No. 700

The M-Vision 100 high-performance **frame grabber** for the PCI bus from MuTech Corp., Woburn, MA, is a gray-scale imaging system that supports variable rate RS-170/CCIR cameras and digital cameras with either 8-bit or 10-bit pixel resolution. An on-board video multiplexer can switch between up to four video sources, while its dual-ported onboard memory can be read by the host CPU at rates up to 50 MB/sec.

For More Information Write In No. 701



Integrated Systems Inc., Santa Clara, CA, has released the MATRIX$_x$ family of **visual design and development tools** for PC users, including: Xmath™ for object-oriented analysis and visualization; SystemBuild™, a modeling/simulation environment; and the AutoCode® and Document-It™ automatic code generators. They enable engineers to design, test, and modify models seamlessly throughout the design cycle.

For More Information Write In No. 709

Edge Industries Inc., Laurel, MD, has announced the Model 8100 PocketDSP™, a hand-held **digital signal processing unit** for collecting and processing analog and digital signals in lab or field operations. The device offers two analog input and two output channels with a sampling rate up to 48 kHz. A serial digital I/O port operates in either asynchronous or synchronous mode with programmable transfer rates in TTL or RS-232 format.

For More Information Write In No. 711

The versatile NanoScope® Dimension™ 3000 **atomic force microscope** from Digital Instruments, Santa Barbara, CA, permits analysis of samples up to 8" in diameter, in air or liquid, and with manual and automated stepping for scanning multiple areas completely unattended. The Trak-Scan™ laser tracking system monitors the scanning probe tip to eliminate artifactual image bow.

For More Information Write In No. 710

Fieldworks Inc., Eden Prairie, MN, has introduced its first ruggedized **portable workstation with an integrated internal double-speed CD-ROM drive**. The FW7500 Field WorkStation CD-ROM platform contains a proprietary card-cage technology that allows the user to plug six half-size, three full-size, or a combination of IBM ISA-compatible expansion cards in a package 9.5 cm in height and weighing 6.3 kg.

For More Information Write In No. 704

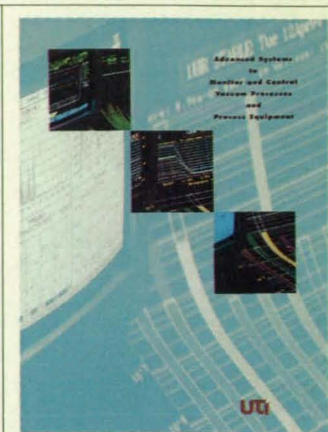
New Literature

A 128-page catalog from Galil Motion Control Inc., Sunnyvale, CA, showcases precision **motion controllers** including PC, VME, and STD bus cards and industrial package controllers with RS-232/RS-422. Also described are software tools such as a dynamic link library for Windows, DDE server, VBX custom controls for Visual Basic, and software for automatically tuning and translating AutoCAD, G-code, or HPFL files into motion.
For More Information Write In No. 723

Dianachart Inc., Rockaway, NJ, has announced *How to Measure in Lab and Industry*, a 74-page booklet that presents **data acquisition hardware for PCs** and explains how to specify systems for particular applications. Topics include connecting thermocouples, RTDs, thermistors, strain gages, and pressure transducers. Systems are described for portable measurement, data acquisition workstations, and NEMA industrial, rackmount, and high-speed systems.
For More Information Write In No. 724

APD Cryogenics Inc., Allentown, PA, has assembled the most widely used **cryogenic data** onto an easy-to-use wall poster. Eliminating the need for multiple reference books, the poster includes charts on the thermal conductivity of common solids, mean linear thermal expansions, specific heat of solids, cryogenic liquid properties at the normal boiling point, and vapor pressures of cryoliquids.
For More Information Write In No. 717

The industry's first **sealless rotary pump standard** has been published by the Hydraulic Institute, Parsippany, NJ. Approved by the American National Standards Institute, the new standard provides information on magnetic drive and canned motor rotary pumps; a description of pump types, nomenclature and definition of parts and terms; and design requirements for key components.
For More Information Write In No. 715



UTI Instruments Co., San Jose, CA, has released a brochure highlighting its **residual and process gas analysis instruments** for vacuum system maintenance, process monitoring and control, and laboratory analysis. Products include DetecTorr I and II, residual gas analyzers for system characterization at base pressure and equipment, process, and contamination monitoring.
For More Information Write In No. 722

Blue Earth Research, Mankato, MN, has published a catalog of its **microcontrollers**, accessories, and development software. The 24-page brochure highlights the Micro-440e programmable microcontroller featuring an advanced 8051-family CPU, 32k EPROM, 32k RAM, real-time clock/calendar, and 8-bit A/D. Also described is the Xplor series of personal digital controllers.
For More Information Write In No. 718

Expert systems, fuzzy logic, and neural networks—all forms of artificial intelligence that can be used for information acquisition and management—are the focus of *Better Products-Faster*, a new book from Irwin Professional Publishing, Burr Ridge, IL. Written by William H. VerDuin, it focuses on ways to integrate AI with a company's existing manufacturing and design systems.
For More Information Write In No. 726

New Literature

An engineering catalog from PCD Inc., Peabody, MA, provides technical detail and specifications for its expanded line of **interconnect products for electrical, industrial, and machine control applications**. Enhancements to the ELF family of .200"/5.0 mm spacing pluggable terminal blocks and headers include selectively gold-plated contacts and integrally molded locking ears.
For More Information Write In No. 720

The first edition of the *Advanced Engineered Materials Research Profile Directory* has been announced by Synergistic Technologies Inc., Research Triangle Park, NC, in conjunction with the Materials Research Society. The directory provides information on more than 1600 researchers actively involved in **materials research** in North American universities and laboratories. Descriptions of research efforts, available resources, and technologies ready for development are included.
For More Information Write In No. 719

A 16-page brochure from Materials Research Corp., Orangeburg, NY, describes the company's products and support for all **metal deposition** applications in semiconductor manufacturing and a variety of **thin-film deposition** applications in the data storage industry. Sections specify optimum solutions for major thin-film application areas such as sub-half-micron CVD and PVD, advanced rapid thermal processing, and submicron metal deposition.
For More Information Write In No. 721

VAT Inc., Woburn, MA, has released a design manual to assist in specification of **vacuum welded bellows** suited to pressures from atmosphere to UHV, which are not readily available as catalog items. The 28-page guide helps define materials, extended and compressed lengths, styles, special bends, end pieces, leak rates, operating temperatures, and required cycle life.
For More Information Write In No. 716

A 1300-page catalog of **industrial equipment and supplies** from DoALL Company, Des Plaines, IL, lists 48,000 products from more than 200 manufacturers. Offerings include blades, cutting tools, abrasives, measuring instruments, machine tool accessories, industrial supplies, safety equipment, cutting fluids, and chemical specialties.
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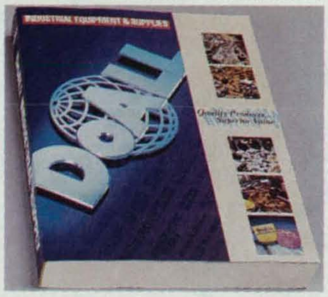
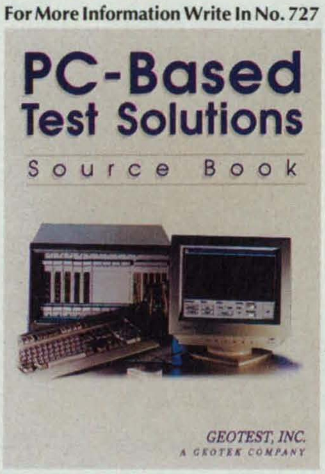


Plastics Design Library, Morris, NY, has published *The Effect of UV Light and Weather on Plastics and Elastomers*, which describes how UV radiation and other weather components (ozone attack, thermal air and water aging, microbiologic attack) affect **plastic materials**. More than 80 families of plastics are covered, including thermoplastics, thermosets, elastomers, and alloys. Exposure data addresses changes in strength, elongation, yellowness, ΔE color, hardness, appearance, modulus, and optical properties.
For More Information Write In No. 725

A 40-page **PC-based test solutions** source book from Geotest Inc., Irvine, CA, describes the company's hardware, software, and system products for PC-based ATI, data acquisition, and test and measurement applications. Highlighted software products include ATEasy®, a Windows-based ATE development environment with built-in drive editors for VXI, GPIB, RS-232, and PC-based instruments.
For More Information Write In No. 727



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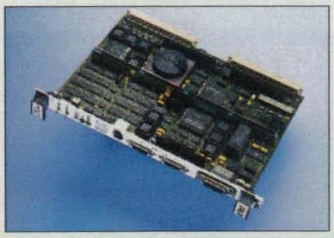

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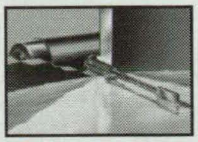

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Errata

In the "Technology Leaders" section of the September 1994 issue, under the subhead "Astro-Med, Inc." on p. 135, the sentence beginning "One specialty printer, the Tough Printer" should read, "One specialty printer, the Tough Writer." On p. 148, under the subhead "MGS Software," the sentence beginning "DV-Draw will be MGA Software's first offering under its ACSL Video product family" should read, "DV-Draw will be MGA Software's first offering under its ACSL Vision product family." We apologize for the errors.

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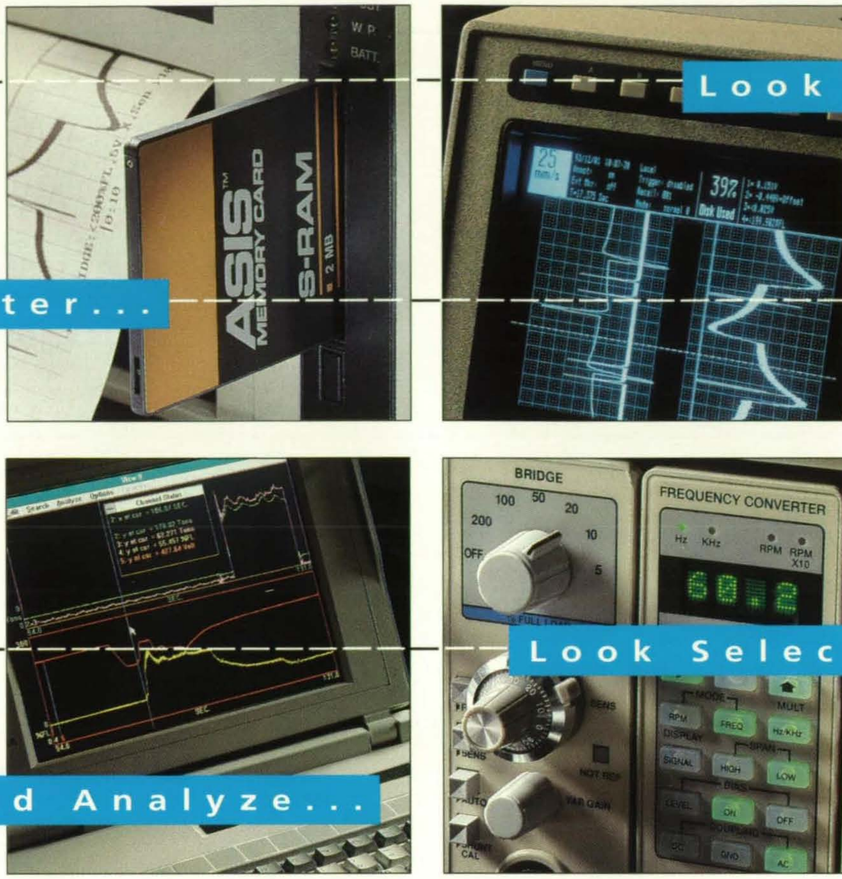

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