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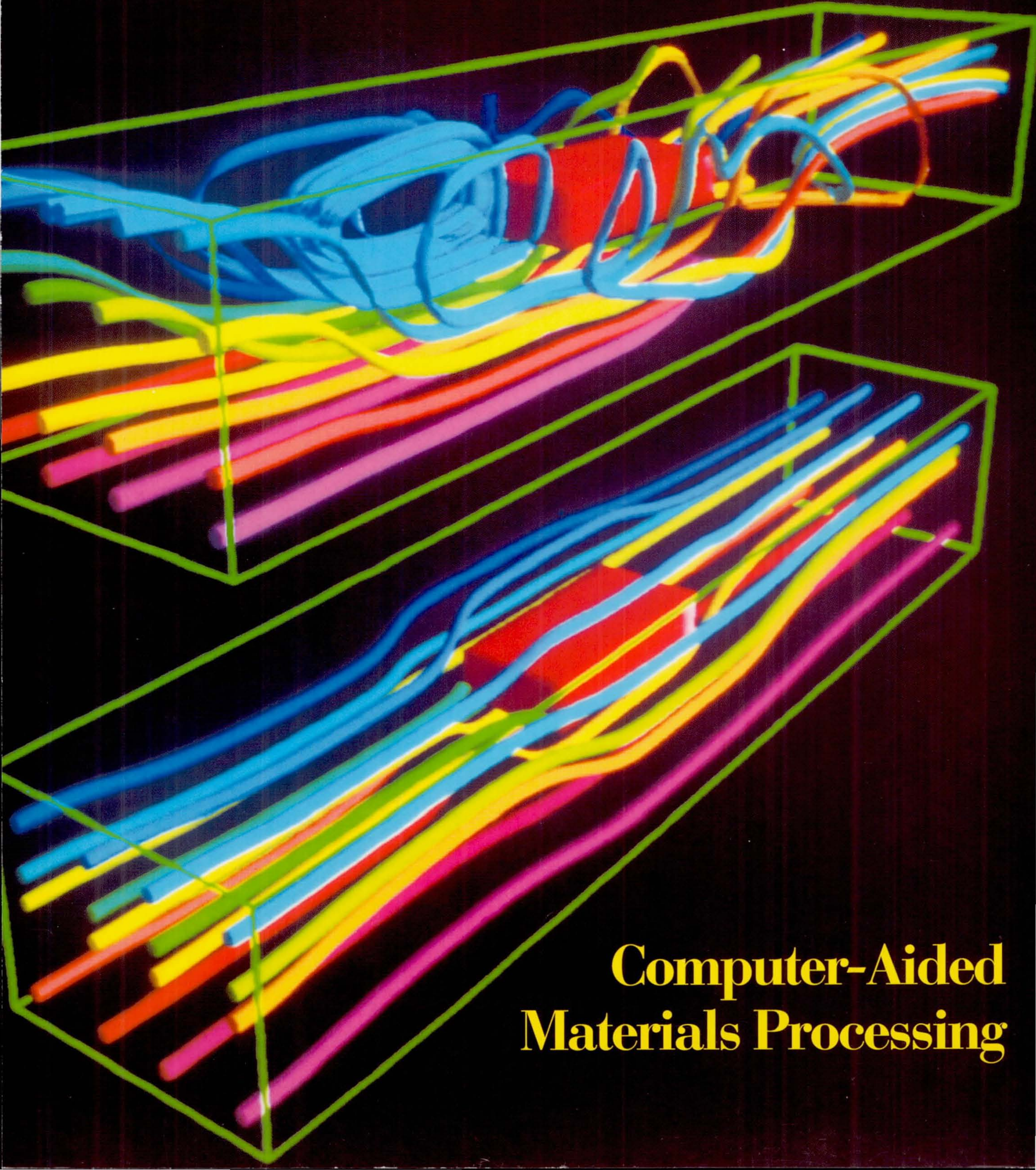
Volume 15 Number 10

Transferring Technology
to Industry and
Government
October 1991



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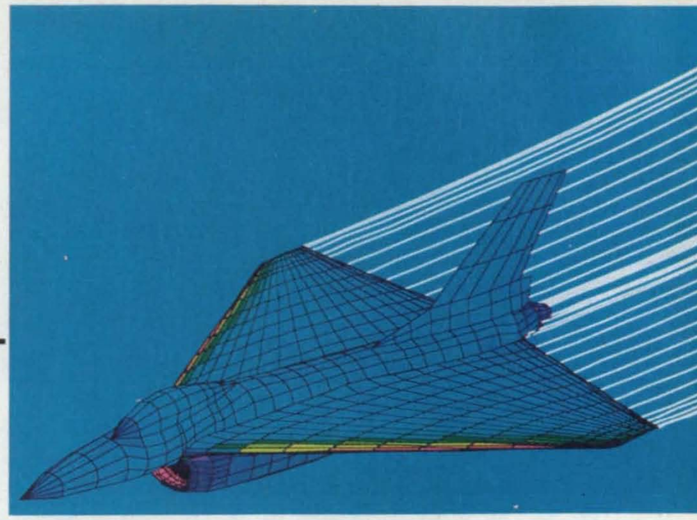

Photo courtesy Ames Research Center

The NASA-developed PMARC computer program numerically simulates the flow field around complex three-dimensional bodies, such as this E-7A aircraft model. The colors represent pressure coefficients. See the tech brief on page 66.

SPECIAL FEATURE

TECHNICAL SECTION

DEPARTMENTS

On The Cover: Researchers at NASA's Lewis Center produced this simulation of the flow in a chemical vapor deposition reactor. The top figure exhibits a complex three-dimensional flow field in 1g that results in nonuniform deposition of material on the suceptor (in red). The bottom figure presents a hypothetical space experiment showing a simpler flow field which should result in more uniform deposition. Turn to NASA's Innovators, page 10.
(Photo courtesy Lewis Research Center)

Photo courtesy Jet Propulsion Laboratory

A new interferometer enables testing of optical components at wavelengths from ultraviolet to infrared without having to readjust the focus when changing the wavelength. See page 38.

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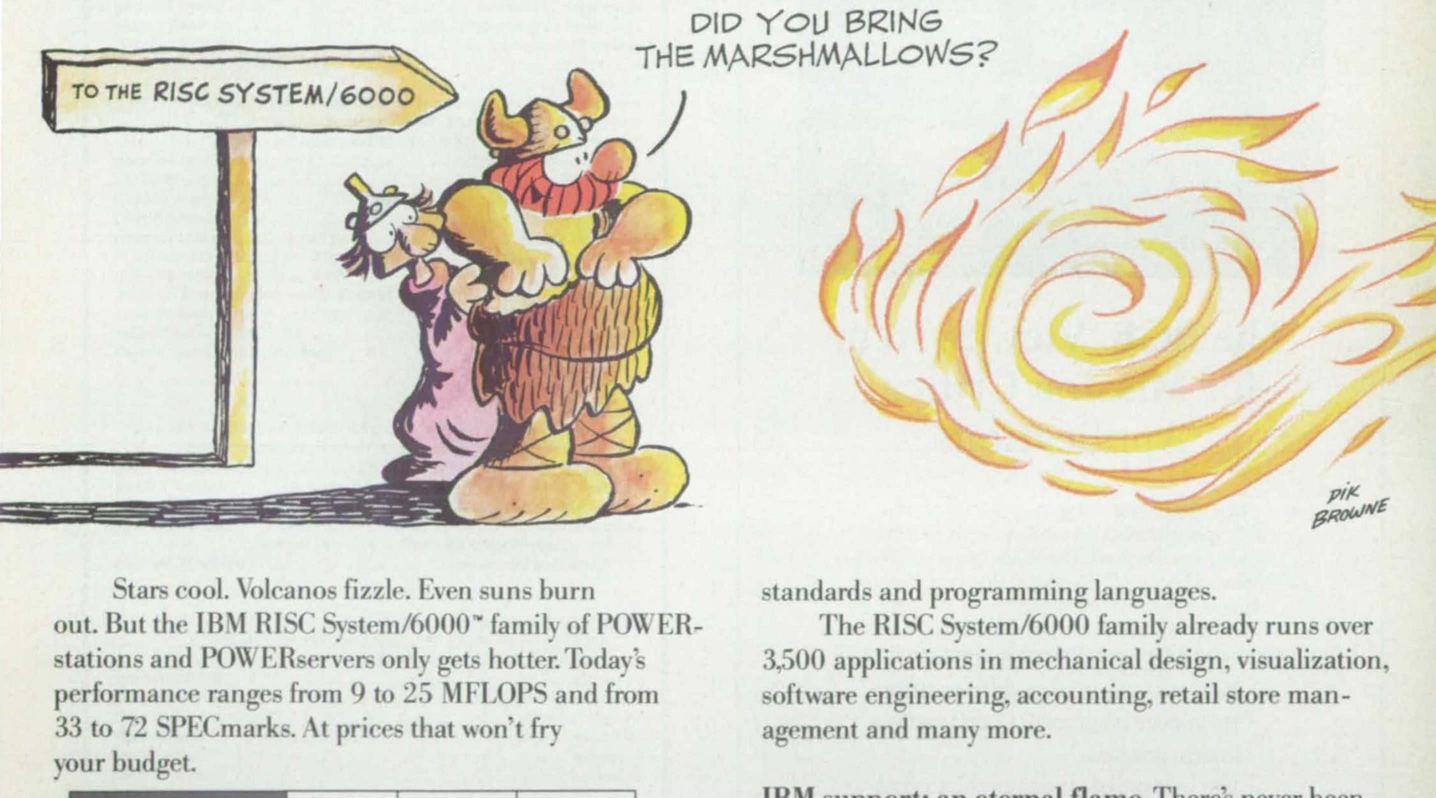

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MFLOPS are LINPACK double-precision where n=100. AIX XL FORTRAN Version 2.1 and AIX XL C Version 1.1 compilers were used for these tests. SPECmark is a geometric mean of the ten SPECmark tests. All prices current at publication.

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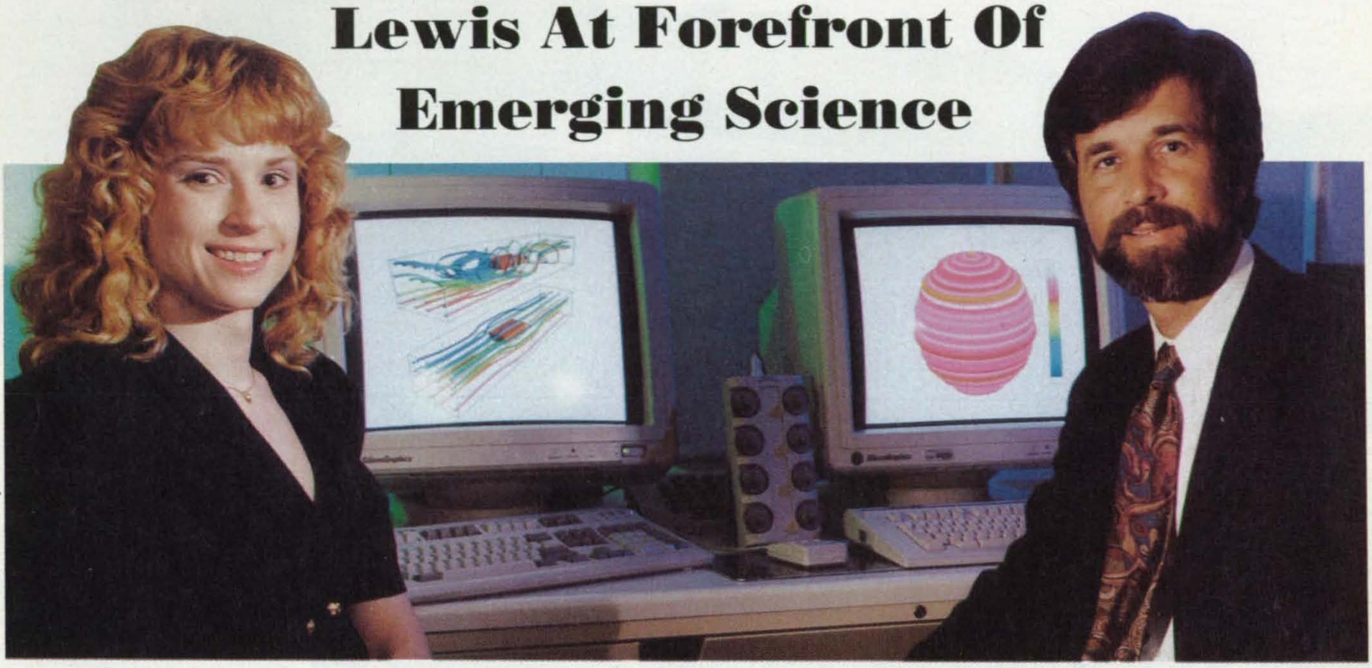
NASA's INNOVATORS

Modeling Materials Experiments:

Lewis At Forefront Of Emerging Science



NASA innovators: Maria Kuczmarski, a CVD researcher whose work is shown on this month's cover, and Arnon Chait, leader of the CML's modeling efforts

by Arnon Chait, Chris Johnston, David Thompson, and Thomas Glasgow

NASA's Lewis Research Center in Cleveland, Ohio is home to a unique materials science lab that looks more like a computer facility than a laboratory. The Computational Materials Laboratory (CML) has no fume hoods, furnaces, or instrumentation, and no crystals or alloy samples. All experiments are done in the lab's computers.

The CML was created to address problems posed by materials processing in space. The microgravity environment of space offers the opportunity for materials experiments that can't be done on Earth, but conducting such experiments isn't easy. Since only a few experiments get a chance to fly, a substantial effort is made to ensure that these experiments will work. As a result, flight experiments have long lead times, high cost, and the administrative overhead of any big project.

To reduce the expense and difficulty, researchers have sought ways to do some of the preliminary experiments on the ground in inexpensive hardware, or without building any hardware at all. To this end, NASA established two laboratories, both part of the Lewis Center's Processing Science and Technology Branch: the Microgravity Materials Science Laboratory (MMSL), intended for the development of microgravity experiments but not flight hardware, and the CML, dedicated to computational modeling of space experiments.

Computational modeling involves the complete simulation of an experiment using a computer. A perfect model would allow you to "run" the experiment in the computer and predict the performance of the real experiment before flight without building hardware. More reasonably, a good model would help in designing equipment and in interpreting both ground-based and flight experiments.

Modeling is certainly nothing new, having been used successfully in many kinds of aerodynamics studies at NASA and around the world. A good aerodynamics model can reduce the number of test runs in a wind tunnel, enabling a project to produce better data faster and at less cost. Because of special problems presented by modeling materials processes, such as the presence of interacting solid and liquid phases, applying modeling to materials experiments isn't as common as aerodynamics modeling. It offers much of the same potential, however, and is just starting to come into its own in the 1990s.

Modeling techniques can be employed in every phase of a flight experiment: design, characterization, in-flight troubleshooting, and post-flight analysis. The model can be particularly beneficial when used to predict the experiment's performance in a reduced gravity environment before it is flown. This is important if the flow or heat transfer characteristics of a sample change radically as the gravitational environment changes.

A good model also can help determine which experiments deserve to be candidates for space flight. It can indicate that the underlying assumptions made about a process appear to be correct, and that the experiment has a good chance of providing useful data. Or it may show that the experiment is a poor subject for modeling and that the flight experiment is the only way to obtain the necessary data. Even if modeling's only contribution is to focus on the process of determining which experiments should fly, the effort will have paid off.

Further, modeling can reduce the cost of an experiment, especially if it involves a significant amount of time, material, energy, or risk. Any important process that will run a large number of times is worth modeling to allow researchers to fully characterize it, for it is far easier to optimize and troubleshoot a well-characterized process than one with unpredictable responses to changes in operating conditions.

Some processes aren't worth trying to model, simply because they are easier to do than to model or because the modeling technology isn't advanced enough to account for some of their features. An experiment involving turbulent flow, for example, is difficult and may not be worth the effort. The real universe is a messy place, and many processes are much too complex to be easily modeled. Real furnaces, for instance, change shape as they heat, their insulation changes with use, and thermal stresses on the structure must be controlled, making for a complicated model.

A Team Approach

Much of the CML's modeling work focuses on simulating the transport of fluid flow, heat, and mass during a process, and how they affect the experiment. Other work attempts to relate process parameters to the final materials properties to optimize experiments and to provide a "critical mass" of expertise in several related areas of modeling and materials science.

Because of the interdisciplinary nature of the problems, the CML staff represents a wide range of expertise, including mathematics, the physical sciences, and various aspects of computer science. Some of the people working in the CML also are involved in the creation and operation of experiments in the adjacent MMSL. The staff's varied backgrounds encourage a team approach to problems, and any project may gather a group of people that changes over time as the work progresses and different skills are needed.

The backbone of the CML's computer facility consists of two large computers: the lab's file server, a Sun 4/260 computer with nearly 6 gigabytes of disk space and a high-capacity backup system; and a Silicon Graphics Iris 4D/340VGX, a four-processor machine with a high-quality graphics system, used for both computational work and graphics generation. Most of the dozen or so workstations supporting the CML staff are Sun SPARCstations.

The relatively small size of the CML forces the lab to take a "middle of the road" approach to software. Its researchers don't have the time or resources to write all of the modeling code from scratch, but commercially-available programs often are not sufficient to meet their needs. Instead, they typically work with customized commercial programs. The customization is done in the CML, often in cooperation with the software vendor. In cases where no suitable software exists, they resort to writing the code themselves, or to creating it cooperatively with university sources. For example, they develop algorithms to describe free surface motion and radiative heat transfer in participating media. They support float zone and interface detection modeling at the University of Akron, and inverse problem solving at the University of Illinois. (An inverse problem is created when a scientist specifies the desired output of a process and the lab must determine the appropriate process inputs to produce that output.)

A typical model generates an abundance of data that is difficult to interpret when presented as pages of numbers. Three-dimensional fluid flow fields, for instance, are exceedingly difficult to understand numerically. The same data, presented visually, is much easier to comprehend. The CML features both hardware and software to facilitate visualization, including the ability to animate time-dependent data on 3/4" videotape and 16 mm film. While much of the modeling is done on the lab's computers, users also can take advantage of the capabilities of Lewis' Computer Services Division and the Ames Research Center's Numerical Aerodynamic Simulation facility.

A unique feature of the CML is its intimate connection with the MMSL, which is literally across the hall. Models can be created of experimental hardware located just a few feet from the modelers, making verification of the model from experimental data much easier. Since they can build hardware and do modeling in the same building, it is easier for model data to be directly applied to the experiment, often as it is built.

The philosophy underlying CML activities parallels the way the MMSL operates. Close collaboration with other NASA centers, national labs, universities, and industry is encouraged at all levels. Historically, most requests have been handled informally, resulting in a short study leading to a solution for a specific problem. Some requests result in joint

Modeling And The Real World

One of the main advantages of the physical and organizational proximity of the CML and MMSL is that it facilitates collaboration on projects. An apparatus can be developed in the MMSL at the same time it is being modeled in the CML, allowing for rapid feedback between the theoretical and physical versions. While it is fairly simple to apply "sanity checks" to a model to ensure that the results are reasonable, the model's acceptance as a useful predictive tool can only come when it is compared to a real experiment. CML-MMSL interaction provides a chance to do such verification easily.

The experiment's builders can benefit from lessons learned by the modelers. Further, the design of the experiment can be influenced by the modelers' needs. If the model's requirements are known, they often can be incorporated into the design of an experiment, making it simpler to model and increasing the ability of the experimenters and modelers to cooperate.

The MMSL has a number of projects that are being pursued in this manner. It is developing, for example, a family of transparent furnaces for future terrestrial and space processing of semitransparent electro-optical materials. These furnaces typically are constructed of quartz tubing heated by conventional resistance heating wire. The main advantage of the transparent furnace is the obvious one—you can see through it and, if the material's properties are suitable, watch the crystal growth process in real time. In addition, you may be able to use your observations to control the process.

Most transparent furnaces are simple in design, making them excellent subjects for modeling in the CML. At the same time, they present a challenge to the modelers because their transparency allows a significant amount of energy to be lost to radiation.

Another advanced furnace, the Programmable Multi-Zone Furnace (PMZF), is being developed in the MMSL with the help of a full numerical model. The model is being used to suggest ways to improve the furnace's performance. It also will be used in the design of space experiments that will employ the PMZF, allowing investigators to rapidly improve their experiments over several iterations.

Modeling can serve to improve a furnace in yet another way. A furnace can be thoroughly characterized in the lab, but only in a 1g environment. Once verified, a model figuratively can take the apparatus into space and see how it performs. The model may indicate that the design is fine at 1g but not acceptable at low-g, and suggest ways of arriving at the desired operational characteristics. ❑

Why Do Snowflakes Look So Interesting?

We are all familiar with the complex shapes that snowflakes take. Similar shapes, called dendrites, also exist in virtually any solid material processed from the melt. The pattern is responsible for the material's ultimate properties, but it is poorly understood. The question of how a smooth interface becomes unstable and forms these complex structures is a vexing one—one of the hotter topics in the physics literature today.

The subject is of vital interest to CML researchers because many of the problems they undertake require the computation of solid-liquid interfaces. The laboratory is developing computational techniques for moving interfaces that are multidimensional and time-dependent in nature. These will be applied to problems ranging from the formation of a single dendrite—a NASA space experiment scheduled for next June—to the computation of general phase-transition problems including ablation, melting, and solidification. ❑

The initial stages of solidification of a small solid nucleus are traced in time, showing the natural development of solid-melt interfacial instabilities. These instabilities later result in tree-like dendritic structures common in many types of solidification.

research, but in all cases the work is driven by the time constraints of the final application.

CVD Research

The CML recently has modeled several chemical vapor deposition (CVD) experiments. CVD is a flexible technique with wide application, used at Lewis to make fibers for high-temperature composite materials, to cover parts with oxidation-resistant coatings, and to develop high-temperature semiconductor materials. CVD models have two important functions: they enable comparison of the experimental and simulation results at 1g, and they permit researchers to explore changes in the performance of the CVD reactor predicted for the microgravity environment.

The modeled 1g results clearly show that the complex three-dimensional structure of the deposited material is affected by natural convection. They also predict more uniform deposition when the experiment is run in a microgravity environment. The CML has produced a computer-animated film of the results that has been widely distributed as a way to illustrate the CVD process.

The lab also modeled the GTE GaAs experiment flown in June on space shuttle mission STS-40. This experiment assessed the effects of reduced natural convection in the molten gallium arsenide semiconductor during solidification. The CML produced a detailed model of the experiment, predicting flow modes in the shuttle's residual gravity environment. Such a model should be an integral part of all solidification experiments, since post-mortem examination of the returned sample can provide only indirect data on convective effects, by observing the distribution of dopant.

Other processes the CML has modeled include directional solidification, float zone, laser-heated float zone, physical vapor deposition, thermal radiation effects in semitransparent materials, and fundamental fluid and heat transport in space. Moreover, the laboratory has been involved in the development of computational methodologies for intelligent processing of materials (IPM), including process control, optimization, and inverse design. The IPM concept recognizes that the lead time for development and commercial introduction of new materials is becoming excessively long, resulting in increasing uncertainties about application of the future technologies that depend on these materials. Under the IPE framework, the contributions of process modeling, smart sensors, and intelligent control are tightly coupled. The CML is an ideal environment for the development of advanced process models that can be readily coupled to other IPM components.

The CML team is enthusiastic about the future of this young field. Materials science is recognized as a key enabling technology for this country's leadership in critical technical areas, both in space and on Earth. Computational techniques are, in turn, among the enabling technologies for materials science, allowing the rapid development and commercialization of new materials. The CML, part of a tradition of materials research at NASA Lewis, is ready to respond to the challenges and help bring this new science to maturity. ❑

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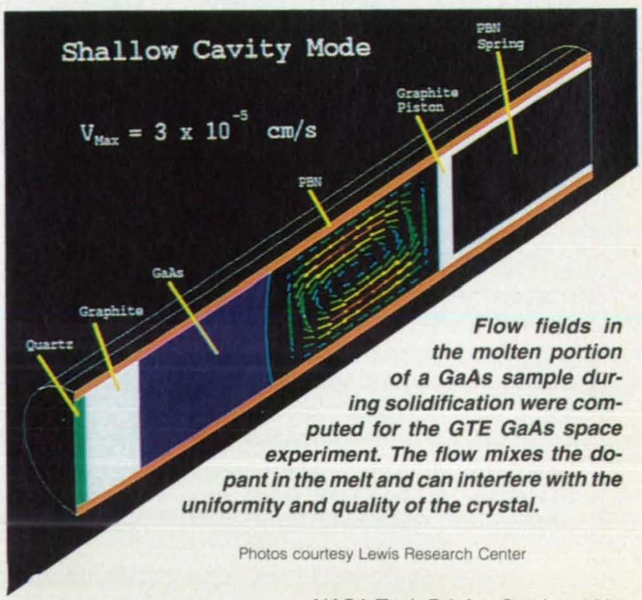
About The Authors

Arnon Chait, deputy chief of the Lewis Center's Processing Science and Technology Branch, leads the CML's modeling efforts. He holds a PhD in mechanical engineering from Ohio State University.

Chris Johnston writes data acquisition software for the MMSL and is involved in the CML's visualization and animation work. He has a PhD in chemistry from Cleveland State University.

David Thompson provides graphics, visualization, and animation services for the CML. He holds a master's degree in physics from Akron University.

Thomas Glasgow is chief of Lewis' Processing Science and Technology Branch. Mr. Glasgow has degrees in metallurgy and materials science from Case Western Reserve University.



Flow fields in the molten portion of a GaAs sample during solidification were computed for the GTE GaAs space experiment. The flow mixes the dopant in the melt and can interfere with the uniformity and quality of the crystal.

Photos courtesy Lewis Research Center

New Product Ideas

New Product Ideas are just a few of the many innovations described in this issue of *NASA Tech Briefs* and having promising commercial applications. Each is discussed further on the referenced page in the appropriate section in this issue. If you are interested in developing a product from these or other NASA innovations, you can receive further technical information by requesting the TSP referenced at the end of the full-length article or by writing the Technology Utilization Office of the sponsoring NASA center (see page 16). NASA's patent-licensing program to encourage commercial development is described on page 16.

Deposition of Diamond-like Films by ECR Microwave Plasma

Hard, amorphous hydrogenated carbon films of diamondlike quality have been deposited at room temperature on silicon, optical glass, and quartz. This technique could provide hard, abrasion-resistant coatings for lenses and other optical components.
(See page 42)

Photorefractive Crystal Compresses Dynamic Range of Image

The dynamic range of the spatial variation of illumination within an image can be compressed by use of a photorefractive crystal. The crystal would be placed in the optical path at some stage preceding the video camera, photographic camera, or final photodetector stage.
(See page 37)

Apparatus Circulates Sterilizing Gas

A sterilizing apparatus circulates a gas mixture containing ethylene oxide through tubes, valves, and other parts of equipment to be sterilized. The apparatus contains the toxic ethylene oxide and is cheaper than an ordinary commercial gas sterilizer because the gas is used at relatively low pressure.
(See page 116)

Sensing Temperatures Via Prostheses and Manipulators

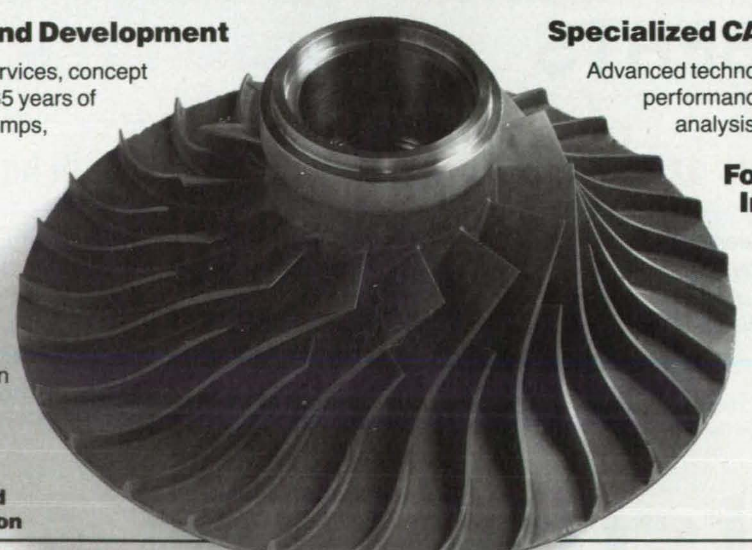
A proposed temperature-sensing system for artificial limbs or telerobotic manipulators allows one to sense the temperature of the grasped object. The temperature of the object is conducted via a thermoelectric heat pump that would heat or cool the skin of the operator's shoulder.
(See page 35)

Bidirectional Drive-and-Brake Mechanism

A new bidirectional drive-and-brake mechanism is part of a small vehicle that is driven manually along a monorail. The mechanism is applicable to very small railroad handcars or crawling vehicles for use on large structures, in pipelines under construction, in mining, or underwater.
(See page 88)

Ruling Blazed, Aberration-Corrected Diffraction Gratings

A proposed optoelectromechanical apparatus would rule blazed, aberration-corrected diffraction gratings. The apparatus makes it possible to combine the precision of an aberration-corrected, holographically produced grating with the diffraction efficiency of a blazed grating.
(See page 97)



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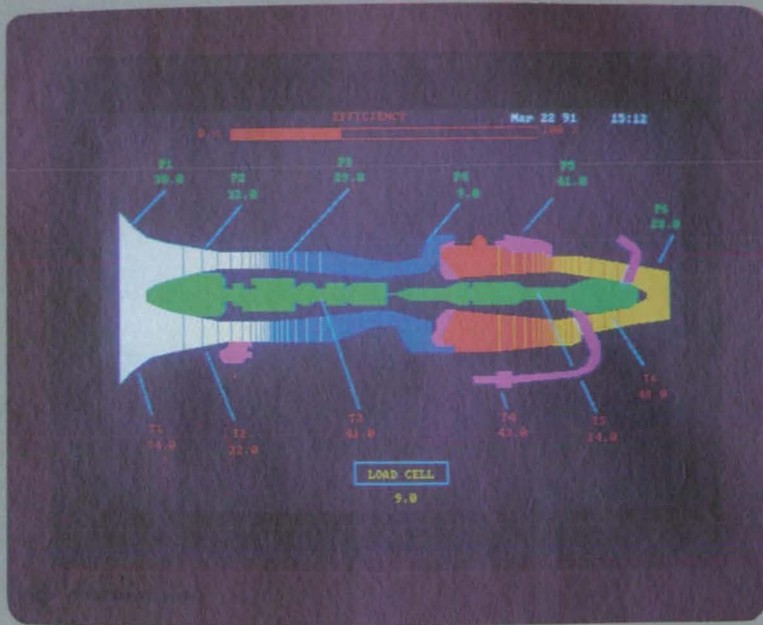

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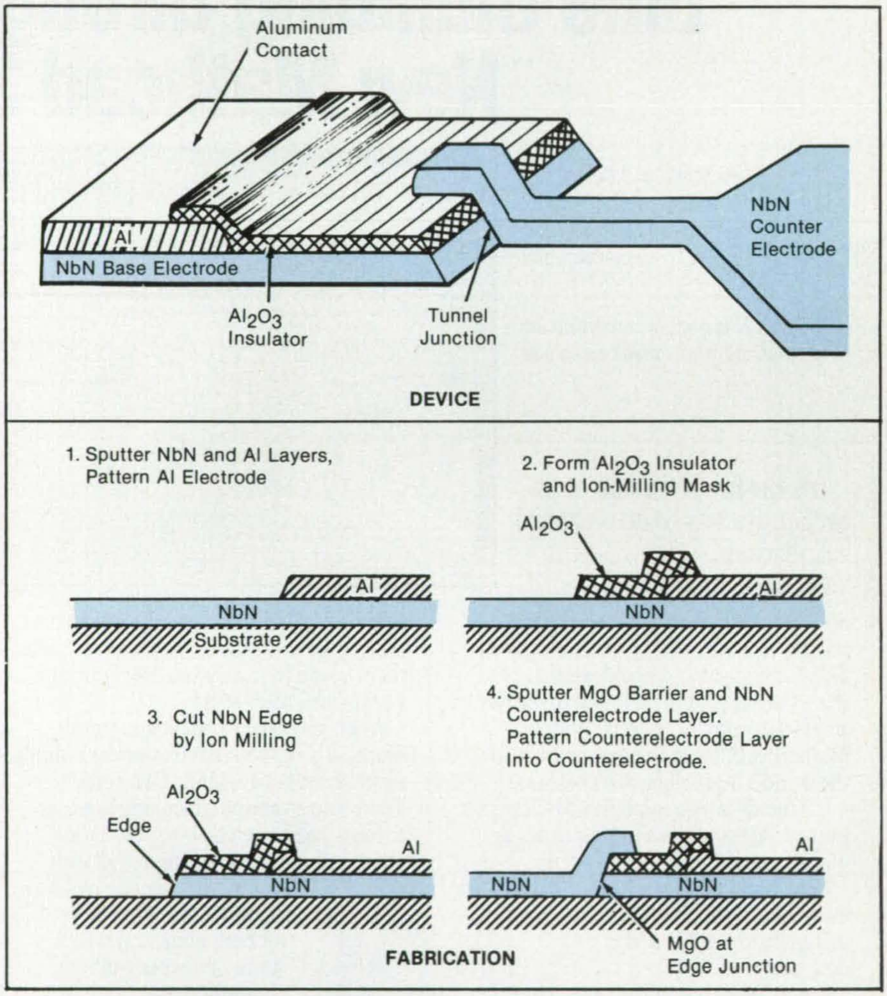
Edge-Geometry NbN/MgO/NbN Tunnel Junctions

Superconductor/insulator/superconductor tunnel junctions of high quality have been fabricated.

NASA's Jet Propulsion Laboratory, Pasadena, California

Superconductor/insulator/superconductor (SIS) tunnel junctions have been fabricated with base and counter electrodes of NbN (the superconductors) separated by thin layers of MgO (the insulator). SIS junctions are useful as submillimeter-wave mixers and fast switches. To obtain a junction resistance adequate for coupling to external circuitry (typically ≥ 50 Ω) and adequate frequency response (≥ 200 GHz), it is necessary to make a small (area ≤1 μm^2) junction that has a current-vs.-voltage characteristic of high quality. The use of an edge geometry to define the small junction makes it possible to fabricate such a junction by a process that includes conventional photolithography.

The figure illustrates the junction and the fabrication process. In edge-geometry fabrication, the tunnel junction is formed on the exposed edge of the NbN superconducting film that constitutes the base electrode. The junction is completed by deposition and patterning of the counterelectrode. In this geometry, the area of the junction is governed by the thickness of the base electrode and the width of the tip of the counterelectrode. Because the base electrode can easily be made as thin as about 0.1 μm and the tip can be made as narrow as about 1 μm by conventional photolithography, the area of the junction can be made as small as 0.1 μm^2. One subtle advantage of this geometry is that it minimizes the current-crowding effects that can lead to electrode transitions in high-current-density, planar-geometry junctions.



This **NbN/MgO/NbN** SIS tunneling junction is made small by use of an edge geometry and standard photolithographic techniques.

The fabrication process begins with the sputter deposition of the NbN base-electrode layer to the desired thickness of about 0.1 μm on a sapphire substrate. During the deposition of NbN, the substrate is heated to 350 to 450 °C to promote the formation of high-quality NbN near the surface of the substrate: this is essential for obtaining an edge junction that has low subgap leakage and sharp gap edges. An aluminum overlayer about 0.5 μm thick is deposited on the base electrode to serve as a contact. After the aluminum layer is patterned, a thick, insulating layer of aluminum oxide is deposited and patterned; this layer also serves as a mask to protect the underlying NbN in the next step.

A 500-eV argon-ion beam is used to define the edge of the NbN base electrode. Next, an 80-to-150-V argon-ion milling beam is used to remove surface damage from the edge. The MgO tunnel barrier (insulating layer) is deposited by radio-frequency-magnetron sputtering. The NbN counterelectrode layer is then deposited by dc-magnetron sputtering and patterned into the counterelectrode by standard photolithography and reactive-ion etching.

Junctions that have areas from 0.1 to 0.4 μm^2 have been fabricated by this process. These are the first reported NbN/MgO/NbN edge junctions. The electrical characteristics of these junctions have been found to be suitable for testing the junctions as SIS mixers at frequencies from 200 to 600 GHz.

This work was done by Brian D. Hunt and Henry G. LeDuc of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 119 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 16]. Refer to NPO-17812.

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Low-Noise Charge-Coupled Device

The same quantity is measured many times to reduce the uncertainty.

NASA's Jet Propulsion Laboratory, Pasadena, California

The "skipper" charge-coupled device (CCD) underlines the development of a new class of imaging detectors that exhibit exceptionally low readout noise. The skipper CCD operates on a nondestructive-readout scheme that can be combined with other advances in CCD technology to reduce the average readout noise to less than 1 electron rms. The skipper concept has obvious potential for improving video images made at ultra-low light levels, involving only a few incoming photons per picture element (pixel).

For modern scientific CCD's, read noise originates within the on-chip amplifier. Today's CCD amplifier has been thoroughly optimized and, for all practical purposes, has reached the theoretical minimum noise level of approximately 2 electrons rms. Conventional CCD's destructively sample the charge contained in a pixel only once before it is reset. With the skipper CCD signal, charge can be sampled nondestructively as many times as desired before the pixel is reset. Multiple sampling allows the pixel samples to be averaged, reducing the random noise by the square root of the number of samples taken. For

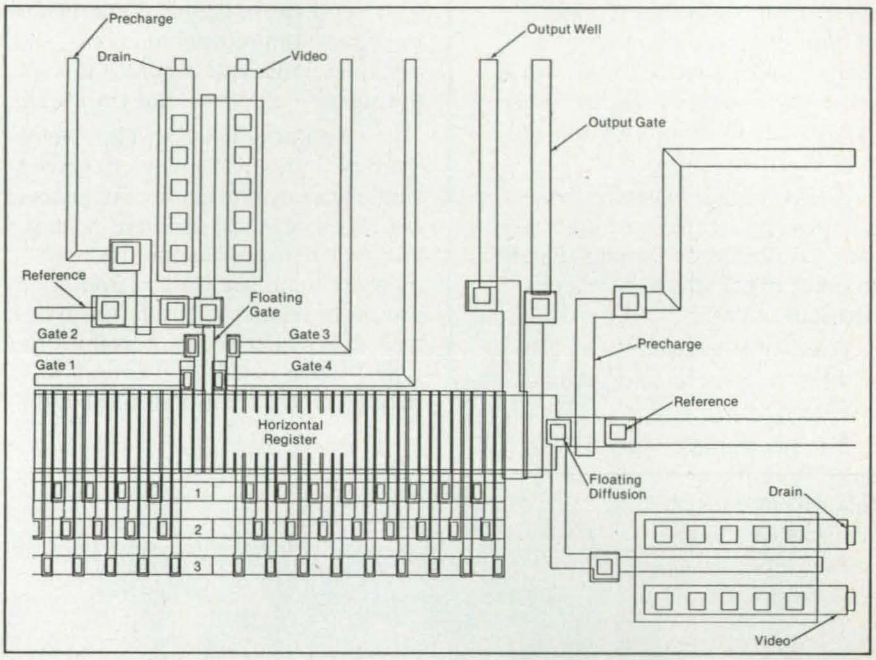

Figure 1. In this **Skipper CCD Output Circuit**, the packet of charge from a picture element is transferred a number of times between gate 1 (where it is held) to the floating gate (where it is sensed) before it is finally transferred through gates 3 and 4 to the destructive-readout circuit.

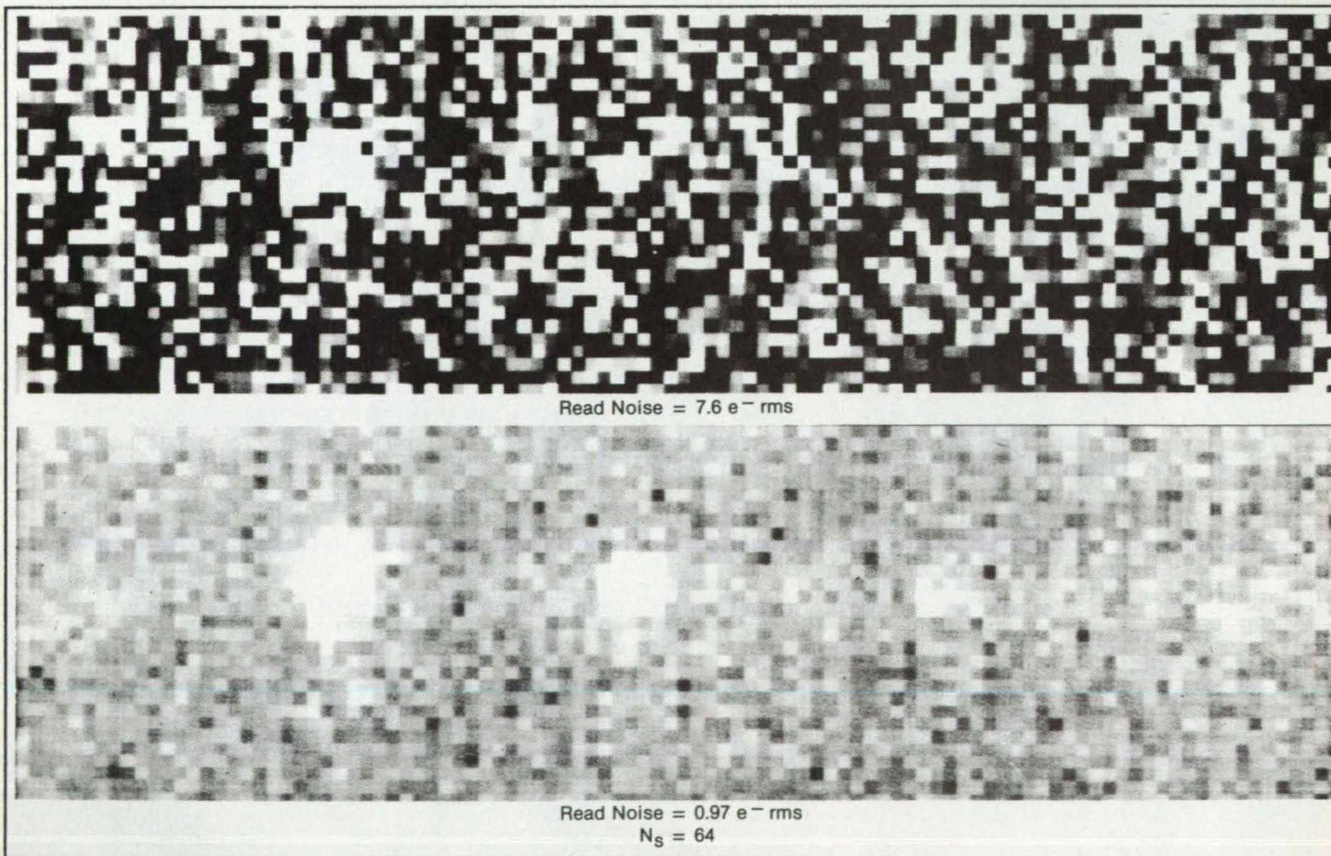

Figure 2. These **Images of Four Points in a Row** were made by a skipper CCD. In the upper image, made with only one sample per picture element, the noise makes it difficult to identify all but one of the points. In the lower image, made with 64 samples per picture element, all four points can be seen.

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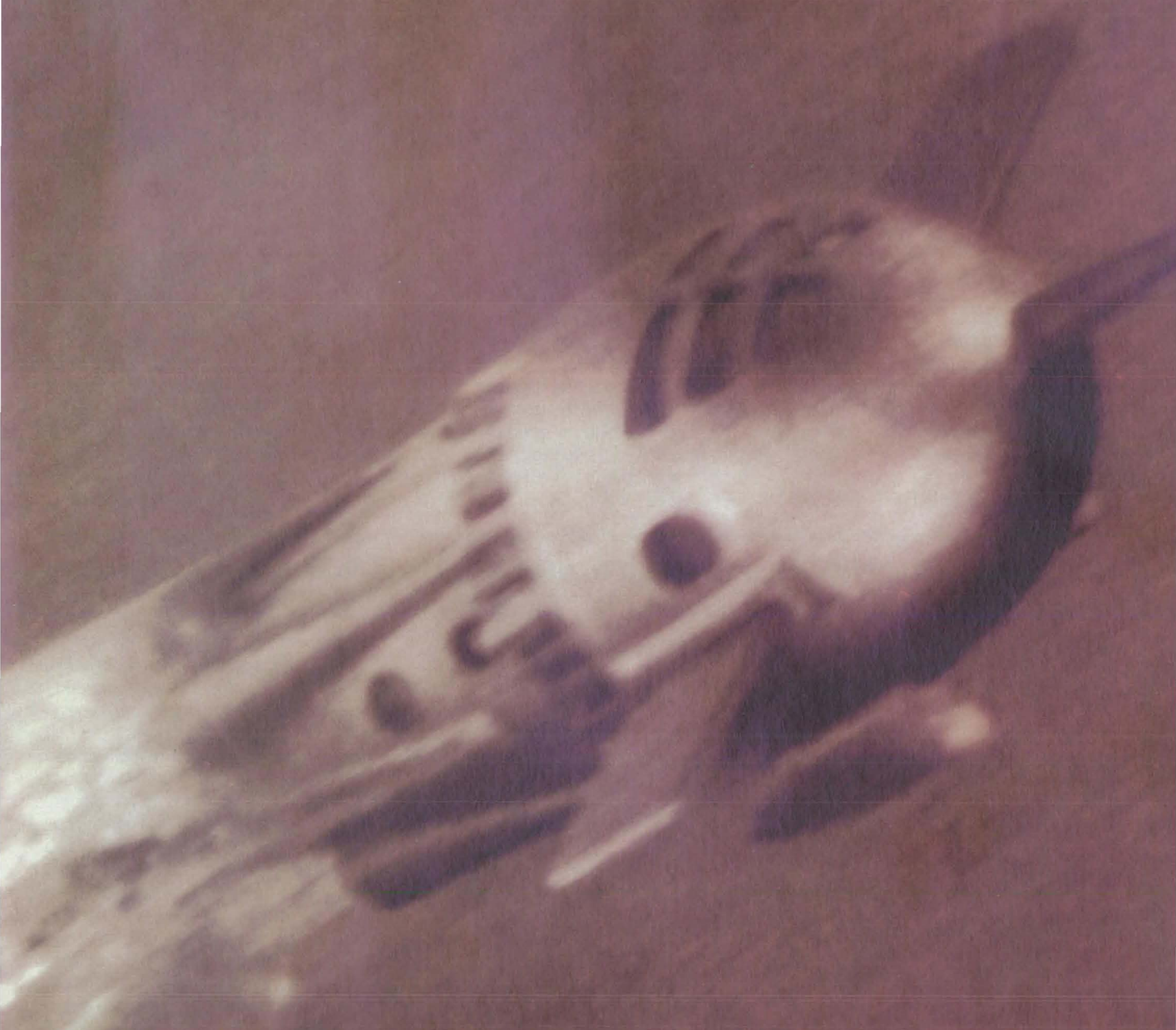

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example, if the noise exhibited by single sampling is 5 electrons, collecting 100 samples for each pixel will reduce the uncertainty in charge measurement to 0.5 electron.

Figure 1 illustrates one design using the skipper concept. Charge from a pixel is transferred to the right in a CCD register where it is sensed by a floating-gate amplifier. After the first sample is taken, clock voltages on gates 1 and 2 are sequenced in such a way that the charge is transferred backward to the left to gate 1. Then, the clocks move the charge packet forward again to the floating-gate amplifier where the charge is sensed again. This process is repeated many times to reduce the uncertainty of charge measured to the desired level. When all the required samples are collected, the charge is sent forward via gates 3 and 4 toward a conventional destructive amplifier, where charge can be sampled again (only once) or discarded through a reset amplifier.

Figure 2 illustrates the noise-reducing capability of a prototype skipper CCD in response to four low-light-level point sources. The upper image is generated by single pixel sampling and exhibits a read noise of 7.8 electrons. The lower image is noticeably clearer because 64 samples per pixel have been utilized. A readout noise of less than 1 electron is achieved. The fourth point source from the left is only 3 electrons in size. Other skipper images have been generated by taking more samples and have achieved noise levels of less than 0.5 electron.

Although ultra-low noise floors can be achieved with this approach, the readout time for large pixel CCD arrays can sometimes be excessive since multiple sampling does require time to perform. For many CCD applications, ultra-low noise readout is not required for the entire image. In these cases the user can readily command the CCD to perform multiple sampling only in those regions of interest and to skip through the pixels outside these areas (hence the name skipper).

State-of-the-art skipper CCD's are currently in process that will achieve still lower noise levels. With these new devices, it is hoped that the single electrons can be detected.

This work was done by James R. Janesick of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 120 on the TSP Request Card.*

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

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Refer to NPO-18031, volume and number of this NASA Tech Briefs *issue, and the page number.*

Ir/IrSi$_3$/Si Schottky-Barrier Infrared Detector

Quantum efficiency would be increased.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed Schottky-barrier infrared detector would have a double metallic layer of Ir and $IrSi_3$ instead of a single metallic layer of Ir, IrSi, or $IrSi_3$ as in previous Schottky-barrier detectors made of Ir and Si. The quantum efficiency of the proposed detector should be greater than that of one made with a single metallic layer of $IrSi_3$. Many detectors of this type could be used to form a focal-plane array that could be integrated with charge-coupled-device-addressing and image-processing circuitry.

Heretofore, the attainment of reproducible Schottky-barrier heights (and, consequently, reproducible cutoff wavelengths) has been impeded by the formation of mixed silicide phases by chemical reaction between Ir and Si during fabrication. $IrSi_3$, the most stable of these phases, yields a reproducible barrier height of about 0.12 eV (corresponding to a cutoff wavelength of about 10 μm). Unfortunately, the infrared absorption in this and the other silicides is relatively low, so that in a detector made with a single layer of $IrSi_3$, the overall quantum efficiency is low.

The proposed detector (see figure) would offer the advantages of both the relatively high infrared absorption in a thin film of Ir and the stability and reproducibility of a layer of $IrSi_3$ in contact with Si. Furthermore, the $IrSi_3$ layer would serve as a barrier to chemical reactions between the Ir overlayer and the Si substrate.

The thickness of the $IrSi_3$ layer would lie approximately in the range of 2 to 10 Å, while the total thickness of the $IrSi_3$ and Ir layers would typically lie between 20 and 100 Å. The $IrSi_3$ layer could be formed by deposition of Ir and Si in stoichiometric ratio in ultrahigh vacuum onto an Si substrate. The Si substrate could be heated during deposition as in conventional molecular-beam epitaxy. Alternatively, the substrate could be held at room temperature during deposition, and the

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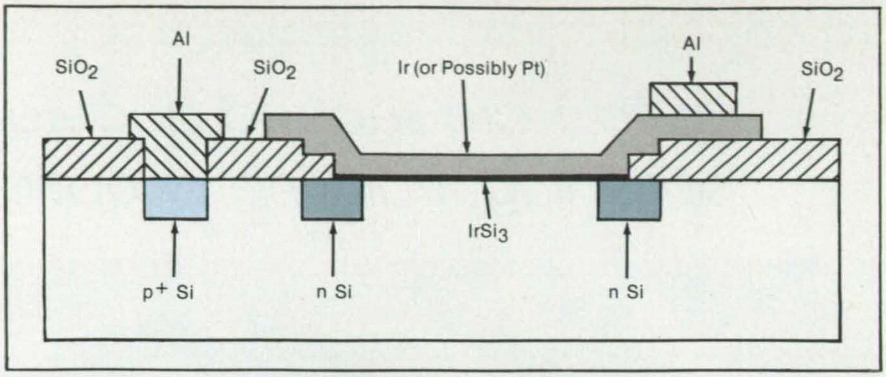
substrate and deposited layers heated subsequently to anneal the $IrSi_3$ (solid-phase epitaxy). The Ir layer would then be evaporated onto the $IrSi_3$ layer.

An overlayer of metal other than Ir could be deposited on the $IrSi_3$ layer. Preferably, this layer would be Pt or another metal that exhibits high infrared absorption.

This work was done by True-Lon Lin of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 115 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 16]. Refer to NPO-18144.



The proposed **$Ir/IrSi_3/Si$ Schottky-Barrier Detector** would have a quantum efficiency greater than that of an $IrSi_3/Si$ detector. The increase in quantum efficiency would be contributed by the relatively high infrared absorption of the Ir layer.

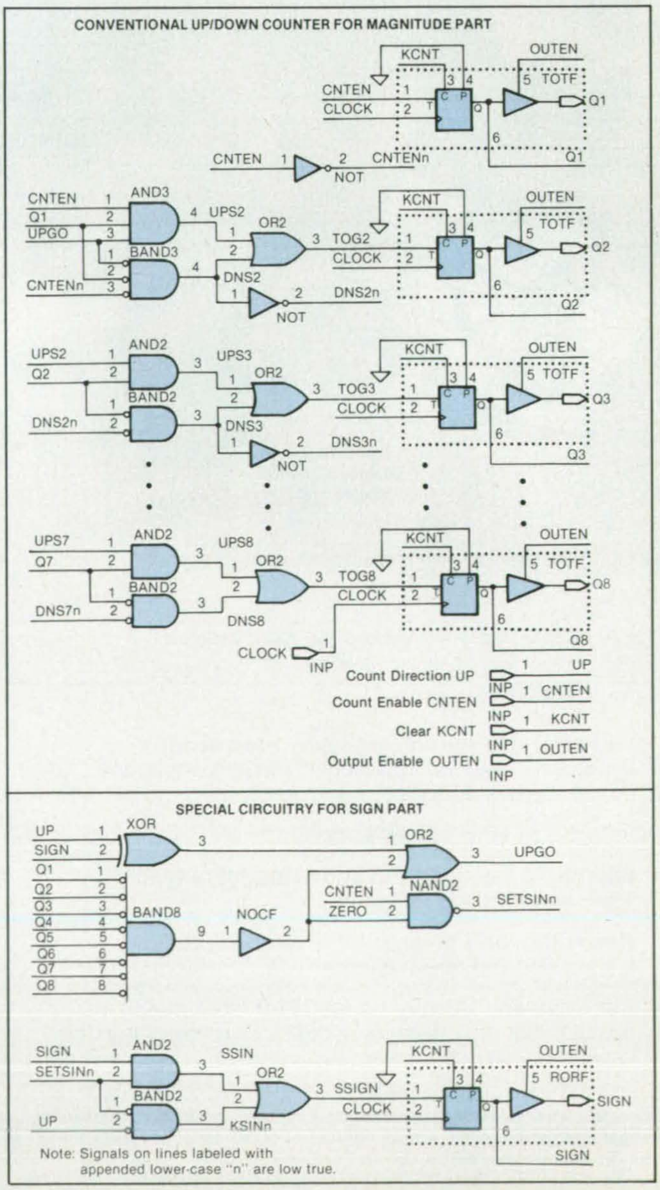
Sign-and-Magnitude Up/Down Counter

Negative numbers are indicated more directly.

NASA's Jet Propulsion Laboratory, Pasadena, California

An electronic up/down counter (see figure) puts out a count signal in two parts: a sign part and a magnitude part that is always positive. Therefore, when it counts down from zero, its output is more directly readable and processable than is the output of a conventional up/down counter, which puts out numbers in two's-complement representation when its count goes below zero. (The reading and/or further processing of two's-complement output requires additional circuitry.)

When the counter counts down from zero, the magnitude indicates a count up from zero, and a sign bit is set to indicate a negative value. When it counts up from a negative number, the magnitude value decreases toward zero. As it continues to count up from zero, the sign bit is cleared,



The Magnitude-and-Sign Counter includes a conventional up/down counter for the magnitude part and special additional circuitry for the sign part.

and the magnitude part rises from zero as an ordinary positive number.

The counter can be implemented by programming an erasable programmable logic device (EPLD) or a programmable logic array (PLA). The EPLD or PLA can then be used in place of a conventional up/down counter to provide sign and magnitude values directly to other circuits.

This work was done by Steven W. Cole of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 94 on the TSP Request Card.*

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

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Refer to NPO-17760, volume and number of this NASA Tech Briefs *issue, and the page number.*

$Si_{1-x}Ge_x$/Si Infrared Photodiodes

Cutoff wavelengths depend on *x* and can also be adjusted somewhat via reverse bias.

NASA's Jet Propulsion Laboratory, Pasadena, California

$Si_{1-x}Ge_x$ photodiodes with cutoff wavelengths in and beyond the practically important range of 8 to 12 μm have been made by molecular-beam epitaxy. Unlike prior long-wavelength infrared detectors, these are compatible (in terms of fabrication processes) with silicon readout circuitry, exhibit long-term stability, can be manufactured with sufficient uniformity for use in focal-plane arrays; and can operate at temperatures ≥ 65 K, for which temperatures small, portable refrigerators are available.

Figure 1 illustrates the structure and energy diagram of one of the diodes. A degenerate layer of p^+ $Si_{1-x}Ge_x$ serves as an emitter of hot carriers, while a substrate of p-Si serves as the collector. Free carriers in the emitter absorb infrared photons and thereby become hot carriers, which are subsequently emitted over a potential barrier into the collector. The potential barrier is the discontinuity between the valence bands of $Si_{1-x}Ge_x$ and Si. By choosing the proportion, *x*, of Ge in the $Si_{1-x}Ge_x$ layer, one can choose the height of the barrier, which can range from <0.05 eV (corresponding to a cutoff wavelength >24.8 μm) to >0.7 eV (corresponding to a cutoff wavelength <1.8 μm).

The physical mechanism of photodetection is partly similar to that of a Schottky-barrier detector, in which photoelectrons are excited over a potential barrier from initial states in a metal, the energies of which states range to several eV below the Fermi level. However, a Schottky barrier exhibits low quantum efficiency because those photoelectrons that are excited from initial energy states below the Fermi level have low probability of being detected. In the $Si_{1-x}Ge_x$/Si detector, carriers in the emitter are excited from energy states close to the edge of the valence band. Photoholes excited by photons of energy greater than the height of the potential barrier have high probability of being collected, provided that their distances from the barrier are less than the mean free path for hole/hole scattering.

The photodiodes were fabricated on p-Si(100) substrate wafers that had resistivities of 1 to 10 Ω-cm. Each photodiode includes a p^+ substrate contact and an n-doped guard ring around the periphery of the $Si_{1-x}Ge_x$ layer to suppress edge leakage. The $Si_{1-x}Ge_x$ layers were grown in a commercial molecular-beam-epitaxy system with a base pressure of 3×10^{-11} torr (4×10^{-9} Pa). $Si_{1-x}Ge_x$ layers 100 to 4,000 Å thick, heavily doped with boron (p^+), and with *x* ranging from 0.18 to 0.28, were deposited on the substrates by coevaporating Si and Ge during molecular-beam epitaxy. The growth temperatures range from 550 to 650 °C. The p^+ doping of the $Si_{1-x}Ge_x$ layers was achieved by coevaporating HBO_2 during molecular-beam epitaxy. Aluminum contacts were deposited on the $Si_{1-x}Ge_x$ layers and p^+-Si substrate contacts.

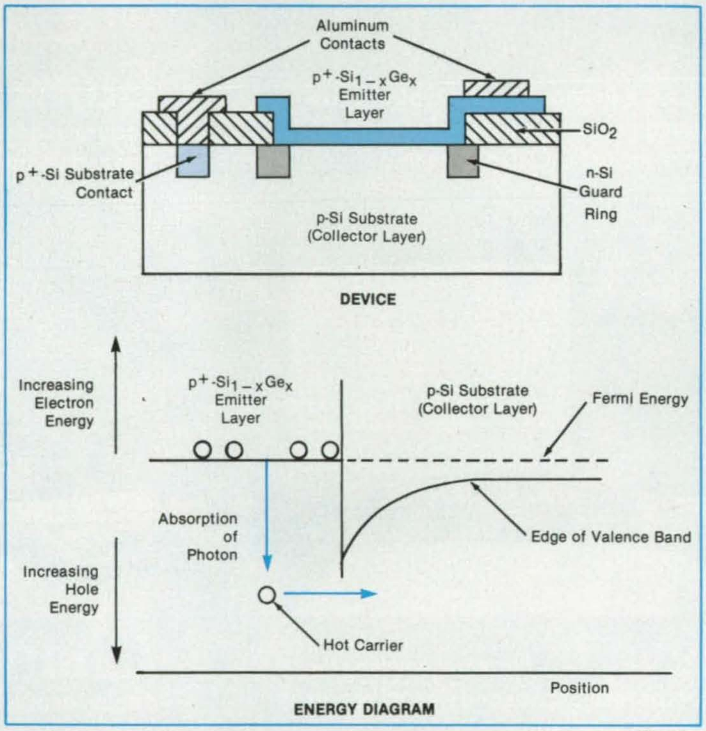


Figure 1. The **Photodiode Structure**, fabricated by molecular-beam epitaxy, detects long-wavelength infrared photons by excitation of photoholes over the potential barrier.

The photodiodes were tested optically, and the photoresponse of a heterojunction-internal-photoemission (HIP) detector with a boron concentration of 4×10^{20} cm^{-3} is shown in Figure 2. The measurement was done at 20 K with −1.5 V bias. Quantum efficiencies (QE's) of 3 to 5 percent have been achieved in the 8-to-12-μm region. By further optimizing the doping profile and thickness of the SiGe layer, the QE of the HIP detector can be significantly improved.

This work was done by True-Lon Lin of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 50 on the TSP Request Card.*
NPO-17950

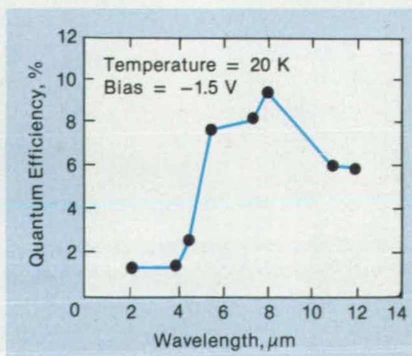
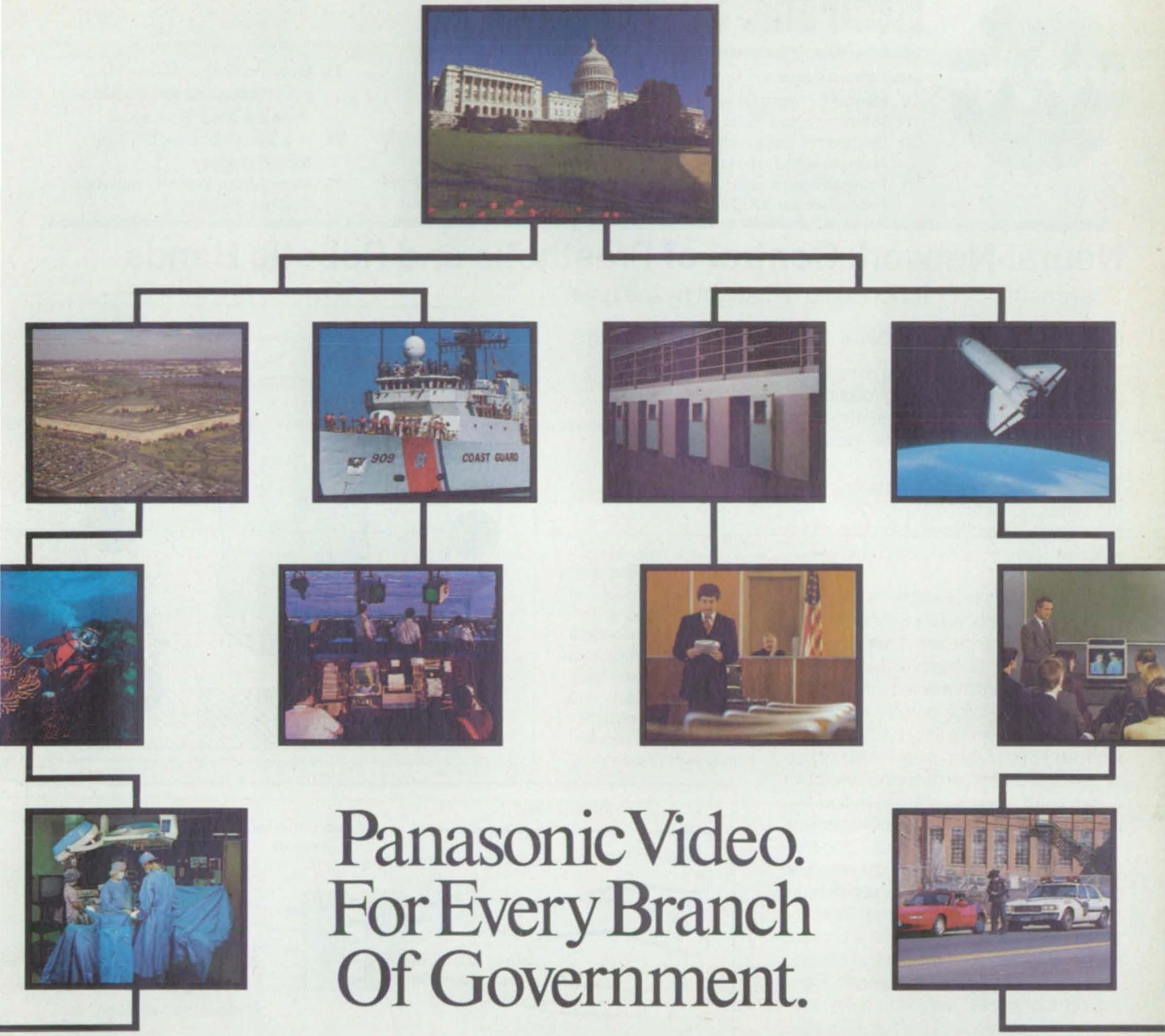


Figure 2. A **Photoresponse of a HIP Detector** is shown with 30-nm thick SiGe layers doped with a boron concentration of 4×10^{20} cm^{-3}.


909
COAST GUARD

Electronic Systems

Hardware, Techniques, and Processes

Neural-Network Control of Prosthetic and Robotic Hands

The prosthesis or robot could be taught by the user.

Lyndon B. Johnson Space Center, Houston, Texas

Electronic neural networks have been proposed for use in controlling robotic and prosthetic hands and exoskeletal or glovelike electromechanical devices that would aid intact but nonfunctional hands. The neural-network approach differs from the conventional artificial-intelligence approach, which has limited ability to achieve adaptive, real-time anthropomorphic grasping motion.

Figure 1 helps to illustrate the development of a grasping-motion algorithm in the neural-network approach. Each finger of a robotic hand (or the prosthetic equivalent) would be instrumented with proximity and grasping-force sensors at various positions along every finger. A neural network would be used to map a relationship, at each increment of robot clock time, between a set of input parameters and the commanded next angle and/or increment of angle of each joint. The input parameters would include the distances between the fingers and potential contact points on the object to be grasped (as measured by the proximity sensors) and, once contact has been established, the force of contact (as measured by each force sensor). From the contact forces, the joint angles, and the known positions of the force sensors on the fingers, the grasping torques can also be computed.

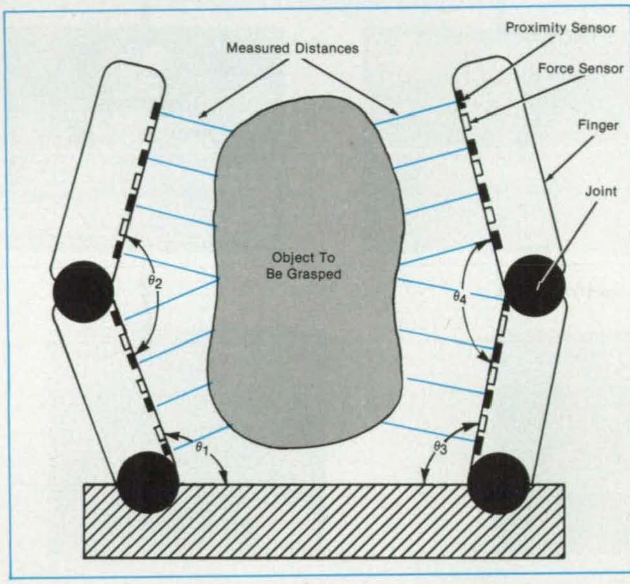


Figure 1. This **Simplified Robot Hand** illustrates the principle of training a neural network by teaching it to map a relationship between increments of the joint angles ϕ_1 through ϕ_4 and the distances and forces measured by the proximity and force sensors.

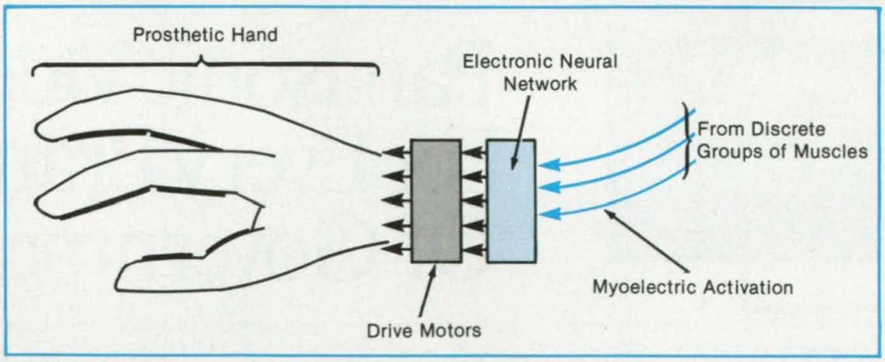


Figure 2. **Myoelectric Impulses** would be used to activate an electronic neural network, which would act as a miniature brain that would control a prosthetic hand.

The neural network might be taught ("trained" in neural-network jargon) with the help of an instrumented master prehensor that could be commanded to act like the robotic hand or prosthesis that the neural network is intended to control. This prehensor would be commanded to grasp an object by use of the desired motions, and the commanded-joint-angle, proximity, and force parameters would be recorded at each increment of time. Next, the force and proximity data would be shifted back to make them lag the joint-angle data by one increment of time.

The resultant set of input (proximity and force) and output (prediction of next increments of angles and/or next angles) data at all increments of time would constitute a training set of training patterns of data. The training set could include data obtained by grasping more than one object. The training set would teach the neural network to map the cause-and-effect relationship between the force and proximity feedback and the next desired change in the angle of each joint. Thus, an animatable sequence would be created, and motion would be learned.

A patient and a prosthetic or exoskeletal device would be trained together, using an instrumented master device to establish the desired motion. The proximity, force, and angle data would be entered in a software model of the neural network. Through an iterative procedure, this model of the network would be taught, and a set of weights of interconnections among the artificial neurons determined. Once trained on a generic program, these weights would be stored in a microprocessor in the form of electrical conductances.

The resultant electronic neural network would be specific to the patient, who would activate the grasping motion by a voice command, by a mechanical switch, or, ideally, by myoelectric impulse (see Figure 2). The patient would retain higher-level control, while the lower-level control provided by the neural network would be analogous to that of a miniature brain. Furthermore, during training, the patient could teach the miniature brain to perform specialized, anthropomorphic movements unique to himself or herself.

This work was done by Theresa M. Buckley of **Johnson Space Center**. *For further information, Circle 1 on the TSP Request Card.*
MSC-21642

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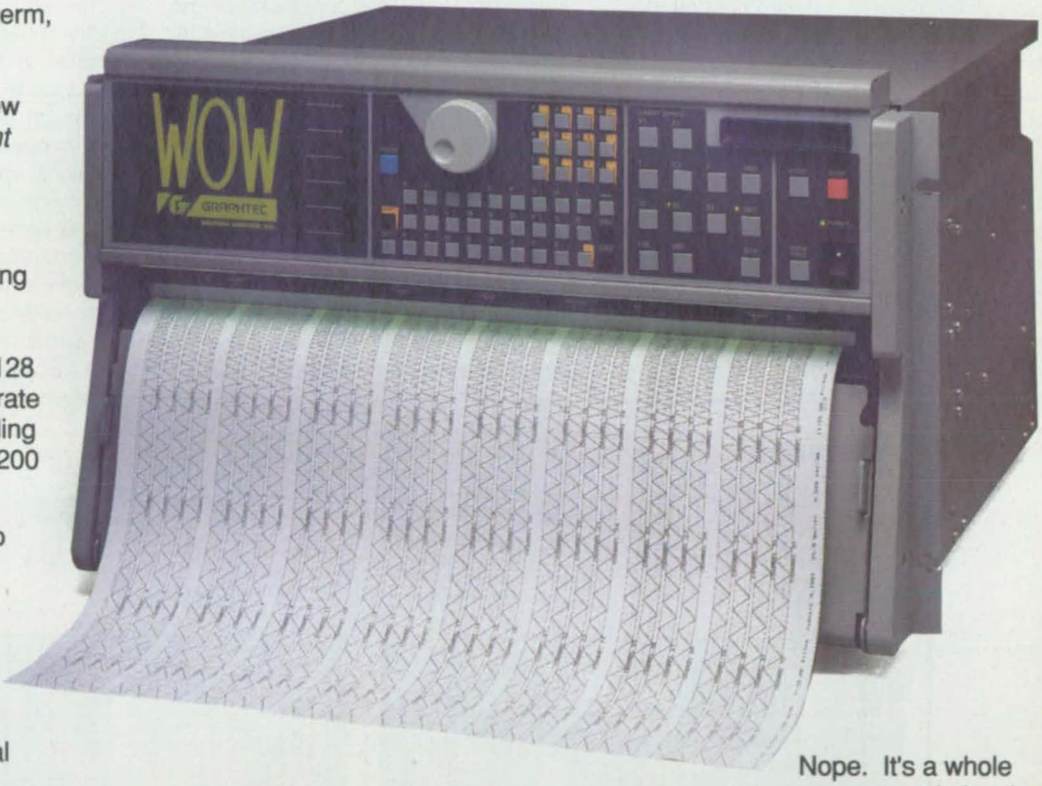

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System for Research on Multiple-Arm Robots

A modular system provides flexibility for programming and control.

NASA's Jet Propulsion Laboratory, Pasadena, California

The Kali system of computer programs and equipment provides an environment for research on distributed programming and distributed control of coordinated-multiple-arm robots. The Kali system is suitable for telerobotics research involving sensing and execution of low level tasks. The software and the configuration of the hardware in Kali are designed to be flexible so that the system can be modified easily to test various concepts in the control and programming of robots, including multiple-arm control, redundant-arm control, shared control, traded control, force control, force/position hybrid control, the design and integration of sensors, teleoperation, task-space description and control, methods of adaptive control, control of flexible arms, and human factors.

The initial Kali system will be implemented specifically for control of multiple coordinated manipulators. At the high level of the Kali system, a collection of functions in the C programming language enable the user to describe and implement coordinated motion of multiple manipulators. At the lower level of the Kali system, processes are distributed over multiple processors in a VMEbus hardware environment (see figure).

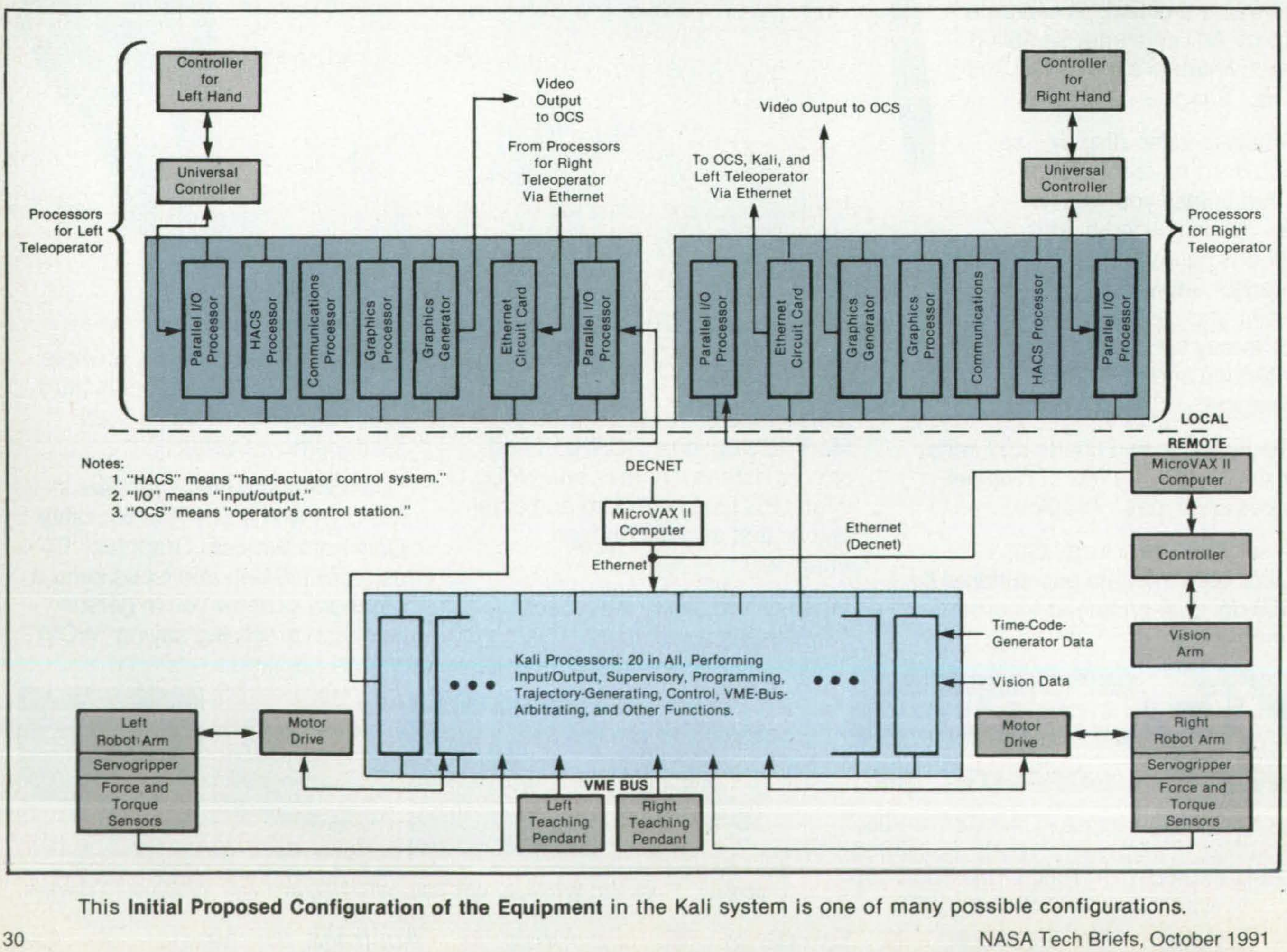
The interface between the user and Kali is intended to provide a software environment in which the user can, as generally and easily as possible, describe (and thereby cause the execution of) a task that requires the motion of one or multiple coordinated arms. This is done by separating the description of the task from the specifics of the underlying mechanical system. The user describes the task in task space; i.e., the motion and forces of a Cartesian frame along with task-space constraints. Underlying constraints on the mechanical system can be specified independently from a specific task and can be considered automatically by the Kali system, which removes the burden of the details of the underlying mechanical system from the user.

The dynamical constraints of the underlying mechanical system are considered in the generation of trajectories. The limitations on the loads that can be applied to a manipulator can be specified, and the Kali system determines a trajectory that does not require the arm to produce forces greater than the specified limits. This requires the user to provide dynamical models of all manipulators and objects.

An important feature of the Kali system is its modular functionality. Modularity simplifies the customization of software and hardware, resulting in a convenient environment for research or customization for a specific installation. Such software modules as those devoted to the generation of trajectories and to servocontrol have defined functionalities that make it possible to replace them without altering other parts of the system.

The equipment was selected for simplicity of implementation, speed of computation, and compatibility with advancing processor technology. The distributed overall design of the equipment in the Kali system provides for parallelization of computations, simplified integration of sensors, and modular functionality of hardware.

This work was done by Paul G. Backes, Samad Hayati, and Kam S. Tso of Caltech, and Vincent Hayward of McGill University for **NASA's Jet Propulsion Laboratory.** *For further information, Circle 142 on the TSP Request Card. NPO-17971*



This **Initial Proposed Configuration of the Equipment** in the Kali system is one of many possible configurations.

Programmable Maintenance Processor for XAIDS

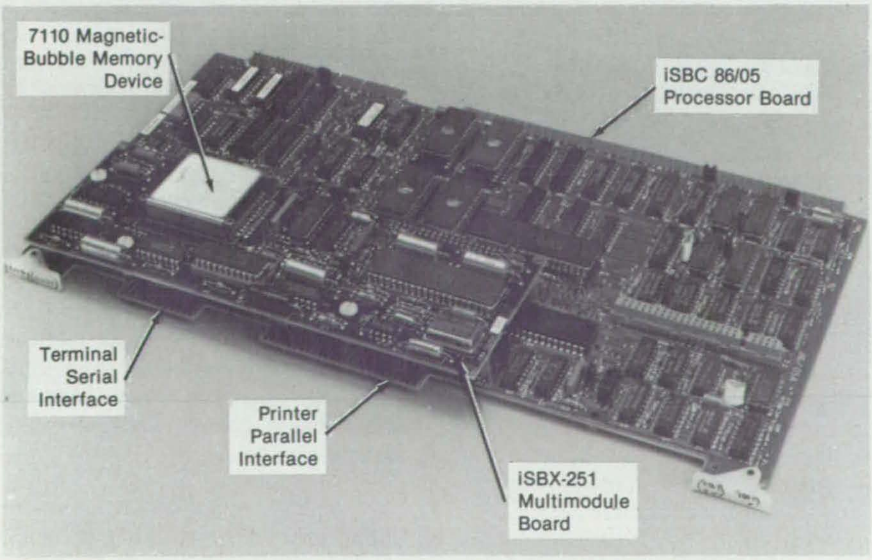
The processor assists in the testing of other digital equipment and programs.

Ames Research Center, Moffett Field, California

The programmable maintenance processor (MAINT) is an autonomous one of four digital electronic processors in the extended aircraft interrogation and display system (XAIDS). Intended to serve as multiprocessing general-purpose ground support equipment for testing digital equipment and programs aboard aircraft, the XAIDS has been evolving during the past decade. The MAINT was developed in response to the need for the testing of system and application computer programs as well as for testing equipment. The MAINT has independent terminal and printer interfaces and a dedicated magnetic bubble memory that stores system-testing sequences entered from the terminal.

The XAIDS MAINT is a single-circuit-board computer that contains an 8086-2, 16-bit microprocessor operating at a clock rate of 8 MHz. It is configured with 8 Kbytes of static random-access memory, four 2732A programmable read-only memories (PROM's) of 16 Kbytes, and a "piggyback" magnetic-bubble-memory module of 128 Kbytes. The jumpers of the magnetic-bubble memory are configured for the polled mode of operation so that no interruptions or direct-memory-access operations are involved.

The serial interface for the terminal is controlled by an 8251A programmable communications interface (PCI) circuit chip on the 86/05 processor board. The PCI, plus its interface driver and receiver chips, are configured for full duplex RS-232 in data-set mode. Any baud rate from 110 to 19,200 can be selected from software using the clock-2 output from the 8253 programmable interval timer chip.



The **Programmable Maintenance Processor** is made of commercially available integrated circuits.

The printer interface is controlled by the 8255A programmable peripheral interface chip on the 86/05 board. Port A is configured for output through an 8287 driver chip on the board and controls the eight printer data lines. Bits PC0 through PC3 of port C are configured for output through a 7408 driver chip. Bit PC0 is used to control the printer-strobe signal, while bit PC3 is used to control the light-emitting diode mounted on the 86/05 board. Bits PC4 through PC7 of port C are configured for input by use of one SBC-902 terminator chip containing four 1,000-Ω pullup resistors. Bit PC4 is to used for the "printer select" signal, bit PC6 is used for the "printer acknowledge" signal, and bit PC7 is used for the "printer busy" signal. Port B is not used but is configured with two SBC-902 terminators.

The software for MAINT is written in PLM86 programming language and is broken into four separate modules: a main program, interruption routines, line-printer routines, and magnetic-bubble-memory routines. These modules are separately compiled using the COMPACT and OPTIMIZE(3) controls that minimize the sizes of the segments of the resulting code. The four object files produced by the compiler are then linked together and located by use of the utilities LINK86 and LOC86. The utility LOC86 is invoked using controls that cause it to generate the PROM bootstrap instruction, the register-initialization code sequence, and the main-program-entry instruction. Thereafter, software for programming the PROM's is used first to create PROM files from the LOC86 output, and then to program the four 2732A PROM's on a universal programmer.

The major contribution of the maintenance-processor concept is improved efficiency in testing of system hardware and software. Experience to date with the magnetic-bubble memory indicates that it has adequate speed and is very reliable, making this type of nonvolatile memory ideally suited for this application. The ability to print out screen displays selectively further speeds testing. Because it is made of off-the-shelf commercial circuitry, the processor is highly cost-effective. Although the MAINT remains idle most of the time, it is nevertheless invaluable when needed (usually on short notice) to gain access to bus-mapped memory or other equipment.

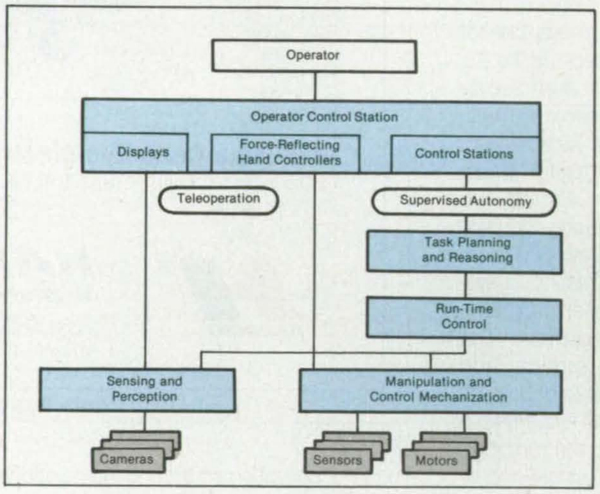
This work was done by Richard Glover of **Ames Research Center**. *Further information may be found in NASA TM-100406 [N88-17333], "Concept of a Programmable Maintenance Processor Application to Multiprocessing Systems."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. ARC-12164

Testbed for Telerobotic Servicing

Various combinations of operator control and robot autonomy can be evaluated.

NASA's Jet Propulsion Laboratory, Pasadena, California



The **Telerobot Testbed** accommodates both human-controlled teleoperation and supervised robot autonomy with five subsystems.

A telerobot testbed is used to evaluate technologies for remote servicing, including assembly, maintenance, and repair. This type of servicing will be used on the Space Station and on the Space Shuttle and satellites in orbit. It could also be used in hazardous and underwater environments on Earth.

With the testbed, the benefits of individual technologies in the overall servicing system can be quantified and recommendations can be made for their use. The testbed operates in several different modes:

- Direct teleoperation with and without force reflection;
- Shared control, in which the human operator controls some aspects of the operation and the remote robot controls other aspects semiautonomously;
- Traded control, in which the human operator plans gross motion and maneuvering of the remote end effector and the robot then performs the task semiautonomously under the supervision of the operator, who can intervene at any time;
- Operator designate, in which the operator, using a video model, registers the location of an object and otherwise identifies the object for the robot for later autonomous robot operations; and
- Relative update, in which the operator points out two objects, such as the workpiece and the robot end effector, and the system calculates the distance between them for use by the robot in carrying out a task autonomously.

The testbed enables the study of the advantages and disadvantages of the modes and the problems encountered in implementing them. The best technologies for implementing these modes can be chosen. It provides delays that simulate the transmission delays between the control stations on the ground and orbiting spacecraft.

The testbed includes five major equipment subsystems (see figure), each consisting of such commercially available equipment as video cameras, computers, and robot arms. One of these subsystems is the operator control station, which provides an efficient, user-friendly interface between an operator and the telerobot, including keyboards, video monitors, hand controllers, mice, and voice inputs. The station provides graphical displays of force and torque measurements. It also provides displays and function switches for a second operator, who observes the telerobot operator and the operation of the system.

The task-planning-and-reasoning subsystem does the high-level planning of tasks and gross motions. It provides menus and a kinematic-simulator capability, which can be used to preview the effects of an operator's command so that collisions can be avoided.

The run-time control subsystem plans fine motions and controls the execution of autonomous operations by the telerobot. It maintains a current data base on the kinematic, dynamic, and inertial properties of the manipulator arms and the objects in the workspace.

The sensing-and-perception subsystem contains the cameras and machine-vision software. It includes a tracker that supplies information about the positions and orientations of objects.

The manipulation-and-control-mechanization subsystem includes one robot arm for cameras and two robot arms for the manipulation of objects, all with six degrees of freedom. This subsystem also includes computers and sensors for force reflection and for autonomous and shared control.

In a contemplated demonstration of its capabilities, the testbed will be used to move a module and place it in a truss structure. First, the operator will remove the module from a platform between the robot arms and insert it into the truss by use of force-reflecting teleoperation. Next, the operator will repeat the task, using the operator-designate function to locate the truss and the place of insertion, the relative-update function to determine the distance between the end effector and a grapple lug on the module, and traded control to move the arm near the insertion slot and turn control over to the robot. Finally, the operator will repeat the task using shared control and a 2-second transmission delay.

This work was done by Jacob R. Matijevic of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 127 on the TSP Request Card.*
NPO-18061

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Circle Reader Action No. 530

Stereoscopic Configurations To Minimize Distortions

Placement of cameras and processing of images can be adjusted to enhance perception of depth.

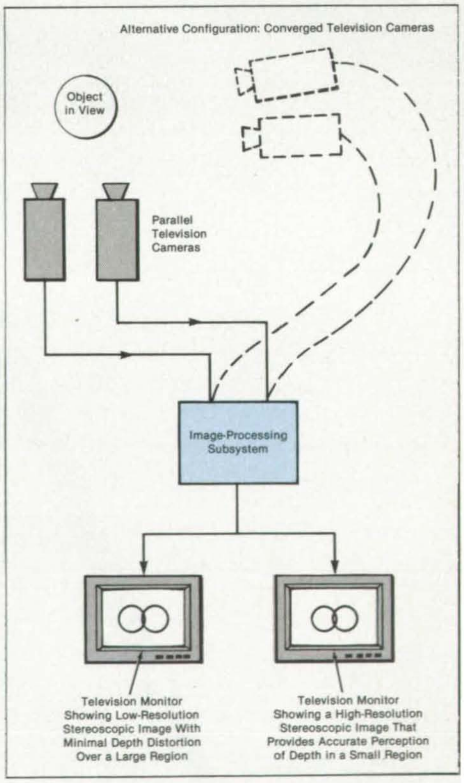
NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed television system would provide two stereoscopic displays (see figure) each of which would minimize a different subset of the geometric distortions that appear in stereoscopic views. The proposed system is based on an extensive theoretical analysis of the depth distortions of a space viewed by stereoscopic television. Potential applications include industrial, medical, and entertainment imaging and the monitoring and control of telemanipulators, telerobots, and remotely piloted vehicles.

One of the problems addressed by the theoretical analysis is that of tradeoffs among maximization of depth and spatial static resolutions, minimization of static depth distortion, and minimization of dynamic depth distortion caused by motion of the cameras and/or the viewed object. For example, in a stereoscopic system of two cameras and one monitor, the cameras could be configured for high resolution. However, this configuration would almost always result in high static and dynamic depth distortion, with consequent degradation of the performance of a human operator attempting to control a telemanipulator in the workspace.

The theoretical analysis shows, among many other things, that for converged cameras, the size of the image on the monitor can be adjusted to minimize the dynamic depth distortion. It also shows that even in an image so optimized in size, the apparent depth can be made to vary linearly with respect to real depth on only three planes in the workspace. These planes are perpendicular to the line between the observer's eyes. For these planes, graphical overlays are useful. The analysis also shows that for parallel television cameras, the size of the image could be adjusted to reduce the static and dynamic depth distortion to zero.

In the proposed system, the configura-



The **Two-Camera, Two-Monitor** television system could be used in various camera configurations and with stereoscopic images on the monitors magnified to various degrees. The system would be designed to satisfy the observer's need to perceive spatial relationships accurately (at the price of low resolution) throughout a workspace or to perceive them at high resolution in a small region of the workspace.

tion of the two cameras and the sizes of the images on the two monitors would be tailored to the distance between the observer's eyes, according to the results of the analysis. The image data acquired by the two cameras would be used to generate both stereoscopic displays. Optimally, the cameras would be aimed parallel. The images on one monitor would be optimized for high depth resolution in a selected portion of the scene; the images on the other monitor would have lower resolution but would provide the viewer with a true-to-scale 3-D representation of the entire scene; that is, with no distortions at all.

This work was done by Daniel B. Diner of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 96 on the TSP Request Card.*

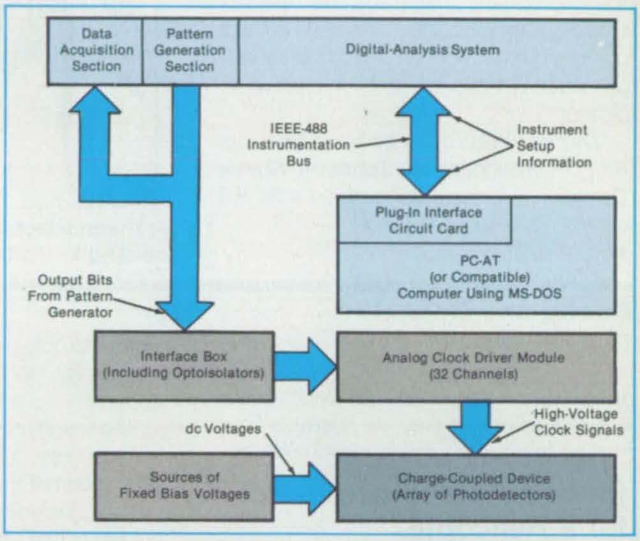
This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 16]. Refer to NPO-18028.

Flexible Generation of Array-Detector Timing Signals

Timing patterns can be changed easily via software.

Goddard Space Flight Center, Greenbelt, Maryland

An assembly of some custom-made electronic equipment and some multipurpose commercial electronic equipment commonly found in electronics-development laboratories facilitates the generation and modification of timing pattern signals for the control of array detectors; that is, imaging arrays of photodetectors, (for example, charge-coupled-device arrays). The assembly (see figure) is designed to serve as a flexible electronic array-detector-testing apparatus that can be configured via software; timing patterns can be created, stored, and changed easily. Thus, the assembly can be prepared for the experimental evaluation of a new detector design in much less time and for less expense than would be necessary to construct special circuits to generate all the timing patterns to be tried on the new design.



This **Array-Detector-Driving System** is an assembly of commercial and custom-made equipment that can be configured easily and quickly via software to test detectors with a large variety of timing pattern signals.

The most important piece of equipment in the assembly is a commercial digital analysis system, which comprises a logic analyzer with a pattern-generator section and a data-acquisition section. The pattern generator simultaneously puts out a bit pattern and executes one of the instructions in its set: "no operation," "go to," "call," "return," "repeat," "hold," and "halt." This enables the creation of an algorithm that executes the few basic detector operations the correct number of times and in the correct order.

After the pattern generator bits have been assigned to the clock signals required to operate the detector, the algorithm is created and entered on the screen of the pattern generator. The output bits from the pattern generator are both sent to an analog clock driver module and looped back to the data-acquisition section of the digital-analysis system so that the timing patterns can be viewed in a graphic format.

The digital analysis system communicates via a standard instrumentation bus and a plug-in interface circuit card with a personal computer. Application software enables the user to store a complete description of the state of the instrumentation (including the pattern-generator program) in compressed binary file format on the hard or floppy magnetic storage disks of the computer.

The analog clock driver module, which is built in-house, accepts the logic signals from the pattern generator. It performs voltage-translating and buffering functions on these signals so that they can be applied to the detector under test. This module can drive as many as 32 independent electrodes on the detector, with flexible configuration of the voltage-translation levels.

An interface box, also built in-house, couples signals while it provides electrical isolation (via optocouplers) between the digital analysis system and the analog clock driver module. The interface box also serves as a convenient means of assigning pattern-generator bits to channels of the analog clock driver module.

This work was done by Jeffrey W. Travis and Peter K. Shu of **Goddard Space Flight Center**. *For further information, Circle 163 on the TSP Request Card.*
GSC-13345

Sensing Temperatures Via Prostheses and Manipulators

Heat and cold are applied to the operator's back.

Lyndon B. Johnson Space Center, Houston, Texas

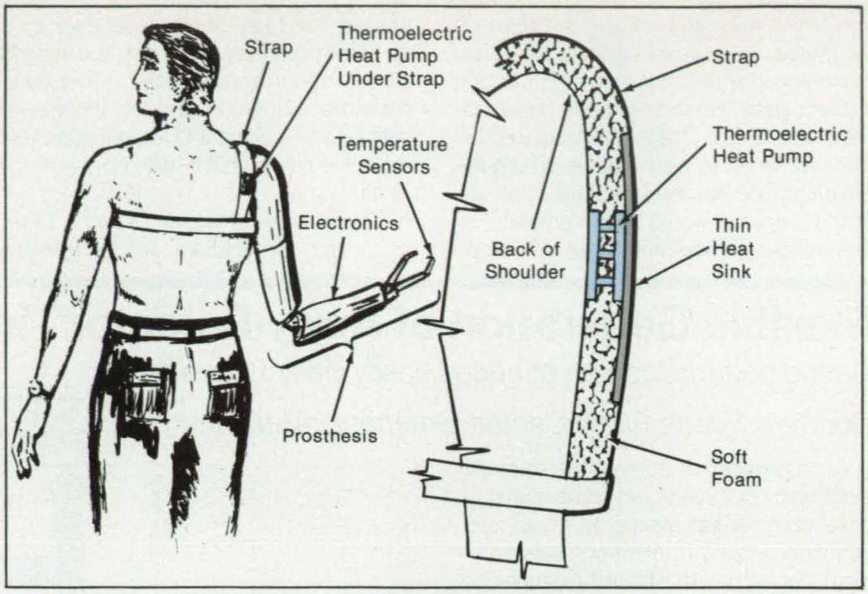
A proposed temperature-sensing system would apply heat to (or remove heat from) a human user's skin according to the temperature of a remote object. The system would be used in artificial limbs and in telerobotic manipulators.

In a prosthetic arm and hand, for example, temperature sensors on the tips of the artificial fingers would send signals to an electronic control network that would drive a small, lightweight thermoelectric heat pump worn on the back of the user's shoulder (see figure). The heat pump would heat or cool the skin according to the signals from the temperature sensors. Unlike in a prior temperature-sensing system for prostheses, it would not be necessary to implant electrodes in the skin to transmit the sensation of temperature. The heat pump and control network would be worn like an article of clothing. A limiting circuit would prevent the heat pump from heating or cooling the skin excessively.

In manual control of a remote robot, temperature sensors would be placed in the fingers of a remote manipulator. The sensors would drive, via a similar electronic control network, thermoelectric heat pumps in the fingers of a glove worn by the operator, who would then have the benefit of information about the temperatures on the manipulated object, in addition to the usual information from tactile sensors. A sensing system of this kind could also be incorporated in a protective garment to give a wearer more complete information on the environment.

Yet another potential application is as an emergency alarm. For example, an operator in a chemical or power plant could wear a light glove with thermoelectric heat pumps in the fingers, each representing the condition of a process variable. An out-of-limits condition would produce heat in the appropriate finger, and the operator would quickly perceive a potentially hazardous situation without having to look in any particular direction to observe a panel indicator.

This work was done by Mike Zerkus of Krug International for **Johnson Space Center**. *For further information, Circle 153 on the TSP Request Card.*
MSC-21676



A **Thermoelectric Heat Pump** would heat or cool skin on the back of the shoulder, according to the temperature sensed by the fingertips of the prosthesis.

Books and Reports

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

Precise Autohover Control for a Helicopter

A control system attempts to maintain a constant horizontal position.

A report describes the development and testing of an experimental precise autohover control system for a helicopter. This work is part of a continuing effort to develop such systems for the next generation of military rotorcraft. The principal design requirement for a precise autohover control system is the ability to maintain a nearly constant horizontal position while operating in a strong wind. The requirement for precision in the maintenance of horizontal position is severe because the helicopter is expected to operate in proximity to obstacles.

The experiments were performed on a CH47 variable-stability research helicopter equipped with a position-measurement subsystem that used acceleration, velocity, and position inputs from accelerometers, rate gyroscopes, Doppler radar, a radar altimeter, and a ground-based laser tracking system. The pilot can actuate a switch to mark the reference horizontal position, which the system then attempts to maintain, even during sudden climbs or descents, or when the helicopter is turned about the vertical axis. In the experimental autohover system, measurements from the laser tracking system were transmitted to the flight computer aboard the helicopter, where they were combined with measurements from the sensors aboard the helicopter to obtain precise position feedback for use by the horizontal-position-holding system.

The report provides a brief description of the helicopter, followed by a more detailed description of the position-measuring subsystem, including the means for filtering out unwanted transients and biases. Then it describes the mathematical model used in the design of the horizontal-position-holding system. Next, the report presents data on the performance of the autohover system in strong winds. It concludes with a discussion of the relationships between the design and the observed performance and discusses the implications for future design efforts.

This work was done by W. S. Hindson and G. E. Tucker of **Ames Research Center**. *To obtain a copy of the report, "Development and Flight Test of a Precision Autohover Capability for Tactical Rotorcraft," Circle 4 on the TSP Request Card.*
ARC-12243

More About Video-Feedback Docking System

Retroreflective targets are described in more detail.

Two documents provide additional information on the system described in "Docking System With Video Feedback" (MFS-28421), *NASA Tech Briefs* Vol. 15 No. 3, 1991, p. 31. To recapitulate: The docking system is a video-sensor/electronic-feedback control system. A video camera on an active or chasing vehicle views a target on a passive or chased vehicle. The target could be illuminated by light-emitting diodes on the active vehicle. An image-data-processing subsystem converts the video image of the target into data on the relative position, orientation, linear velocity, and angular velocity of the two vehicles. These data are then used by a maneuver-control subsystem to control the approach of the active vehicle to the passive vehicle.

The first document, "Standard Remote Manipulator System Docking Target Augmentation for Automated Docking," emphasizes the use of retroreflectors in the target. The retroreflective patches mentioned in the noted previous article could be made of retroreflective tape. Alternatively, the target could include corner-cube reflectors, other retroreflectors of various sizes and shapes, or a combination of reflectors and narrow-band optical filters to increase the signal-to-noise ratio in the image of the target.

The second document, "Development of a Video-Based Automatic Rendezvous and Docking System," is a technical paper from the Conference on Robots in Aerospace Manufacturing (February 20–23, 1989) sponsored by the Society of Manufacturing Engineers. This document represents the first public disclosure of the docking system. It describes the hardware and software of the system. It also describes an experimental apparatus in which selected aspects of the active vehicle were to be simulated by an air-bearing vehicle maneuvered horizontally by jets of compressed air under control by a computer.

This work was done by Richard Howard, Richard Dabney, and Thomas Bryan of **Marshall Space Flight Center**. *To obtain copies of the reports, Circle 149 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 16]. Refer to MFS-28419.

Physical Sciences

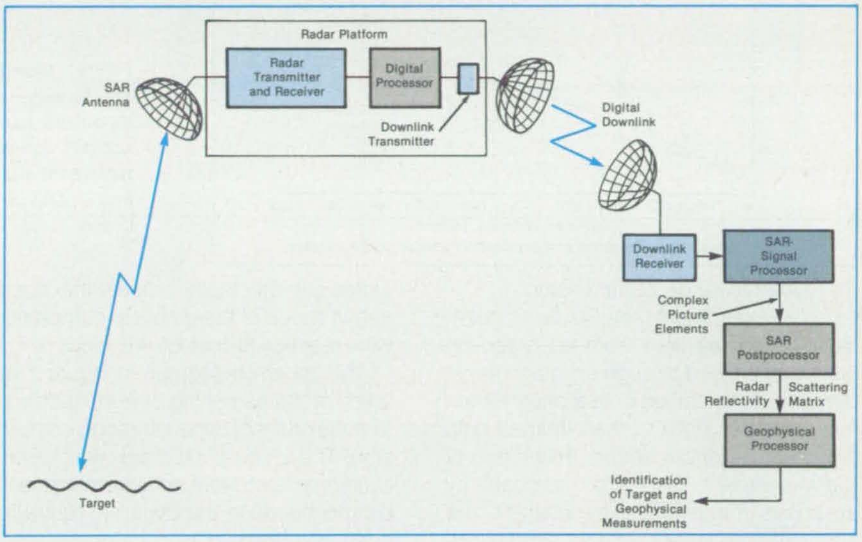
Improved Radiometric Correction for SAR Images

A correction algorithm is reversible and applicable to both detected and complex images.

NASA's Jet Propulsion Laboratory, Pasadena, California

A method has been developed for the radiometric calibration and correction of synthetic-aperture-radar (SAR) images that account for the primary sources of calibration error. Using calibration data estimated from the system itself, the "end-to-end" radiometric performance (with respect to amplitude only, not phase) of a radar system can be estimated and applied in processing raw SAR data into images such that the local brightness represents the radar reflectivity or radar cross section of the corresponding local terrain. The method is implemented by an algorithm that is reversible, so that one can, in principle, recover the raw SAR amplitude data from the calibrated imagery. The method is applicable to both detected (amplitude-only) and complex (amplitude and phase) SAR image data and provides for the optional subtraction of the estimated noise floor from the image.

The method is based on the development of appropriate equations for the power in the radar signal returned by both point and distributed targets. It accounts for the effects of processing on the apparent power. One particularly noteworthy consideration is attention to the proper dependences of the processed signal and noise powers on the slant range. These terms depend, in turn, on the form of the applied azimuth reference function used in the azimuth-compression stage of processing of image data and are needed to normalize the azimuth reference function.



A **Synthetic-Aperture-Radar System** can be viewed as a multistage radiometric system in which each stage affects the calibration. The method described in the text accounts for the major effects of the transmitter, antenna, receiver, and certain aspects of the SAR signal processing upon the calibration and provides for appropriate reversible corrections that can be applied in processing.

The relative calibration is performed by selecting a reference value for each parameter in the applicable equation and normalizing, across all images, each picture element in the image of interest by the ratio of the reference value to the estimated value of that parameter for that picture element. The absolute calibration for a distributed target is then given by a scale factor and a bias term. All corrections can be incorporated into the normal signal-processing chain without adding any stages that would require an additional pass over the data.

This work was done by Anthony Freeman and John C. Curlander of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 76 on the TSP Request Card.* NPO-17931

Photorefractive Crystal Compresses Dynamic Range of Image

Predetection dynamic-range compression in real time could prevent saturation in images.

NASA's Jet Propulsion Laboratory, Pasadena, California

An experiment has shown that the dynamic range of the spatial variation of illumination within an image can be compressed by use of a photorefractive crystal. Provided that the brightness of parts of a scene vary as slowly as or more slowly than a photorefractive crystal responds, this effect could be exploited to provide real-time dynamic-range compression to prevent saturation of bright areas in video or photographic images of the scene, thereby helping to preserve the spatial-variation information in such images. In this dynamic-range-compression technique, the photorefractive crystal would be placed in the optical path at some stage preceding the video camera, photographic camera, or final photodetector stage.

The technique relies on scattering of light from inhomogeneities in the photorefractive crystal. Interference between the scattered and incident light acts, via the photorefractive effect, to create random microscopic diffraction gratings in the crystal. The incident light is scattered further by the random gratings, reducing the intensity of the transmitted (the surviving portion of the incident) beam. The overall scattering effect is nonlinear; the more intense is the incident beam, the faster the scattering builds up, and the greater is the proportion of light scattered. This nonlinearity is the phenomenon responsible for

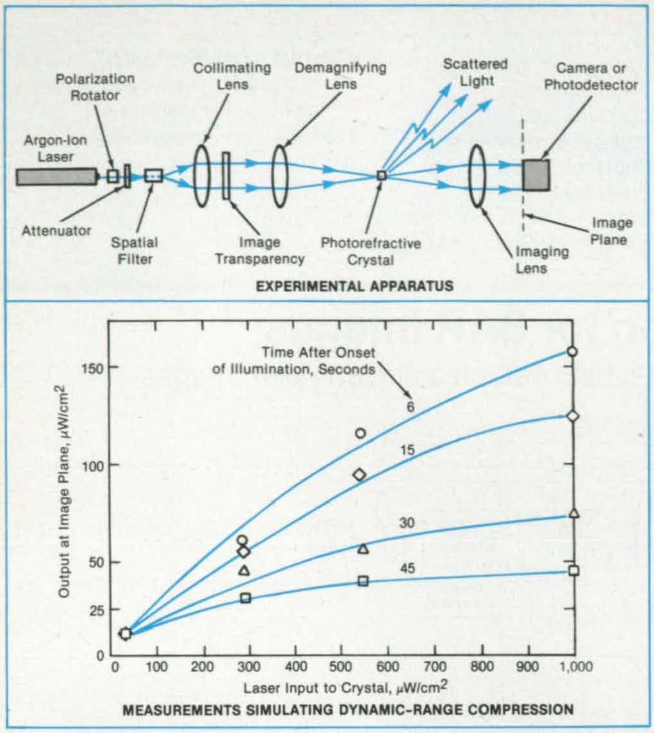


Figure 1. **Nonlinear Scattering From Inhomogeneities** in the photorefractive crystal compresses the dynamic range of the image formed on the camera or photodetector.

Without Dynamic-Range Compression

Figure 2. **More Details Emerge** when dynamic-range compression eliminates saturation in bright parts of the image.

With Dynamic-Range Compression

the dynamic-range compression.

In the experiment (see Figure 1), polarized, collimated light from an argon-ion laser was passed through an image transparency, demagnified onto a photorefractive crystal of $BaTiO_3$, then imaged onto a photodetector or camera. In one part of the experiment, the image-transparency area was made totally transparent, the luminous-flux density incident on the crystal was varied, and the luminous-flux density incident on the image plane was measured by the photodetector. The plot in the lower part of Figure 1 shows the input-vs.-output curves for various times up to 45 s after the onset illumination. These curves clearly indicate that the dynamic range of the output is compressed with respect to that of the input.

The upper photograph in Figure 2 was taken at the beginning of illumination, before the onset of dynamic-range compression. The lower photograph was taken a short time later. More details emerge in this picture because the dynamic range has been compressed.

This work was done by Hua-Kuang Liu of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 73 on the TSP Request Card.*

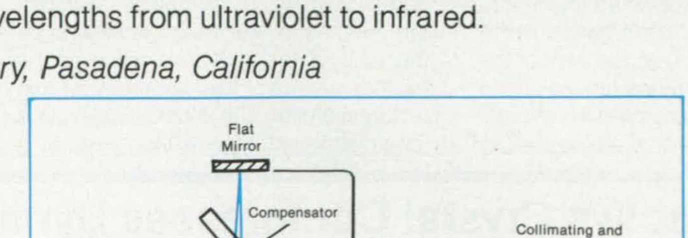
This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 16]. Refer to NPO-18098.

Broadband, Achromatic Twyman-Green Interferometer

Specimens can be tested at wavelengths from ultraviolet to infrared.

NASA's Jet Propulsion Laboratory, Pasadena, California

An improved Twyman-Green interferometer can be used in wave-front testing optical components at wavelengths from 200 to 1,100 nm, without having to readjust the focus when changing the wavelength. This interferometer was built to measure the aberrations of light passing through optical filters. It overcomes some of the limitations of classical Twyman-Green interferometers; namely that (1) they are useful in visible light only (wavelengths from 400 to 700 nm) because the lenses in them transmit poorly at other wavelengths and because human eyes and conventional photographic films are insensitive at other wavelengths, (2) the visibility of the interference fringes is often poor, making use difficult and tedious, and (3) shifts in focuses caused by axial chromatic aberration in the lenses degrade the interferograms.



The **Broadband, Achromatic Twyman-Green Interferometer** operates at wavelengths from 200 to 1,000 nm, without the need to readjust the focus when changing the wavelength.

The improved apparatus (see figure) is denoted the "broadband achromatic Twyman-Green interferometer." The collimating and imaging lenses of the classical Twyman-Green configuration are replaced by a single spherical mirror. The field lens is replaced by a field mirror. Unlike lenses, mirrors exhibit no axial chromatic aberration and can be made to reflect light efficiently over the desired broad range of wavelengths.

The glass beam splitter and compensator of the classical version are replaced by corresponding elements of fused silica, which is more transparent to ultraviolet. The beam-splitting layer is a thin film of aluminum, which reflects approximately the same fraction of the incident energy at all wavelengths in the desired range. A small, relatively-low-resolution monochromator is used in several orders to cover the broad wavelength range. Two or three types of light sources are also necessary.

Whereas the human eye or photographic film is the final imaging detector in the classical version, in this version the imaging detector is a charge-coupled-device television camera that is modified to enhance its sensitivity to ultraviolet light. The modification consists in removing the cover windows and coating the surface of the charge-coupled device with coronene, which fluoresces visibly under ultraviolet light.

The use of the single concave spherical mirror both to collimate and to image makes it possible to build a more compact instrument. At first glance, it might seem foolish to use such a mirror because it introduces huge aberrations into the wavefront. However, provided that the lengths of the T and R optical paths are equal, the apparatus can still produce straight, parallel, and equally spaced interference fringes, because the deviations of both interfering wavefronts from a perfect plane are identical and, therefore, cancel in the interference pattern. The requirement for equal path lengths is met automatically because the coherence path length of the light from the monochromator is only a few microns. The interference fringes cannot be seen unless the path lengths are equal.

This work was done by Lawrence J. Steimle of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 53 on the TSP Request Card. NPO-17675*

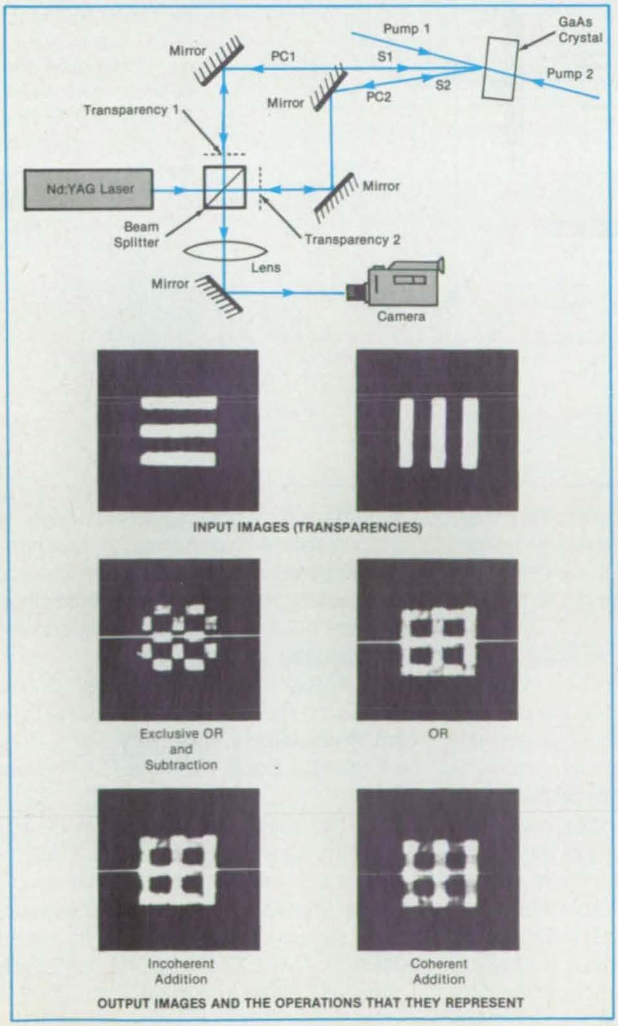
Improved Interferometric Photorefractive Optical Processor

Processing speed is increased substantially.

NASA's Jet Propulsion Laboratory, Pasadena, California

An improved optical interferometric image-processing scheme is based on four-wave mixing via the photorefractive effect in GaAs or InP. The four-wave mixing gives rise to index-of-refraction gratings that act as phase-conjugate mirrors: the interactions among the four input beams generate wave-front-reversed replicas (phase conjugates) of two of these beams. Each phase-conjugate beam travels precisely back along the path of the corresponding input beam, regardless of the angle of incidence. Any distortions introduced into the input beam during forward propagation are removed from the phase-conjugate beam during backward propagation. In contrast, a conventional flat mirror merely reflects each beam and increases the distortion.

This **Four-Wave-Mixing Apparatus** was built to illustrate the principle of fast optical processing by use of the photorefractive effect in an interferometric configuration. The output images illustrate some of the mathematical operations that are obtained at various alignments of S1 and S2.



Prior interferometric image-processing schemes based on this effect involved such photorefractive oxides as $BaTiO_3$ and $Bi_{12}SiO_{20}$. Because of the relatively long photorefractive-response times of these oxides, the index-of-refraction gratings cannot change rapidly enough to provide the desired speed of operation. They also cannot change rapidly enough to stabilize operation in the presence of such environmental fluctuations as air turbulence and vibrations of optical components. The improved scheme can provide the required operating speed because the photorefractive responses of GaAs and InP are of the order of 100 times as fast as those of the photorefractive oxides.

In a demonstration of the improved scheme (see figure), light from a neodymium:yttrium aluminum garnet (Nd:YAG) laser at a wavelength of 1.06 μm was split into two coherent beams: S1 and S2. These beams were reflected along different optical paths that intersected in a GaAs crystal. Each of these optical paths included a transparency that contained one of two images to be processed with each other.

Beam pump 1, which was generated by the same laser and is coherent with S1 and S2, was also aimed at the point of intersection of S1 and S2. The interference between pump 1 and each of S1 and S2 created two index-of-refraction gratings oriented at slightly different angles. Beam pump 2, which was also generated by the same laser but was not coherent with the other beams, was aimed at the intersection of the other beams along the axis of pump 1 from the opposite direction. Parts of pump 2 were diffracted by the two gratings, forming beams PC1 and PC2, which were the phase conjugates of S1 and S2, respectively.

PC1 and PC2 were combined in the beam splitter, forming an output beam that was imaged in a vidicon camera sensitive to infrared. Because the output image was the interference pattern of PC1 and PC2, its appearance depended on the alignment of S1 and S2. This alignment could be altered to obtain different mathematical operations on the images in the transparencies.

This work was done by Li-Jen Cheng and Tsuen-Hsi Liu of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 80 on the TSP Request Card.*

NPO-17773

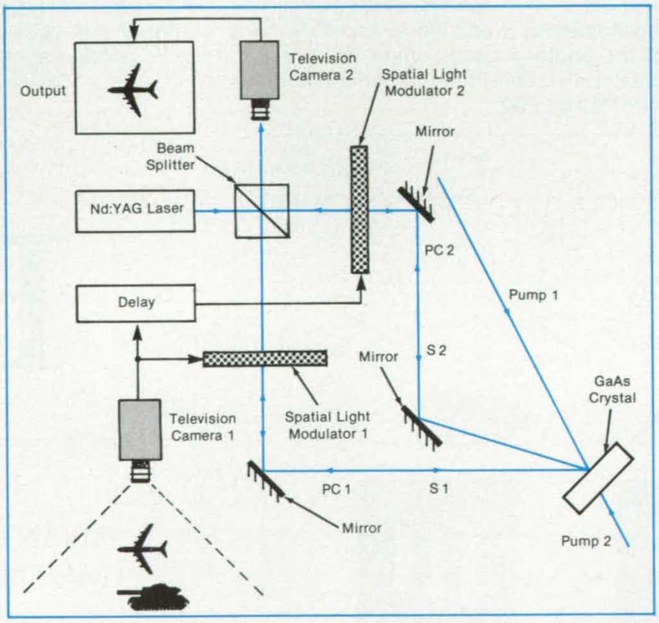
Detection of Motion With a Phase-Conjugate Mirror

A photorefractive image-processing apparatus acts as a novelty filter.

NASA's Jet Propulsion Laboratory, Pasadena, California

A photorefractive image-processing apparatus generates images of rapidly moving objects and suppresses images of stationary and slowly moving objects. This apparatus is an optical analog of the tracking novelty filters that have been used since the early days of radar to keep images from being cluttered by stationary objects. Although novelty filters can be implemented easily via digital processing, optical processing is analogous to massively parallel digital processing and, for this and other reasons, is potentially much faster.

The apparatus (see figure) resembles the one described in the preceding article, "Improved Interferometric Photorefractive Optical Processor" (NPO-17773). The principle of operation is similar, except that the system includes two video cameras and instead of transparencies, electro-optical spatial light modulators are used to impress the image information from video camera 1 on laser beams S1 and S2. The image pattern is transformed in the spatial light modulator to a corresponding pattern of variations of the index of refraction and, equivalently, of the length of the optical path. Beams S1 and S2 are aligned in such a way that the apparatus acts as image subtractor; that is, the output image in video camera 2 shows the difference between the two input images.



This **Refractive Image-Subtracting Apparatus** operates on the four-wave-mixing principle of the similar apparatus of the previous article. In this case, the output image consists of the rapidly varying part of the input image.

The input image fed to one of the spatial light modulators is delayed by a preset interval. In those parts of the scene in which objects are stationary or moving slowly with respect to both the delay and the response time of the photorefractive crystal, the image-subtraction process yields no output image. When an object in the scene moves rapidly enough to give rise to an observable difference between the immediate and delayed input images, the image-subtraction process puts out the difference image, which is the image of the moving object.

The minimum detectable speed is approximately the spatial resolution of the apparatus as a whole divided by the photorefractive-response time (the time required to form the index-of-refraction gratings). This response time depends on the photorefractive material (in this case, GaAs) and is proportional to the square of the spatial period of a grating and inversely proportional to the intensity of illumination. Both of these quantities can be varied to obtain a response time between tens of microseconds and a large fraction of a second. At the shortest response times, the gratings can adjust rapidly enough to accommodate themselves to mechanical vibrations and air turbulence, thereby suppressing image noise that would otherwise be generated by such environmental fluctuations.

This work was done by Li-Jen Cheng and Tsuen-Hsi Liu of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 75 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 16]. Refer to NPO-17784.

Books and Reports

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

Calculating Electronic Spectra of Diatomic Molecules

Studies of vehicles reentering the atmosphere require knowledge of nonequilibrium effects.

A NASA technical memorandum discusses recent advances at NASA in the calculation of electronic spectra of diatomic molecules. The document appears to be based partly on a lecture given at a conference sponsored by the Hungarian Academy of Sciences in honor of professor I. Kovacs, an internationally recognized authority on the topic and author of the textbook *Rotational Structure in the Spectra of Diatomic Molecules.*

The discussion begins with an introductory section that places the recent advances in the historical context of international scientific missions in outer space. The next section gives an overview of the proposed National Aerospace Plane and the proposed Aeroassisted Space Transfer Vehicle (ASTV), both of which are intended to fly in the atmosphere at high speeds and high altitudes for relatively long times. Extensive portions of the air flowing around these vehicles will not be in chemical or thermal equilibrium, and one of the consequences will be increased radiative heating of the vehicles. The design of these vehicles for safety and efficiency requires understanding of the radiative heating from nonequilibrium flows; this, in turn, requires spectroscopic research and the development of engineering methods based on spectroscopic techniques and results.

The next section discusses the proposed Aeroassist Flight Experiment (AFE), in which a test vehicle intermediate in the development of the ASTV will be flown and radiometric data crucial to understanding the excitation mechanisms and chemistry of the flow field around the vehicle will be taken. The authors note that the interpretation of these data would involve a complex interplay of predictions based on various flow-field, chemical, excitation, and radiation models. The signal recorded by each radiometric instrument would be an integral of all optical effects taking place within the view field and optical bandpass of that instrument. The principal tool for interpretation of these data would be the flow-field solution being developed by experts in various aspects of computational fluid dynamics. The accuracy of the flow-field solution would depend upon realistic mathematical models of chemistry and excitation, and upon accurate reaction rates, cross sections, partition functions, transport properties, and transition moments in gases characterized by multiple temperatures, some of which are well above the temperatures at which reliable experimental data are now available.

The next section discusses a new computer program for the calculation of high-resolution spectra of any spin-allowed transitions in diatomic molecules. It is based on direct diagonalization of the Hamiltonian matrix. It includes the matrix elements for rotational energy and rotational distortion up to fourth order; spin–orbit, spin–spin, and spin–rotation interactions to first order; and the Λ splitting by a perturbation calculation. This program will be used to help understand the radiative transport of energy at wavelengths from 1,000 to 2,000 Å in the flow field of the AFE.

The next section describes the Computational Chemistry Branch at Ames Research Center. It presents examples of the research there in gas-phase and gas/surface interactions. The gas-phase work is further subdivided into molecular properties, reaction rates and scattering, and transport properties and cross sections. The gas–surface work is subdivided into metallic and polymer surfaces. For each of these subdisciplines, selected molecular systems or reactions that have been studied recently are listed to illustrate the broad range of topics covered.

This work was done by John A. Paterson of **Ames Research Center** *and Ellis E. Whiting of Eloret Institute. Further information may be found in NASA TM-101034 [N89-12622], "Recent Advances at NASA in Calculating the Electronic Spectra of Diatomic Molecules."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.
ARC-12412

Materials

Deposition of Diamondlike Films by ECR Microwave Plasma

Negative dc self-bias induced by radio-frequency bias appears to be essential.

NASA's Jet Propulsion Laboratory, Pasadena, California

Hard, amorphous hydrogenated carbon (a-C:H) films of diamondlike quality have been deposited at room temperature on silicon, optical glass, and quartz through the decomposition of CH_4 in an electron-cyclotron-resonance (ECR) microwave plasma of CH_4 diluted with H_2. This technique could provide hard, abrasion-resistant coatings for lenses and other optical components. In addition, a-C:H diamondlike films are chemically inert and posses high electrical resistivity and breakdown fields, valuable properties in microelectronics applications.

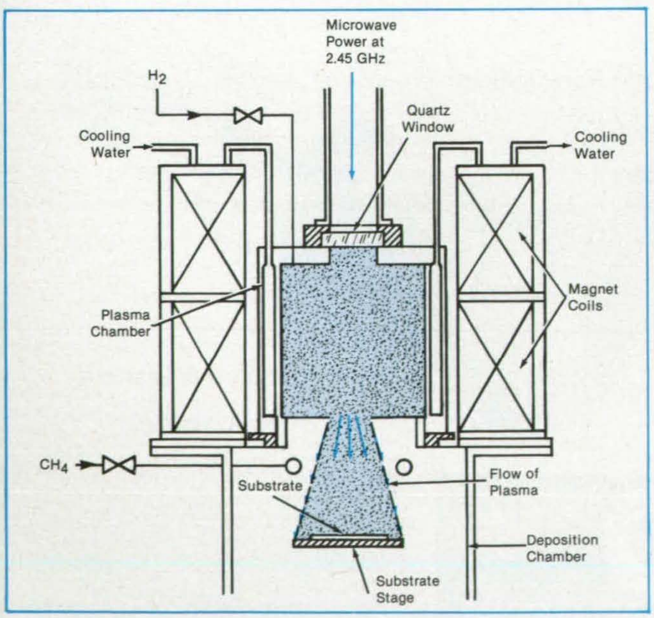
The apparatus used in experiments on the deposition technique is shown schematically in Figure 1. The ECR plasma is generated by 2.45-GHz microwaves transmitted in a rectangular waveguide and coupled to the plasma chamber via a symmetric mode coupler and a quartz window. Electron resonance at 2.45 GHz occurs at a magnetic field of 875 gauss. Two coaxial coils mounted approximately 33 cm apart supply the confining magnetic field in a magnetic-mirror configuration.

Directly below and connected to the plasma chamber is the deposition chamber, within which the deposition substrate is mounted on a stage. The substrate stage is approximately 15 cm below the aperture leading to the plasma chamber and is electrically isolated from the system ground. The CH_4 enters through a circular gas ring in the deposition chamber. All depositions were made at a microwave power of 360 W on substrates that had been prepared by ultrasonic cleaning in acetone, isopropyl alcohol, then deionized water, for 5 min. each.

In the experiments, it was found that the application of no bias or of external negative dc bias to the substrate stage failed to produce hard a-C:H films under a wide range of deposition conditions: the films, deposited at rates of 2 to 3 Å/s, were mechanically soft and had optical energy-band gaps (E_g's) of approximately 2.8 eV. The films had broad fluorescence in the wavelength range of 450 to 650 nm that prevented the measurement of their Raman spectra. Apparently, because of charging of the substrates and films (since both are excellent insulators), external dc bias is not sufficient to obtain the incident ions at the kinetic energies of 10 to 50 eV that are necessary to produce hard, diamondlike films.

In contrast, hard films were produced when a 13.56-MHz radiofrequency bias was applied to the substrate stage, giving rise to a self-induced negative dc bias. Raman spectra indicate the deposition of films of two distinct types (see Figure 2): one exhibiting well defined bands at 1,360 and 1,580 cm^{-1} (the graphitic D and G

Figure 1. This **Electron-Cyclotron-Resonance (ECR) Microwave Plasma** system deposits a-C:H films on a variety of optical substrates.



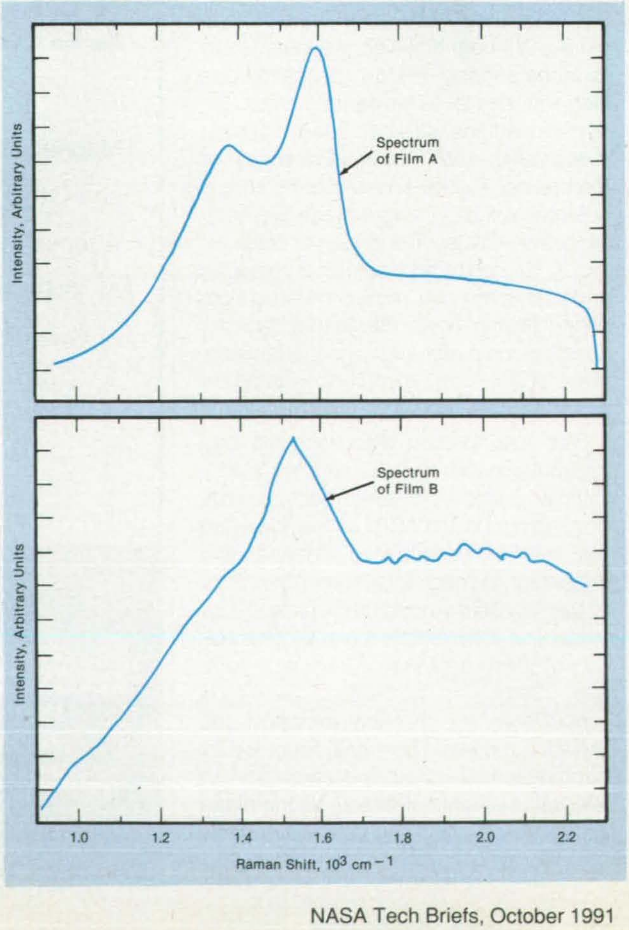


Figure 2. **Two Types of Raman Spectra** were exhibited by diamondlike films deposited with a radiofrequency-induced negative self-bias (V_{sb}) of the substrate stage. Film A was deposited with V_{sb} = -3 V at 30 W radio-frequency power. Film B was deposited at 5 W and V_{sb} = -100 V.

bands), another displaying a broad Raman peak centered at approximately 1,500 cm^{-1}. The E_g's of these films ranged from 1.0 to 1.6 eV, and their electrical resistivities were greater than 10^{12} Ω•cm.

A comparison of the Raman spectra and optical gaps indicates that there is more than one hard diamondlike film molecular structure for a given E_g. Moreover, the characteristics of a film depend on the profile of the magnetic field used during deposition: decreasing the mirror magnetic field was found to increase the E_g by increasing the kinetic energy of the ions extracted from the confinement region between the two coils. Decreasing the pressure in the chamber was found to increase E_g. This seems reasonable inasmuch as a decrease in pressure should result in an increased energy of incident ions because less energy would be lost in collisions. These latter results follow a trend opposite to that observed in radiofrequency-plasma depositions, in which increasing the self-bias (and, thereby, the energy of incident ions) reduces E_g.

This work was done by Frederick S. Pool and Yuh-Han Shing of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 121 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 16]. Refer to NPO-18094.

Reactive Fluorescent Dyes for Urethane Coatings

Unlike prior fluorescent dyes, these would not outgas.

NASA's Jet Propulsion Laboratory, Pasadena, California

Molecules of fluorescent dyes would be chemically bound in urethane conformal-coating materials to enable the nondestructive detection of flaws in the coats through inspection under ultraviolet light, according to a proposal. This dye-bonding technique would prevent the outgassing of the dyes, making the coating materials suitable for use where flaw-free coats must be assured in instrumentation or other applications in which contamination by outgassing must be minimized. In contrast, the nonbonding fluorescent dyes in current use outgas and are, therefore, unacceptable in such applications.

In the dye-bonding technique, the dye molecules would be incorporated as integral parts of the polyurethane coats. This chemical incorporation of a dye would involve the chemical modification of the dye to make it react with the two-part urethane mixture. A small amount of the modified dye would be added to the mixture before curing it. Once the curing reaction was complete, the dye would impart permanent fluorescence.

Such chemically modified dyes may include those with hydroxy, amine, or isocyanate functional groups, amine or hydroxy groups being preferable because of their insensitivity to moisture. Examples of such fluorescent compounds include, but are not limited to, adducts of 5-dimethylaminonaphthalene-1-sulfonyl chloride or 9-fluorenylmethyl chloroformate with glycerine, triisopropanolamine, or trifunctional amine-terminated polypropylene oxides.

This work was done by Paul B. Willis and Edward F. Cuddihy of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 46 on the TSP Request Card.*
NPO-18038

Chemically Layered Porous Solids

Sequences of treatments impart desired properties to aerogels and other porous materials.

Lyndon B. Johnson Space Center, Houston, Texas

Aerogels and other porous solids in which the surfaces of the pores have chemical properties that vary with depth below their macroscopic surfaces can be prepared by sequences of chemical treatments. The general class of materials so treatable includes oxides of aluminum, silicon, zirconium, tin, titanium, and nickel, and mixtures of these oxides. Potential

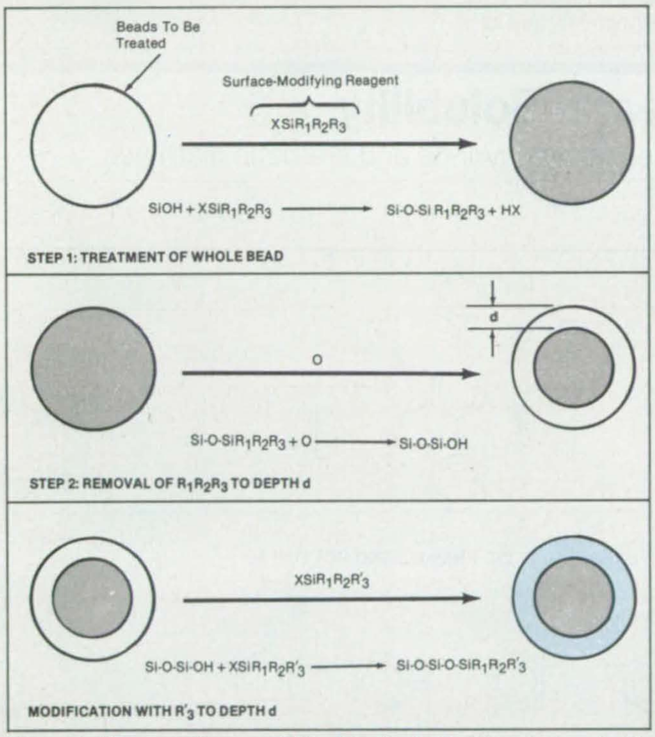


Figure 1. A **Porous Glass or Silica Bead** is treated to make two depth zones that have different chemical properties.

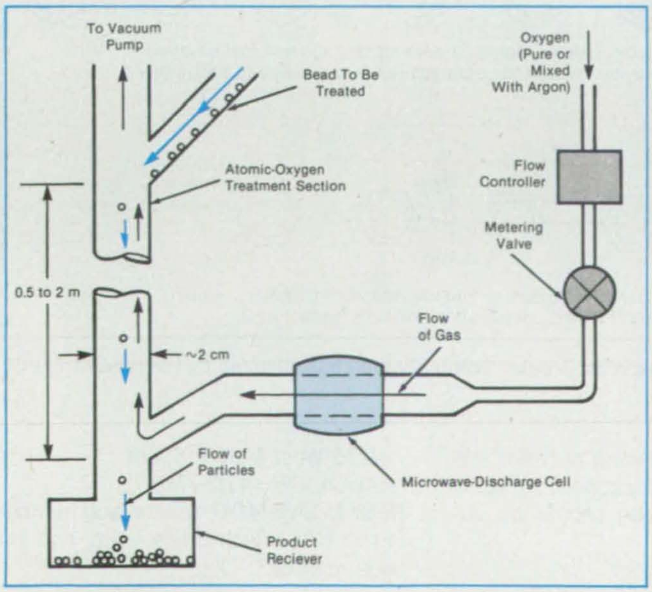


Figure 2. **Beads Are Dropped** along a tube filled with flowing gas containing atomic oxygen, which is generated in a microwave discharge.

uses of the treated materials include chromatographic separations, membrane separations, controlled releases of chemicals, and catalysis.

In the first step of a typical sequence of treatments, the porous solid is exposed to a reagent that can react with atomic oxygen or hydroxyl radicals. In the next step, the reagent is either fixed on the surfaces of the pores as a nonvolatile oxide or else removed partly (that is, to the desired depth) by exposure to atomic oxygen or hydroxyl radicals. In the next step, the solid might be exposed to another regeant. Depending on the solid and reagent materials used, it may also be necessary to wash with solvent between reagent treatments.

Subsequent steps can include various combinations of reagents, atomic-oxygen or hydroxyl treatments, and/or solvent washes that result in layers of pores that have different surface-chemical properties. The thickness of each layer is determined by the kinetics of the reaction and diffusion of atomic oxygen or hydroxyl radicals in the porous solid. The thickness of a layer can be as little as the average width of a pore.

A somewhat generic example of the process is the treatment of porous silica or glass beads. Prior to the sequence illustrated in Figure 1, the beads are treated with a solution of methanol and potassium hydroxide to produce a maximum number of Si-OH groups on the surfaces of pores throughout the depth and on the macroscopic surface. In step 1 of Figure 1, the Si-OH groups are reacted with any of a number of well-known surface-modifying reagents. In step 2 of Figure 1, the beads are exposed to atomic oxygen (see Figure 2) to remove, to a depth *d*, the deposit left by the reagent. In step 3, a different surface-modifying reagent is applied to treat the surface layer of depth *d*.

This work was done by Steve Koontz of **Johnson Space Center**. *For further information, Circle 27 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 16]. Refer to MSC-21487.

Phenylated Polyimides With Greater Solubility

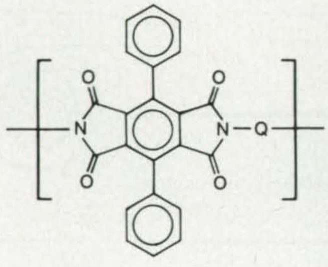
These polymers are made from 3,6-diphenylpyromellitic dianhydride and aromatic diamines.

Langley Research Center, Hampton, Virginia

Pyromellitic dianhydride (PMDA) is one of the dianhydrides most widely used in the preparation of polyimides. For example, it is used by Du Pont in the preparation of Kapton® and several other commercial products. The polyimides prepared from this monomer are known for their excellent mechanical properties and thermal stabilities. In experiments, 3,6-diphenylpyromellitic dianhydride monomer was prepared and polymerized with several different diamines. Polyimides with pendent phenyl groups along the polymer backbones are considerably more soluble than the PMDA-based materials are. Increased solubility eases processing, providing increased potential use in a variety of applications.

The phenylated polyimides, optionally end-capped with polymerizable or inert groups, are prepared by reacting 3,6-diphenylpyromellitic dianhydride or its alkyl diester, alone or in combination with other dianhydrides or their diesters, with aromatic diamines. The polymers are characterized by the presence of the repeating unit shown in the figure.

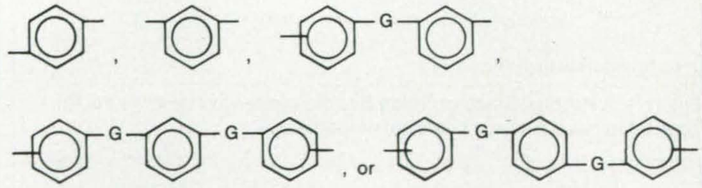
Because most of the polymers are soluble in organic solvents, they should be usable in microelectronics applications. Their excellent thermal stabilities and their high transition temperatures make them ideally suited for such applications. Many of the polymers are extremely rigid and may be useful as reinforcing polymers in molecular composites. The more flexible compositions may be useful as matrix resins in carbon-reinforced composites.



REPEATING UNIT OF PHENYLATED POLYIMIDE

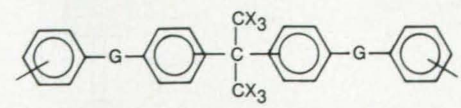
Notes:

1. Q could be



where G is O, S, SO_2, isopropylidine, or nothing, and the terminal covalent bonds are in either the meta or the para position with respect to each other.

2. Q could also be



where G is O or S; X is hydrogen or fluorine; and both terminal covalent bonds are in the ortho, meta, or para position with respect to G.

Phenylated Polyimides With Greater Solubility are characterized by the repeating unit shown at the top.

This work was done by Frank W. Harris of the University of Akron for **Langley Research Center**. *No further documentation is available.*

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. Robert W. Strozier
Oldham & Oldham, Co., LPA
(Representing the University of Akron)
1225 West Market Street
Akron, OH 44313-7188

Refer to LAR-14170, volume and number of this NASA Tech Briefs *issue, and the page number.*

Crystalline Imide/Arylene Ether Copolymers

Crystalline imide blocks impart excellent mechanical properties to the copolymers.

Langley Research Center, Hampton, Virginia

As part of an effort to develop high-performance structural resins for aerospace applications, work has continued on block copolymers containing imide and arylene ether segments. The idea is to take advantage of the attractive features of both polymides and poly(arylene ethers). In this work, a series of imide/arylene ether block copolymers were prepared by using arylene ether blocks (which are amorphous) to impart low melt viscosity, and imide blocks (which are crystalline) to provide high strength and other desirable mechanical properties. This work represents an extension of previous work (see LAR-14159) on imide/arylene ether copolymers.

A wide variety of imide and arylene ether repeat units can be used to yield copolymers with specific desired properties. Furthermore, the lengths of the imide and the arylene ether blocks are easily controlled. By varying these lengths, one can alter the properties of the copolymer to produce materials that have the desired physical and mechanical properties.

After curing, the experimental block copolymers had glass-transition temperatures from 165 to 220° C. Some had two glass transitions, corresponding to the arylene ether segments and to the imide segments, indicating phase separations in the copolymer films due to incompatibilities between the block segments of higher molecular weights. The block copolymers also had broad crystalline melting temperatures (T_m's) from 335° C to 355° C. Some had two T_m's and, therefore, possibly two crystalline forms. Solution-cast, unoriented films of the block copolymers were tough and flexible with tensile strengths, tensile moduli, and elongations at break up to 16,200 psi (112MPa), 535,000 psi (3.69 GPa), and 8 percent, respectively, at 25° C. Depending on the glass-transition temperatures of the arylene ether segments, some block copolymers maintained good mechanical properties at 177° C.

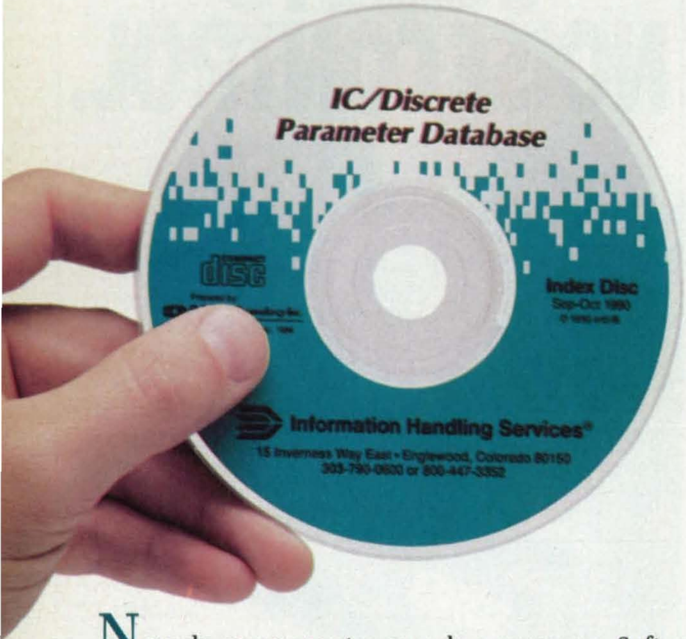
Moldings were prepared from copolymers that had been solution-imidized, by distilling toluene/water azeotropic mixtures from the reactions at 155° C for 16h to form powders. The powders were compression-molded in stainless-steel molds in hydraulic presses with electrically heated platens. The moldings were machined into compact tension specimens and tested for toughness. Values for the homopolymers were found to be extremely high, and values for the copolymers were found to be excellent and to increase with increasing lengths of the blocks.

The copolymers exhibit high toughness and other desirable mechanical properties in the form of films, moldings, adhesives, and composite matrices. The copolymers are potentially useful in a variety of high-temperature aerospace and microelectronic applications.

This work was done by Brian J. Jensen and Paul M. Hergenrother of **Langley Research Center** *and Robert G. Bass of Virginia Commonwealth University. For further information, Circle 137 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 16]. Refer to LAR-14264.

When you need data on:



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Discover Tomorrow's Innovations Today

At Technology 2001
December 3-5, 1991
San Jose Convention Center

US government R&D programs have created a **$65 billion technology storehouse** that's available to you now for use in developing new or improved products and processes. Technology 2001 will show you how to tap into this incredible resource to increase your productivity and competitiveness, and will introduce you to America's premier researchers and technology managers, including **top experts from NASA, the Environmental Protection Agency, the National Science Foundation, and the departments of Agriculture, Commerce, Defense, Energy, Health and Human Services, Interior, Transportation, and Veterans Affairs.**

Technology 2001 will feature:

- Over 40,000 square feet of exhibits by federal laboratories, their prime contractors, and other high-tech firms and universities with cutting-edge inventions available for license or sale;
- 120 symposia presentations spotlighting new advances with commercial promise in such critical areas as biotechnology, electronics, materials science, and manufacturing technology;
- Government-Industry Workshops covering vital information on patent licensing, Cooperative Research and Development Agreements, and Small Business Innovation Research contracts.

Plus these special events:

- A Pre-Show Reception on Monday, Dec. 2 in the exhibit hall, offering attendees and the media the chance to preview the exhibits and meet the presenters in a relaxed, informal atmosphere;
- The second annual Technology Transfer Awards Dinner, recognizing outstanding achievements in tech transfer to industry. This event offers a unique opportunity to network with government and industry executives in an elegant setting—the Imperial Ballroom of the San Jose Fairmont Hotel. (Seating is limited, so reserve tickets early!)

Concurrently with Technology 2001, the federal government is holding a special conference on Intelligent Processing Equipment—one of four critical manufacturing technologies identified in a recent report to President Bush. Sixteen federal organizations will brief industry on new developments in robotics, sensors, and controls that will shape the future of manufacturing. The conference—consisting of symposia, industry-government discussion panels, and exhibits—is open to Technology 2001 attendees at no additional charge.

Who Should Attend Technology 2001

Research directors, project leaders, design engineers, scientists, business executives, and other professionals who manage technology, and who need to stay on the cutting edge to remain competitive in the global marketplace.

Do not miss this opportunity to access a wealth of federally-developed technology, meet the key players in government and high-tech industry, and discover tomorrow's innovations, today.

Show Schedule

Monday, Dec. 2	
6:00 pm - 8:00 pm	Opening Reception
Tuesday, Dec. 3	
9:00 am -10:30 am	Plenary Session
1:00 pm - 3:00 pm	Technical Sessions
4:30 pm - 6:00 pm	Govt./Industry Workshops
Wednesday, Dec. 4	
8:30 am -10:30 am	Technical Sessions
1:00 pm - 3:00 pm	Technical Sessions
4:30 pm - 6:00 pm	Govt./Industry Workshops
7:00 pm -10:00 pm	Awards Dinner
Thursday, Dec. 5	
8:30 am -10:30 am	Technical Sessions
1:00 pm - 3:00 pm	Technical Sessions
4:30 pm - 6:00 pm	Govt./Industry Workshops

Exhibit Hours

Dec. 3	10:00 am - 5:00 pm
Dec. 4	10:00 am - 5:00 pm
Dec. 5	10:00 am - 4:30 pm

Technology 2001 Exhibitors

Here are some of the more than 200 government R&D centers, universities, and high-tech firms exhibiting at Technology 2001:

Aerospace Lubricants Inc.
Aerospatiale
Agema Infrared Systems
Air Force Manufacturing Technology Directorate
Air Force Systems Command
Alsys Inc.
Ambassador Marketing
American Ceramic Society
American Welding Society
Ames Laboratory
Ames Research Center
Ames Spatial Auditory Display Lab
AMPEX
Analytical Graphics
Armstrong Laboratory
Army Laboratory Command
Arthur D. Little Inc.
Assoc. of American Railroads/ US Department of Transportation
Astro-Med Inc.
Bateman Manufacturing Co.
Bend Research
BF Goodrich Aerospace Super-Temp
Biltech Inc.
Bit 3 Computer Corp.
Bionetics Corp.
Brookhaven National Lab
California Institute of Technology
Carnegie Mellon Robotics Institute
Center for Aerospace Information
Ceracon Inc.
CI Systems
Corning Inc.
COSMIC
Creative Designs & Inventions
Crystal River Engineering
Cybernet Systems
Datatape Inc.
Department of Energy
Design & Evaluation Inc.
Diamonex Inc.
Digiray Corp.
Earth Observation Satellite Co.
Eastman Kodak Company
European Space Agency
Fabric Development Inc.
Federal Laboratory Consortium
Fermi National Accelerator Lab
FLIR Systems Inc.
Goddard Space Flight Center
Govt. of Israel Trade Center
Hamilton Technologies Inc.
Hardigg Industries
Heimann Infrared Division/ Pyrometrics Corp.
Hemco Corp.
Hi-Techniques
Hitachi Denshi America Ltd.
HTS Inc.
Idaho National Engineering Lab
Industrial Materials Technology Inc.
Information Handling Services
Inframetrics Inc.
Institute of Environmental Sciences
Integrated Engineering Software
Integrated Systems Inc.
Intel Corp.
Interfinance Corp.
IXYS Corp.
James Grunder & Assoc.
Jet Propulsion Laboratory
Johnson Space Center
JP Technologies Inc.
Keane Controls Corp.
Kennedy Space Center
Kevex X-Ray Inc.
Langley Research Center
Lawrence Livermore Nat. Lab
Lewis Research Center
Los Alamos National Lab
Luxtron Corp., Accufiber Div.
Mantech/NSI
MARC, Murray State University
Marshall Space Flight Center
Martin Marietta Energy Systems Inc.
Martin Marietta Manned Space Systems
Martin Marietta Paducah Gaseous Diffusion Plant
Mathworks Inc.
McClellan Air Force Base
Med Tech Intl.
Metalworking Technology Inc.
Meridian Laboratories
Mikron Instrument Co.
Morgantown Energy Technology Center
NASA
NASA Regional Technology Transfer Centers
NASA Small Business Innovation Research
NASA Tech Briefs
National Center for Manufacturing Sciences
National Institute of Allergies & Infectious Diseases
National Institute of Standards and Technology
National Space Society
Naval Air Warfare Center
Naval Research Laboratory
NERAC Inc.
NIAC
Novespace
Numerical Algorithms Group
NYMA Inc.
Ohio Aerospace Institute
Olympus Corp.
Oracle Corp.
Pacific Northwest Laboratory
Pasha Publications
Patton & Patton Software
Phillips Laboratory
Pittsburgh Energy Tech. Ctr.
PMS Electro-Optics
Princeton Plasma Physics Lab
Proto Manufacturing Ltd.
Quantum Devices Inc.
Raytheon Company
RGB Spectrum
RG Hansen & Associates
Ribbon Technology Corp.
Rockwell International
Rome Laboratory
Salco Circuits
Sandia National Laboratories
Simmonds Precision Aircraft Systems
SMTEK
Solar Energy Research Institute
Sorbilite Inc.
South Carolina Univ. Research
Specialty Steel & Forge
SR Taylor & Assoc.
Stanford Research Institute
Stardent Computer Inc.
Statistical Sciences Inc.
Stennis Space Center
Stephens Analytical
Stereographics Corp.
Strategic Defense Initiative Organization
Sun Microsystems
Superior Products
Symbolics
TechLaw Group
Technical Insights Inc.
Technology Access Report
Technology Center of Silicon Valley
Technology Targeting Inc.
Technology Transfer Society
Tennessee Technology Foundation
Thin Film Technology Inc.
Tiodize Inc.
Triodyne Inc.
Ultramet
United Magnet Technologies
University of Dayton Research Institute
University of Georgia
USDA Agricultural Research Service
US Geological Survey
VA Medical Center, Rehab R&D Center
Vector Aeromotive Corp.
Viking Labs Metrum
Virginia Center for Innovative Technology
Wisconsin Center for Space Automation and Robotics
Wolfram Research
Wright Laboratory

For information on having your organization exhibit at Technology 2001, call Justina Cardillo or Evelyn Mars at (800) 944-NASA. In NY, call (212) 490-3999.

See America's most advanced automobile — the Vector W8 TwinTurbo — in the Technology 2001 exhibit hall. Incorporating an array of aerospace technologies, this "supercar" goes from 0-60 mph in less than 3.8 seconds and reaches speeds of more than 200 mph.

Photo: Vector Aeromotive Corp.

Technology 2001 Program

Tuesday, December 3

Plenary Session
9:00 am—10:30 am

(Speakers to be announced)
9:00: Welcome
9:15: Keynote Address
9:50: Technology 2001 Overview
10:15: Intelligent Processing Conference Overview

Concurrent Technical Sessions
1:00 pm—3:00 pm

Each presentation will last 30 minutes, including a question and answer period. Registrants may attend whole sessions (four presentations) or individual presentations from a number of different sessions. Meeting rooms are situated in close proximity for easy and quick movement during sessions. Room assignments will be listed in the final program distributed at the show.

(Session A1)
Advanced Manufacturing

Ceramic Susceptor for Induction Bonding of Metals, Ceramics, and Plastics
John D. Buckley, Senior Research Engineer, and Robert L. Fox, Electronics Technician, Langley Research Center
Langley researchers have developed a thin flexible carbon susceptor to join ceramics, plastics, metals, and combinations of these materials, using a unique induction heating process that dramatically reduces bonding times. The novel carbon susceptor allows application of heat directly and only to the bond line.

Applying NASA's Explosive Seam Welding
Laurence J. Bement, Senior Pyrotechnic Engineer, Langley Research Center
An explosive seam welding process created for aerospace use is finding a wide range of industrial applications. The process can be used to join aluminum and steel alloys, copper, brass, titanium, and other metals in thicknesses from 0.25 to 4.7 mm, and to remotely plug tubes.

Laser-Based Weld Joint Tracking System
Alan Looney, Welding Engineer, Marshall Space Flight Center
A laser-based system developed to control and monitor welding operations on space vehicles has been modified to provide a weld joint tracking system for industrial applications. The weld beam profiler features a precision laser-based vision sensor, automated two-axis machine motion, and an industrial PC controller. It eliminates weld repairs caused by joint tracking errors, reducing manufacturing costs.

Precision Joining Center
J.W. Powell, Joining Technology, EG&G Rocky Flats
Mr. Powell will describe a new center designed to provide a training ground for precision joining techniques. The center will transfer this advanced technology from the Department of Energy weapons complex and joining equipment manufacturers to US industries, through the training of technologists and engineers in such areas as process control, data acquisition, and joining.

(Session A2)
Biotechnology

Cooperative Research and Development Opportunities with the National Cancer Institute
Dr. Kathleen Sybert, Deputy Director, Office of Technology Development, National Cancer Institute
The National Cancer Institute's Office of Technology Development negotiates Cooperative Research and Development Agreements with university and industry investigators for the development of new products to diagnose and treat cancer and AIDS. Drug screening, preclinical testing, clinical trials, and AIDS program capabilities form the basis for this new technology transfer vehicle.

Technologies for the Marketplace from the Centers for Disease Control
Frances L. Reid-Sanden and R. Eric Greene, Technology Transfer Office, Centers for Disease Control
The Centers for Disease Control develops and transfers technologies designed to prevent and control disease and injury. Recent innovations include a vaccine against hepatitis A, a recombinant rabies vaccine, monoclonal antibodies for the detection of legionellae, a rapid method to diagnose human cysticercosis, and a variety of devices to ensure worker safety.

Enhancement of Biological Control Agents for Use Against Forest Insect Pests and Diseases
Dr. James M. Slavicek, Project Leader, US Forest Service Northeastern Forest Experiment Station
Dr. Slavicek will describe new biological control agents for use against forest pests such as the gypsy moth and diseases such as tree vascular fungal wilts.

Use of T7 Polymerase to Direct Expression of Outer Surface Protein A (OspA) from the Lyme Disease Spirochete, *Borrelia burgdorferi*
John J. Dunn, Senior Scientist, Brookhaven National Laboratory
Brookhaven researchers have cloned the ospA gene of *Borrelia burgdorferi*, the spirochete that causes Lyme disease. They are testing the resultant truncated protein for use as an immunogen in a vaccine against Lyme disease.

(Session A3)
Communications

Commercial Applications of ACTS Mobil Terminal Millimeter-Wave Antennas
Arthur C. Densmore, Antenna System Manager, and Rick A. Crist, Microwave Processor Subtask Manager, Jet Propulsion Laboratory
A JPL research team is developing low-profile, high-gain millimeter-wave antennas for future communication systems. Commercial opportunities include advanced land-mobile satellite communications, hybrid satellite/cellular systems, remote satellite news gathering, aeronautical and maritime satcom, and handheld personal satellite communications.

Antennas for Mobile Satellite Communications
John Huang, Jet Propulsion Laboratory
The NASA-sponsored Mobile Satellite Experiment program has generated several innovative microstrip antennas at L-band frequencies. Due to their thin profile, surface conformability, light weight, and low manufacturing cost, microstrip antennas are finding increasing applications in land-mobile satellite communications.

MMIC Linear-Phase and Digital Modulators for Space Communications Applications
Narayan R. Mysoor, Jet Propulsion Laboratory, and Fazal Ali, Pacific Monolithics
This presentation will review the design concepts, analyses, and development of monolithic microwave integrated circuit (MMIC) modulators for the next generation of space-borne communication systems. Commercial applications include phased arrays, satellite systems, and microwave systems that require continuous phase control in trimming multiple channels.

Phased-Array Antenna Beamforming Using an Optical Processor
Louis P. Anderson, Hughes Aircraft Company, and Richard Kunath, Lewis Research Center

Phased-array antennas are playing an increasingly important role in radar and communications applications, and will soon become the preferred way to achieve fixed spot, scanning spot, multiple spot, and other multi-functional beams for satellite communications. The presenters will discuss how a lightweight optical-processor-based beamformer can provide the required aperture excitations using a single lightweight network.

(Session A4)
Computer Graphics and Simulation

Global Positioning System Supported Pilot's Display
Marshall Scott, Systems Engineer, Kennedy Space Center

A new cockpit display for pilots of test aircraft uses the Global Positioning System to calculate aircraft position. This data is displayed graphically along with the runway, the desired flight path, and "fly-by" alignment needles.

Application of Technology Developed for Flight Simulation
Jeff I. Cleveland, Aerospace Technologist, Langley Research Center

Langley researchers are employing supercomputers for mathematical model computation to support real-time flight simulation. Mr. Cleveland will discuss commercial spinoff of these techniques in fields such as nuclear process control, power grid analysis, process monitoring, and chemical processing.

FAST: A Multi-Processed Environment for Visualization of Computational Fluid Dynamics
Gordon V. Bancroft, Fergus J. Merritt, Todd C. Plessel, Paul G. Kelaita, R. Kevin McCabe, and Al Globus, Research Scientists, Sterling Zero One Inc.

This presentation will focus on the Flow Analysis Software Toolkit (FAST), a software system for visualization and analysis of complex fluid flows. FAST is extensible and able to handle a wide range of problems. It can be adapted to new software and hardware configurations through modular structured programming methods, a graphics library standard, and common network communication protocols.

A Full-Parallax Holographic Display for Remote Operations
Helene P. Iavecchia, CSC/Analytics Inc.; Lloyd Huff, University of Dayton Research Institute; and Neville I. Marzwell, Jet Propulsion Laboratory

A near-real-time, full-parallax holographic display system developed for Jet Propulsion Laboratory could provide a 3D display for remote handling operations in hazardous environments on Earth and in Space.

(Session A5)
Electronics

Nonvolatile, High-Density, High-Speed, Magnet-Hall Effect Random Access Memory
Jiin-Chuan Wu, Romney R. Katti, and Henry L. Stadler, Flight Command and Data Management Systems, Jet Propulsion Laboratory

A radiation-hard, nonvolatile random access memory cell (MHRAM) with a density of 1 Mbit/cm^2 and an access time of less than 100 nsec is being developed using a magnet-Hall effect element. Such a memory will have a very competitive performance/price ratio to replace current commercial nonvolatile memory technologies, including ROM, EPROM, EEPROM, and Flash EEPROM, and will be competitive with static RAM for many applications.

Analog VLSI Neural Network Integrated Circuits
Francis Kub, Head, Microelectronic Device Physics Section, Naval Research Laboratory

Using a standard CMOS foundry process, Navy researchers have fabricated analog VLSI vector-matrix multiplier integrated circuit chips that perform vector-matrix multiplication operations at speeds up to 3 billion multiplications per second. Such high-speed operations are required for artificial neural networks and many signal processing applications, including image processing.

Monolithic Microwave Integrated Circuit Water Vapor Radiometer
L.M. Sukamto, Spacecraft Telecommunications Equipment Section, Jet Propulsion Laboratory

Mr. Sukamto will discuss efforts to design and fabricate a 31.4 GHz monolithic microwave integrated circuit (MMIC) radiometer as one channel of a thermally-stable water vapor radiometer (WVR). With improved thermal stability and signal accuracy, the WVR will have far-ranging commercial applications. It can be used, for example, in weather pattern prediction, calibration of polar-orbiting and geostationary satellites, and monitoring of aircraft icing conditions.

A Noncontacting Waveguide Backshort for Millimeter and Submillimeter Wave Frequencies
William R. McGrath, Technical Group Leader, Jet Propulsion Laboratory

A new backshort design employs a metallic bar with rectangular or circular holes to provide a periodic variation of guide impedance. The size, shape, and spacing of the holes can be adjusted to provide a large reflection of rf power over a useful frequency bandwidth. Mechanically rugged and easy to fabricate for frequencies up to 1000 GHz, the backshort offers applications in radar and communication systems, microwave test instruments, and remote-sensing radiometers, and will help extend waveguide technology into the submillimeter wave band.

(Session A6)
Materials Science

Novel Applications for TAZ-8A
William J. Waters, Sverdrup Technology Inc., and Stephen M. Riddlebaugh, Lewis Research Center

Alloy research for jet engine applications has produced a commercially promising nickel-based alloy called TAZ-8A. The alloy's unique combination of properties includes high temperature strength, oxidation resistance, abrasion resistance, and exceptional thermal shock resistance. Using a plasma vapor deposition technique, TAZ-8A can be applied as a coating with high reflectivity and extreme hardness.

Test Methods for Determining the Suitability of Metal Alloys for Use in Oxygen-Enriched Environments
Joel Stoltzfus, Projects Manager, White Sands Test Facility

Mr. Stoltzfus will describe test methods developed by NASA to study the ignition and combustion of metal alloys, including high- and low-speed particle impact tests, frictional heating and coefficient-of-friction tests, and the promoted combustion test. Test data and the resultant rankings of metal alloys will be discussed, along with licensing opportunities.

A Major Advance in Powder Metallurgy
B.E. Williams, J.J. Stiglich, R.B. Kaplan, and R.H. Tuffias, Ultramet

Under SBIR funding from the Army, Ultramet has developed a process that promises to significantly increase the mechanical properties of powder metallurgy (PM) parts. Conventional PM fabrication processes typically result in nonuniform distribution of the matrix, flaw generation due to particle-particle contact, and grain growth caused by high-temperature, long-duration compaction processes. In Ultramet's process, each particle is coated with the matrix material, and compaction is performed by solid-state processing, improving the part's homogeneity.

Permanent Magnet Design Methodology
Dr. Herbert A. Leupold, Research Physicist, US Army Electronics Technology and Devices Laboratory

The high remanences and coercivities of rare earth permanent magnets have made possible magnet structures of unusual form and performance, including permanent magnet solenoids, cylindrical transverse field sources, and high-field permanent magnet field sources. Dr. Leupold will describe military and commercial applications such as MR imagers, traveling wave tubes, gyrotrons, free electron lasers, Faraday rotators, and ultraviolet/x-ray telescopes.

Concurrent Government-Industry Workshops 4:30 pm—6:00 pm

(Presenters to be announced)

In these highly-interactive sessions, federal agencies will brief attendees on their present and planned R&D initiatives and technology transfer mechanisms, spotlighting opportunities for industry to work with the government to develop and commercialize technology. Cooperative Research and Development Agreements, Small Business Innovation Research, and patent licensing will be discussed. The objective of these workshops is to begin a dialog that will lead to increased use of federally-sponsored technologies by industry, and better utilization of private sector resources by the government. Agencies holding workshops during this time period will include:

- Department of Defense
- Department of Energy
- Department of Health and Human Services
- Environmental Protection Agency

Wednesday, December 4

Concurrent Technical Sessions 8:30 am—10:30 am

(Session B1)

Advanced Manufacturing

Concentrating Solar Systems: Manufacturing with the Sun
Lawrence M. Murphy, Division Director, Bimleshwar P. Gupta, Program Manager, and Steven G. Hauser, Industry Liaison, Solar Energy Research Institute

Recent advances in concentrating solar systems have produced solar flux densities in excess of 20,000 suns, creating unique process conditions of very high temperatures and heating rates. These conditions enable applications in manufacturing, materials processing, surface engineering, and toxic waste destruction.

Ultra-Precision Processes for Optics Manufacturing
William R. Martin, Associate Director, Engineering Technology Division, Oak Ridge National Laboratory

The Optics MODIL (Manufacturing Operations Development and Integration Laboratory) is developing advanced manufacturing technologies for fabrication of ultra-precision optical components, aiming for a ten-fold improvement in precision and a shortening of the schedule lead time. Discussion will focus on diamond single point turning, ductile grinding, ion milling, and in/on process metrology.

Integrated Automation for Manufacturing of Electronic Assemblies
T. Joseph Sampite, CIM Program Manager, Naval Ocean Systems Center

Mr. Sampite will describe how a standardized file transfer format developed with the National Institute of Standards and Technology will be used to create generic, open architecture computer-aided engineering tools for the automatic exchange of data between design and manufacturing.

Air Force Manufacturing Technology (MANTECH) Technology Transfer
Tracy J. Houpt, MTX Program Manager, and Margaret M. Ridgely, Technology Transfer Center Director, Wright Patterson Air Force Base

This presentation will illustrate the techniques and concepts employed in Air Force MANTECH's new comprehensive, proactive technology transfer program, using as an example the successful transfer of transmit/receive modules to industry.

(Session B2)

Electronics

Gallium Arsenide Quantum-Well-Based Far Infrared Array Imaging Radiometer
Kathrine A. Forrest and Murzy D. Jhabvala, Electronics Engineers, Goddard Space Flight Center

A new imaging radiometer developed for the thermal infrared (8 to 12 microns) employs a staring 128 x 128 GaAs quantum well detector array for stability, uniformity, high yield, and radiation-hardness. It is suited for thermal imaging in forestry, electronics processing, and medicine. Potential applications include aerial detection of small forest fires and location of hot spots in integrated circuits.

A Video Event Trigger for High-Frame-Rate, High-Resolution Video Technology
Glenn L. Williams, Electrical Engineer, Lewis Research Center

Mr. Williams will describe a highly-parallel digital state machine that generates a trigger signal at the onset of a video event. Random access memory storage coupled with fuzzy comparator logic devices permit monitoring a video stream for long- or short-term changes caused by spatial translation, dilation, or color change. Pretrigger and post-trigger storage techniques allow researchers to archive only significant images, alleviating costly data storage problems.

Camera Orientation of Pan, Tilt, and Zoom with No Moving Parts
Dr. H. Lee Martin, President, and Steven D. Zimmermann, Design Engineer, TeleRobotics International Inc.

Under contract to NASA Langley, TeleRobotics has developed a remote viewing system that provides pan, tilt, zoom, and rotational capabilities with no moving parts. The system features a fisheye lens for complete hemispherical field-of-view imaging and high-speed image transformation to correct peripheral distortion. Applications include remote viewing, inspection, and surveillance.

Fiber Optic TV Camera Direct
John Edward Kassak, Electronics Engineer, Kennedy Space Center

The Kennedy Center is developing a multiple color camera system for installations where video, synchronization, control camera data, and status data are transmitted via a single fiber cable at distances exceeding five miles. Expected benefits include improved video performance, immunity from EMI and RFI, and more broadcast flexibility.

(Session B3)

Environmental Technology

Waste Management Technology Development and Demonstration Programs
Paul D. Kalb, Research Engineer, Brookhaven National Laboratory

Brookhaven researchers have developed two new thermoplastic processes for the disposal of hazardous wastes: polyethylene encapsulation of nitrate salt wastes and modified sulfur cement encapsulation of incinerator fly ash wastes. Both systems provide significant improvements over conventional solidification techniques and result in durable waste forms that meet regulatory criteria.

Regulated Bioluminescence as a Tool for Bioremediation Process Monitoring and Control of Bacterial Cultures
Robert S. Burlage, Environmental Sciences Division, Oak Ridge National Laboratory; Armin Heitzer and Philip Digrazia, Center for Environmental Biotechnology, University of Tennessee

A new technique for monitoring biodegradation in toxic waste sites employs bioluminescence in a recombinant bacterial strain to detect contaminant levels. The process is rapid, often completed in minutes, and is sensitive in the part-per-billion range.

Fiber-Optic-Based Biosensor
Joel M. Schnur, Head, Molecular Science and Engineering Center, Naval Research Laboratory

Mr. Schnur will illustrate a new fiber-optic-based biosensor for environmental monitoring, pollution control, and clinical diagnostics. The device integrates a novel array of components, long fused silica fibers, and proteins for detection.

Ambient Temperature CO Oxidation Catalysts
Billy T. Upchurch, Senior Research Scientist, Langley Research Center

Langley researchers have produced ambient temperature oxidation catalysts for the recombination of CO and CO_2 dissociation products formed during CO_2 laser operation. The catalysts allow continuous operation of CO_2 lasers in a closed-cycle mode, and offer applications in other closed environments where the removal or control of CO is required, such as in catalytic converters for control of auto emissions.

(Session B4)

Materials Science

High-Temperature Adhesives
Terry L. St. Clair, Head, Polymeric Materials Branch, Langley Research Center

LARC-TPI, a high-temperature linear polymer adhesive developed to bond titanium, offers application as a hot-melt adhesive. Mr. St. Clair will describe the chemical structure and physio-mechanical properties of LARC-TPI and other important new polyimides with commercial potential.

Fluorinated Epoxy Resins with High Glass Transition Temperatures
James R. Griffith, Research Chemist, Naval Research Laboratory

The Navy has developed a new class of easily-processed liquid resins with low dielectric constants and high glass transition temperatures. These materials are useful for the manufacture of composite electronic boards.

Polyimides Containing Pendent Siloxane Groups
John W. Connell, Polymer Scientist, Langley Research Center

Incorporation of siloxane units into the backbone of aromatic polyimides imparts enhanced solubility, lower moisture adsorption, lower dielectric constant, improved toughness, and protection against atomic oxygen erosion. Mr. Connell will describe the physical and mechanical properties of these materials, as well as potential electronics and aerospace applications.

Corrosion-Protective Coatings from Electrically-Conducting Polymers
Karen Thompson, Kennedy Space Center; Brian Benicewicz and Debra Wrobleski, Los Alamos National Laboratory

Researchers are investigating the use of processible conductive organic polymers as corrosion-protective coatings on metal surfaces. Recent tests in saline and acidic oxidizing environments have demonstrated greatly improved corrosion resistance of mild steel with these coatings as compared to steel coated solely with epoxy.

(Session B5)

Medical Advances:

Computers in Medicine

Computation of Incompressible Viscous Flows through Artificial Heart Devices
Stuart Rogers and Dochan Kwak, Research Scientists, Ames Research Center

Ames researchers are applying computational fluid dynamics (CFD) techniques to simulate the blood flow through artificial hearts. Computer modeling will help pinpoint regions subject to clotting and lead to safer, more durable mechanical hearts and valves.

Computer Interfaces for the Visually Impaired
Gerry Higgins, Computer Systems Engineer, Marshall Space Flight Center

Mr. Higgins will address current research efforts to provide computer technology for people with vision-related handicaps. One such effort, the Mercator Project, looks to create a prototype system for audible access to graphics-based interfaces.

Extended Attention Span Training System
Dr. Alan Pope, Leader, Human Engineering Methods Group, Langley Research Center

A biocybernetic system developed to assess the degree to which automated flight management systems maintain pilot engagement is being adapted for treatment of youngsters with attention disorders. The Extended Attention Span Training (EAST) system increases the difficulty of a video game as the player's brain waves indicate attention is waning. The player can only succeed at the game by maintaining an adequate attention level.

Man/Machine Interaction Dynamics and Performance Analysis Capability
Harold P. Frisch, Head, Robotic Applied Research, Goddard Space Flight Center

As part of its flight telerobotics program, NASA is developing the ability to study the consequences of machine design alternatives as they relate to machine and machine operator performance. This capability will have far-reaching medical applications, such as enabling orthopedic surgeons to study the consequences of surgical options from the perspective of post-operative human performance predictions.

(Session B6)

Software Engineering

Hybrid Automated Reliability Predictor Integrated Workstation (HiREL)
Salvatore J. Bavuso, Aerospace Technologist, Langley Research Center

The HiREL system marks a major step toward producing a totally integrated CAD workstation design capability. HiREL uses a graphical input description language to increase productivity and reduce error. It enables reliability engineers to quickly analyze huge amounts of reliability/availability data to observe trends due to exploratory design changes.

Using Ada and the Rapid Development Lifecycle
Lloyd DeForrest, Technical Group Supervisor, Jet Propulsion Laboratory

Under contract to the US Army, JPL is developing a multifaceted computerized command center using an accelerated software development approach called the Rapid Development Lifecycle. Through the use of Ada and the X-Window/Motif Graphical User Interface, software developed under this program can be reused in similar projects requiring non-computer-literate users with little or no training to operate advanced command center tools and applications.

Advances in Knowledge-Based Software Engineering
Walt Truszkowski, Head, Automation Technology Section, Goddard Space Flight Center

The Knowledge-Based Software Engineering Environment (KBSEE) is designed to demonstrate that a rigorous and comprehensive software reuse methodology can enable more efficient utilization of resources in the development of large-scale software systems. Designed for use by both government and industry, KBSEE could aid in improving the reliability of future software systems.

Reducing the Complexity of Software Development through Object-Oriented Design
Mary Pat Schuler, Aerospace Technologist, Langley Research Center

Ms. Schuler will illustrate how Object-Oriented Design (OOD), coupled with formalized documentation and tailored object diagramming techniques, can simplify the software design process. The OOD methodology uses a hierarchical decomposition approach in which parent objects are decomposed into layers of lower-level child objects, with the relationships between design layers represented pictorially. This approach makes the resulting code more portable, reusable, and maintainable.

Concurrent Technical Sessions
1:00 pm—3:00 pm

(Session C1)
Data and Information Management

Techniques for Efficient Data Storage, Access, and Transfer
Robert F. Rice, Jet Propulsion Laboratory, and Warner Miller, Goddard Space Flight Center

Advanced techniques for efficient data representation have been placed in practical hardware and software form though the joint effort of three NASA centers. The techniques, which involve the use of high-speed coding and decoding modules as well as machine-transferable software routines, adapt to local statistical variations to continually provide optimum code efficiency when representing data without error.

A Vector-Product Information Retrieval System Adapted to Heterogeneous, Distributed Computing Environments
Dr. Mark E. Rorvig, Library Scientist, Johnson Space Center

The Automated Online Library Management System (AutoLib) provides a ranked list of the most likely relevant objects in collections, in response to a natural language query. AutoLib is constructed with standards and tools such as UNIX and X-Windows, which permit its use in organizations that have many different hosts, workstations, and platforms. Applications include information-intensive corporate management environments, such as finance, manufacturing, and biotechnology.

AutoClass: An Automatic Classification System
Peter Cheeseman, Research Scientist, Ames Research Center

A useful tool for exploratory data analysis, AutoClass enumerates and describes the natural classes in a data set. The program automatically determines the optimal number of classes.

Silvabase: A Flexible Data File Management System
Steven J. Lambing, Marshall Space Flight Center, and Steven T. Harris, Boeing Computer Support Services

Developed for mission planning at the Marshall Center, Silvabase enables efficient forward and backward sequential reads, random searches, and appends to large amounts of data. The system, designed to run on VAX/VMS computers, has unique features applicable to management of data involving time histories and intervals such as in operations research.

(Session C2)
Electro-Optics

Nonlinear Optical Polymers for Electro-Optic Signal Processing
Geoffrey A. Lindsay, Polymer Science Branch Head, Naval Weapons Center

Mr. Lindsay will discuss several new classes of nonlinear optical polymers for use in optical signal processing (photonics). These materials offer large electro-optics figures of merit, high temperature performance, ease of processing into films and fibers, ruggedness, and low cost. They can be applied in electro-optic switches, optical frequency doublers, sensors, spatial light modulators, and optical data storage systems.

High-Resolution Optical Data Storage on Polymers
C.M. Roland, Supervisory Chemist, Naval Research Laboratory

A new thermal method for lithography on amorphous polymer films yields remarkably high resolution images with excellent edge acuity. Images imparted to the films can be made electrically conductive via a single-step process, without using extraneous reagents.

Laser Discrimination by Stimulated Emission of a Phosphor
Dr. V.K. Mathur, Research Physicist, Naval Surface Warfare Center

Dr. Mathur will describe a new method for discriminating near infrared and far infrared laser light sources, based on the use of a magnesium sulfide phosphor which is thermally/optically stimulated to generate a color correlatable to the incident laser radiation. The technology offers potential for discrimination between even smaller bandwidths within the infrared spectrum—a possible aid to communication or wavemixing devices that need to rapidly identify and process optical signals.

Pulsed Laser Prelasing Detection Circuit
George Eugene Lockard, Engineering Technician, Langley Research Center

Langley researchers have developed a circuit to detect prelasing—the premature leakage of energy from a laser rod—in pulsed laser systems. The circuit, which is small, economical, and easily incorporated into virtually any pulsed laser system, shuts off the laser before the prelasing energy can cause costly optical damage.

(Session C3)
Life Sciences

Application of CELSS Technology to Controlled Environment Agriculture
Dr. Maynard E Bates, Bionetics Corporation, and Dr. David L. Bubenheim, Ames Research Center

Controlled Ecological Life Support Systems (CELSS) expand the concept of Controlled Environment Agriculture (CEA)—the use of environment manipulation for the commercial production of organisms—to create miniature ecosystems in which food, oxygen, and water in closed habitats are provided by regeneration of waste streams through systems containing microorganisms, plants, and animals. The development of CELSS will provide information needed to improve the efficiency, reliability, and cost-effectiveness of CEA, while reducing its environmental impact to negligible levels.

Advanced Forms of Spectrometry for Space and Commercial Application
Dr. Kenneth J. Schlager, Chief Technical Officer, Biotronics Technologies Inc.

Biotronics has discovered wide commercial application for two spectrometric technologies developed under the Kennedy Space Center's sponsorship. Ultraviolet absorption spectrometry, originally investigated for on-line measurement of hydroponic plant nutrient solutions, is finding utility in a new line of ultraviolet process analyzers for the water treatment market. A second technology, liquid atomic emission spectrometry, holds even greater commercial promise, representing the first application of atomic emission to direct on-line measurements of liquids.

Ion-Selective Electrode for Ionic Calcium Measurements
John W. Hines and Sara Arnaud, Research Scientists, Ames Research Center

NASA has developed a coated wire ion-selective electrode that noninvasively measures ionic calcium. It can be used to monitor bone calcium changes during extended exposure to microgravity or during prolonged hospital or fracture immobilization, and to conduct osteoporosis research.

A 99% Purity Molecular Sieve Oxygen Generator

Major George W. Miller, Research Chemical Engineer, Air Force Systems Command

A molecular sieve oxygen generator employing a new pressure swing adsorption process produces oxygen concentrations of up to 99.7% directly from air, exceeding the present oxygen purity limitations of 93-95%. The device may find use in aircraft and medical breathing systems, and industrial air separation systems.

(Session C4)

Materials Science

Advanced Composite Materials and Processes

Robert M. Baucom, Group Leader, Composite Materials, Langley Research Center

Mr. Baucom will report on techniques for combining high-performance graphite fibers and resin matrix systems into composite prepregs, innovative tooling concepts, and fabrication procedures for complex structures. The plastics and aerospace industries could benefit greatly by adopting these materials and processing procedures.

RTM: Cost-Effective Processing of Composite Structures

Greg Hasko and H. Benson Dexter, Materials Research Engineers, Langley Research Center

Resin transfer molding (RTM), a method of making high-strength, lightweight composite structures, is used extensively in the automotive, recreation, and aerospace industries. The presenters will compare the material requirements of various industries, methods of orienting and distributing fibers, mold configurations, and processing and material parameters such as resin viscosity, preform compaction, and permeability.

A Low-Cost Method of Testing Compression-After-Impact Strength of Composite Laminates

Alan Nettles, Marshall Space Flight Center

Marshall researchers have developed a new method to test the compression strength of composite laminate specimens as thin as .04 inches and up to 3 inches wide. This method is easier and less costly than the current compression-after-impact standard, and yields more meaningful results.

Resonant Acoustic Determination of Complex Elastic Moduli

Steven L. Garrett, Professor of Physics, and David A. Brown, Electronics Engineer, Naval Postgraduate School

The presenters will describe a new technique for measuring and tracking the complex shear and Young's moduli of nonmagnetic samples using the resonance frequency of an unconstrained bar sample. The same inexpensive electrodynamic transducers are used to excite and detect the sample's longitudinal, flexural, and torsional resonances. Sample data for composites, metals, plastics, and viscoelastic materials will be presented.

(Session C5)

Robotics

A Unique Cable Robot for Space and Earth

James Kerley, Design Engineer, Goddard Space Flight Center

A novel cable robot bends like a worm, moving up and down, back and forth, and even upside down. With magnets on its feet, the robot can climb or adhere to tall structures. It can be used to clean or paint towers, tanks, bridges, and ships, and, with an attached video camera, to inspect structures for damage or rust.

A Lightweight, High-Strength Dexterous Manipulator Arm

Neville I. Marzwell, Jet Propulsion Laboratory; Bruce M. Schena and Steve M. Cohan, Odetics Inc.

The presenters will describe the design and features of a lightweight, high-strength, modular manipulator arm developed for space and commercial applications. Fully operational in 1 g, the arm has seven degrees of freedom, a reach of 55 inches, and can lift 50 pounds. Bilateral teleoperator control can be added to the current robotically operated system.

Real-Time, Interactive Simulator System for Telepresence

Neville I. Marzwell, Jet Propulsion Laboratory; A.H. Chiu, P.G. Gottschalk, F.S. Schebor, and J.L. Turney, KMS Fusion Inc.

The Global-Local Environment Telerobotics Simulator (GLETS) immerses an operator in a real-time, interactive, visually-updated simulation of the remote telerobotic site. Stereo graphics are shown on a computer screen and fused together by the operator's special glasses to form stereoscopic views of the simulated world. The operator, interacting with the GLETS through voice and gesture commands, can form a gestalt of the virtual "local site" that matches his/her normal interactions with the real remote site.

A Hazard Control System for Robot Manipulators

Ruth Chaing Carter, FTS System Safety Manager, Goddard Space Flight Center

Ms. Carter will review system safety management and engineering techniques developed for telerobotic operations in space, focusing on a precise hazard control system for test flight of NASA's Flight Telerobotic Servicer. The same software monitoring and control approach could ensure the safe operation of a slave manipulator under teleoperated or autonomous control in undersea, nuclear, or manufacturing applications.

(Session C6)

Test and Measurement

Knowledge-Based Autonomous Test Engineer (KATE)

Dr. Carrie Belton and Barbara Brown, Computer Engineers, Kennedy Space Center

Developed for ground launch operations at the Kennedy Center, KATE employs concepts of sensor-based and model-driven monitoring and fault-location, and performs control and redundancy management of process control systems. KATE is designed as a generic, model-based expert system shell for autonomous control, monitoring, fault recognition, and diagnostics in the electrical, mechanical, and fluid system domains.

Advanced Computed Tomography Inspection System (ACTIS)

Lisa H. Hediger, Materials Engineer, Marshall Space Flight Center

ACTIS, developed at the Marshall Center to support its solid propulsion test programs, is being applied to inspection problems in the aerospace, lumber, automotive, and nuclear waste disposal industries. Ms. Hediger will discuss the unique capabilities of ACTIS and present a broad overview of computed tomography technology.

High-Resolution Ultrasonic Spectroscopy System for Nondestructive Evaluation

Dr. C.H. Chen, Information Research Laboratory Inc.

Under SBIR funding from the Army, IRL researchers are developing a high-resolution ultrasonic inspection system supported by modern signal processing, pattern recognition, and neural network technologies. This presentation will review the details of the system and its software package.

Force Limited Vibration Testing

Terry D. Scharton, Jet Propulsion Laboratory

An improved method of controlling vibration tests used to verify equipment design and manufacturing workmanship closely simulates field conditions. Offering commercial application throughout the aerospace, electronics, and automotive industries, the new test method eliminates costly failures associated with overtesting in the laboratory.

Concurrent Government-Industry Workshops 4:30 pm—6:00 pm

(Presenters to be announced)
Agencies holding workshops during this period will include:

- Department of Energy
- Department of Transportation
- Environmental Protection Agency
- National Aeronautics and Space Administration

Thursday, December 5

Concurrent Technical Sessions 8:30 am—10:30 am

(Session D1)
Advanced Manufacturing

Development of a Rotary Joint Fluid Coupling for Space Station Freedom
John A. Costulis, Technical Project Engineer, Langley Research Center

Langley researchers have developed and tested a 360-degree rotary joint fluid coupling for the Freedom station's thermal control system. The mechanism can be applied commercially to transfer fluid across rotating interfaces, such as in gun turrets, coal slurries, and farming machinery.

Spline Screw Comprehensive Fastening Strategy
John M. Vranish, Electronics Engineer, Goddard Space Flight Center

A fastener developed for assembly, maintenance, and equipment replacement operations in space also has down-to-Earth manufacturing applications. Use of the "spline screw" fastener in prime subassemblies would enable machines to disconnect and replace parts with ease, reducing product life cycle costs and enhancing the quality, timeliness, and consistency of repairs and upgrades.

Commercial Application of an Innovative Nut Design
Jay Wright, Materials Research Engineer, Johnson Space Center

A nut developed for space station use allows a fastener to be inserted or removed from either side by simply sliding the fastener in or out of the nut. Detentes on either face of the nut ensure positive engagement of the threads. The nut has applications wherever a fastener needs to be taken on and off quickly or used on a threaded part which could become so damaged that a conventional nut could not be removed.

Inflatable Traversing Probe Seal
Paul A. Trimarchi, Mechanical Engineer, Lewis Research Center

Mr. Trimarchi will describe an inflatable seal that acts as a pressure-tight zipper to provide traversing capability for instrumentation rakes and probes. The seal can replace sliding face-plate/O-ring systems in applications where lengthwise space is limited.

(Session D2)
Artificial Intelligence

CLIPS: An Expert System Building Tool
Gary Riley, Computer Engineer, Software Technology Branch, Johnson Space Center

The C Language Integrated Production System (CLIPS) provides a complete environment for the development and delivery of rule- and/or object-based expert systems. CLIPS offers a low-cost option for developing and deploying expert system applications across a wide range of hardware platforms.

Fuzzy Logic Applications to Expert Systems and Control
Dr. Robert N. Lea, Aerospace Engineer, Johnson Space Center

Commercial use of fuzzy technology in Japan and China indicate that it should be exploited by government and private industry to save energy and reduce human involvement in industrial processes. Johnson Center researchers have applied fuzzy logic in guidance control systems for space vehicles, control of data processing during rendezvous navigation, collision avoidance algorithms, and camera tracking controllers. The technology may also find use in diagnostic systems, control of robotic arms, pattern recognition, and image processing.

Neural Network Technologies
James A. Villarreal, Computer Engineer, Johnson Space Center

Mr. Villarreal will describe the Neural Execution and Training System (NETS), a software tool designed to facilitate and expedite the use of neural network technology in industry, government, and academia. Neural networks have been successfully applied to modeling and data fusion problems, robotics, structural design, speech synthesis, financial forecasting, spectrographic analysis, and many other areas. This presentation will highlight various commercial projects under development with NETS.

From Biological Neural Networks to Thinking Machines
Dr. Muriel D. Ross, Research Scientist, Ames Research Center

Dr. Ross is studying the three-dimensional organization of a simple biological neural network found in inner ear organs of balance to uncover basic principles of neural organization and function. This effort will result in new applications of biological attributes to artificial systems, and could lead to the development of highly-intelligent parallel-processing computers.

(Session D3)
Biotechnology

The Microassay on a Card—A Rugged, Portable Immunoassay
Dr. David Kidwell, Research Scientist, Naval Research Laboratory

The Microassay on a Card (MAC), a portable, handheld immunoassay, can test for a wide variety of substances in the environment. Intended for use as an on-site screen for drugs of abuse in urine or saliva, the MAC may also be applied to test for intoxication, to identify seized materials, and to test for environmental pollutants.

Flow Immunosensor for Drug Detection
Joel M. Schnur, Head, Molecular Science and Engineering Center, Naval Research Laboratory

Dr. Schnur will describe an antibody-based sensor designed to detect drugs of abuse. The biosensor is faster, less expensive, and as sensitive as any current method for cocaine detection. It can be operated outside the laboratory by personnel with no scientific training. Opportunities exist for Cooperative Research and Development Agreements.

Nucleic Acid Probes in Diagnostic Medicine
Phillip A. O'Berry, National Technology Transfer Coordinator for Animal Science, US Department of Agriculture

Mr. O'Berry will discuss the application of nucleic acid probe technology to the diagnosis of disease in humans and animals, and will present examples of commercially-promising probes.

The Rotating Spectrometer: New Biotechnology for Cell Separations
David A. Noever, Universities Space Research Association, and Helen C. Matsos, Marshall Space Flight Center

A new rotating spectrometer, able to separate previously inseparable cell cultures, is intended for use in pharmacological studies requiring fractional splitting of heterogeneous cell cultures based on cell morphology and swimming behavior. Unlike standard separation and concentrating techniques such as filtration or centrifugation, the instrument can separate motile from immotile fractions.

(Session D4)

Electronics

Method for Producing High-Quality Oxide Films on Surfaces

Mark W. Ruckman, Associate Physicist, Brookhaven National Laboratory

Mr. Ruckman will describe a new method for the reactive deposition of metal oxide and other inorganic compound thin films for use in microelectronic devices fabricated on compound semiconductors and high-temperature superconducting oxides. The technology can be integrated with ion, electron, or photon beam methods used to accelerate or selectively promote deposition and etching.

Advanced Silicon on Insulator Technology

Francis J. Kub, Senior Research Engineer, and David J. Godbey, Research Chemist, Naval Research Laboratory

Navy researchers have developed bonding, thinning, and selective etching techniques for producing ultra-thin silicon on insulator materials. These techniques can be used to fabricate silicon membranes, balometers, and other devices requiring free-standing thin-film silicon. Other applications include high-voltage/high-temperature power devices, backside-illuminated thinned CCD imagers, and x-ray masks.

High-Temperature Superconducting Stripline Filter

J.J. Bautista, Technical Group Supervisor, Jet Propulsion Laboratory

Mr. Bautista will describe the fabrication of a five-pole interdigital stripline filter made of the 93K superconductor $Y_1Ba_2Cu_3O_y$ coated on a silver substrate. The filter features a center frequency of 8.5 GHz and an extremely high rejection ratio of 80 dB.

An Adjustable rf Tuning Element for Microwave, Millimeter Wave, and Submillimeter Wave Circuits

William R. McGrath, Technical Group Leader, Jet Propulsion Laboratory; Victor Lubecke and David B. Rutledge, Dept. of Electrical Engineering, California Institute of Technology

The presenters have developed an adjustable rf tuning element consisting of a series of thin plates that can slide in unison along a coplanar strip transmission line to allow active tuning. The structure can be fabricated for frequencies as high as 1000 GHz using existing micromachining techniques. By easing constraints on circuit design, it will aid in extending microwave integrated circuit technology into the high millimeter wave and submillimeter wave bands.

(Session D5)

Materials Science

Passive Chlorophyll Detector

Leonard A. Haslim, Research Scientist, Ames Research Center

Using a low-cost, uniquely-dyed optical filter plastic sheet, the Passive Chlorophyll Detector enhances the visual discrimination of vegetation and trees in varying states of health. The invention's far-reaching applications include enabling farmers to identify and nurse or replant unhealthy sections of their fields to achieve higher crop yields, and serving as an early warning device for environmental scientists monitoring the health of forests and wetlands exposed to acid rain or contaminated groundwater.

Commercial Application of Thermal Protection System Technology

Gordon L. Dyer, Technology Transfer Officer, Martin Marietta Manned Space Systems

Thermal protection system materials and processes developed for the space shuttle's external tank have been reapplied in a new type of children's lunch box—a microwavable urethane foam insulation container that keeps a prepackaged meal warm for four to five hours. Two major food manufacturers are currently considering licensing the high-tech foam container.

Oxynitride Glass Fibers

Donald R. Messier, Research Ceramic Engineer, Materials Technology Laboratory, US Army Laboratory Command

Oxynitride glasses offer exciting opportunities for making high-modulus, high-strength glass fibers. Mr. Messier will describe processes for fabricating oxynitride glasses and fibers in compositions similar to commercial oxide glasses, but with significantly enhanced properties.

Commercial Applications of Advanced Photovoltaic Technologies

R.D. McConnell, Technology Transfer Manager, Solar Energy Research Institute

Mr. McConnell will describe research into high-tech photovoltaic materials including III-V, II-VI, amorphous silicon, and crystalline silicon, and will highlight possible spinoff applications such as optoelectronics and space power systems.

(Session D6)

Software Engineering

Software Reengineering

Ernest M. Fridge, Deputy Chief, Software Technology Branch, Johnson Space Center

During space shuttle development, Johnson Center engineers created a set of tools to develop and maintain FORTRAN and C code. This tool set forms the basis for an integrated environment to reengineer existing code into modern software engineering structures which are easier and less costly to maintain and which allow straightforward translation into other target languages.

COSTMODL: An Automated Software Development Cost Estimation Tool

George B. Roush, Software Engineer, Johnson Space Center

One of the most widely used software cost estimation tools, COSTMODL can help reduce the risk of cost overruns and failed projects. COSTMODL has an intuitive user interface and extensive online help system, and can be customized to a particular user environment. It can be used for in-house cost management, cost analysis consulting, or for research.

Increasing Productivity through Total Reuse Management

Mary Pat Schuler, Aerospace Technologist, Langley Research Center

NASA Langley is promoting total reuse management (TRM) as a way to lower software development costs, reduce risk, and increase code reliability. Ms. Schuler will describe methods used to adopt TRM, and will discuss the reuse of products from all phases of the software life cycle.

How Hypermedia Can Increase the Productivity of Software Development Teams

L. Stephen Coles, Group Chief Technologist, Institutional Data Systems, Jet Propulsion Laboratory

Mr. Coles will describe how the productivity of software developers can be dramatically improved through the use of hypermedia, the seamless integration of disparate data structures—including text, graphics, animation, voice, and full-motion video—in a graphical user interface. The presentation will cover basic machine architecture, special-purpose video boards, video equipment, optical memory, software for animation, voice I/O, and networking and integration issues.

Concurrent Technical Sessions 1:00 pm—3:00 pm

(Session E1)

Advanced Manufacturing

Intelligent Robotic System with Dual-Arm Dexterous Coordination and Real-Time Vision

Neville I. Marzwell, Jet Propulsion Laboratory, and Alexander Chen, Scientific Research Associates

The presenters will demonstrate a prototype robot with built-in intelligence. It features 18 degrees of freedom, comprised of two articulated arms, a movable robot head, two CCD cameras for producing stereoscopic views, an articulated cylindrical lower body, and an optional mobile base. The robotic system addresses a broad spectrum of manufacturing demands, including both complex and labor-intensive jobs.

Neural Network Software for Distortion-Invariant Object Recognition
Max B. Reid and Lilly Spirkovska, Research Scientists, Ames Research Center

Ames has created neural network software that performs the complete feature extraction/pattern classification paradigm required for automatic pattern recognition. The software is being used in an autonomous robotic vision system which could have extensive application in robotic manufacturing.

Constraint-Based Scheduling
Monte Zweben, Assistant Chief, Artificial Intelligence Research Branch, Ames Research Center

Mr. Zweben will describe the Space Shuttle Ground Processing Scheduling system, which uses artificial intelligence search methods to solve large-scale scheduling problems. The system can be applied to a variety of scheduling problems. In the manufacturing domain, it can help to minimize set-up time or tardiness.

COMPASS: A General-Purpose Computer-Aided Scheduling Tool
Dr. Barry R. Fox, Project Leader, McDonnell Douglas Space Services Co; and Christopher Culbert, Technical Monitor, Software Technology Branch, Johnson Space Center

COMPASS is an powerful, interactive planning and scheduling system with a mouse-driven, X-Windows user interface. It can be used to manage activities subject to timing constraints, ordering constraints, Boolean conditions, and resource availability, and to manage a wide range of resources including tools, electricity, and water.

(Session E2)

Data and Information Management

ELAS: Powerful General-Purpose Image Processing Software
David Walters, Electronics Engineer, Information Systems Division, Stennis Space Center

Originally developed to process Landsat images, the ELAS software package has evolved to handle a vast range of data types including MRI, soil maps, topographic and rainfall data, and sonar images. Mr. Walters will describe applications in such fields as agriculture, forestry, and geology, and will highlight important new enhancements to the software.

TAE Plus: A NASA Tool for Building and Managing Graphical User Interfaces
Martha R. Szczur, TAE Project Manager, Goddard Space Flight Center

Transportable Applications Environment Plus is a WYSIWYG tool for designing, building, and tailoring an application's graphical user interface. Its main component is the WorkBench, which allows the application developer (who need not be a programmer) to interactively construct an application screen's layout and manipulate graphical objects such as menus, buttons, icons, and dials. TAE Plus is used in such disciplines as image processing, simulation, network management, real-time command and control, database management, and office automation.

Instrumentation, Performance Visualization, and Debugging Tools for Multiprocessors
Jerry C. Yan and Charles E. Fineman, Sterling Federal Systems; Philip J. Hontalas, Ames Research Center

As part of a major effort to advance multiprocessor parallel computing performance, NASA Ames is developing techniques to efficiently monitor and visualize parallel program execution. Such techniques will help simplify the debugging and tuning of parallel programs. The presenters will describe various prototype software tools and their incorporation into the run-time environments of hardware testbeds.

The Data Egg: One-Handed Text Entry Without Positional Constraints
Gary L. Friedman, Technical Group Leader, Jet Propulsion Laboratory

JPL researchers have devised a small, handheld unit that allows text entry with only one hand. Dubbed the Data Egg, it can be operated in any position, either autonomously or tethered to a personal computer. This invention will benefit the handicapped and those normally barred from using a computer on the job, such as astronauts and journalists.

(Session E3)

Electronics

Thermoacoustic Refrigeration
Steven L. Garrett and Thomas Hofler, Naval Postgraduate School

The presenters will demonstrate the first practical, autonomous thermoacoustic refrigerator, which employs high-amplitude sound in inert gas to pump heat. Scheduled for flight on the space shuttle, the acoustically-resonant refrigerator has only one moving part, no sliding seals, and uses inexpensive components. Since thermoacoustic refrigerators use no CFCs and have coefficients of performance comparable with vapor compression cycle refrigerators, they are good candidates for food refrigeration and commercial/residential air conditioning applications.

Ambient Temperature Recorder
Larry D. Russell, Electronics Engineer, Ames Research Center

The ATR-4 ambient temperature recorder is a small battery-powered device that records 32 kilobytes of temperature data from four channels, over a range of -40° to +60°C at sampling intervals from 1.88 to 15 minutes. Data is stored in its internal memory for subsequent readout by a personal computer. Developed for use on the space shuttle, the ATR-4 can answer a variety of needs for a small, remote, unattended temperature recorder, such as in transportation of perishables and recording life system or process temperatures over time.

Fiber-Optic Push-Pull Sensor Systems
Steven L. Garrett and David A. Brown, Naval Postgraduate School

The Navy has created fiber optic "push-pull" sensors that greatly enhance the optical fiber's response to the measurand of interest while providing common-mode rejection of spurious environmental effects such as pressure or temperature changes. The presenters will describe several new fiber optic, interferometric accelerometers and acoustic pressure sensors which generate such large optical phase modulations that their signals can be demodulated with inexpensive lasers similar to those used in CD players.

Commercial Capaciflector
John M. Vranish, Electronics Engineer, Goddard Space Flight Center

Goddard researchers are developing a capacitative proximity/tactile sensor with unique performance capabilities for use on space robots and payloads. The simple, robust sensor will enable robots to avoid collisions with humans in orbit and to dock payloads in a cluttered environment. Mr. Vranish will report on NASA's efforts to "spin" this technology off into the private sector.

(Session E4)

Environmental Technology

Water Quality Monitor
Warren C. Kelliher, Langley Research Center

A portable x-ray fluorescence spectrometer developed for the Viking mission to Mars has been adapted for terrestrial use. Called EMPAX (Environment Monitoring with Portable Analysis of X-ray), the unit answers a critical need for on-site, real-time analysis of toxic metal contamination. The government is seeking a commercial manufacturer for EMPAX.

Remote Semi-Continuous Flowrate Logging Seepage Meter
William M. Reay, Virginia Polytechnic Institute and State University, and Harry Walthall, Langley Research Center

The presenters have created a remote semi-continuous flowrate logging seepage meter that enables direct assessment of ground water discharge and associated solute fluxes. It is designed to replace current manually-operated meters.

Calcification Prevention Tablets
G.A. Lindsay, Naval Weapons Center

The subject invention is a slow-release tablet for preventing or removing calcium crust and build-up in pipes and containers that process hard water and other calcium-containing fluids. Extremely effective in sea water, the tablet is biodegradable and nontoxic. It can be used in urinals, commodes, drains, and holding tanks.

Automated Carbon Dioxide Cleaning System
David T. Hoppe, Marshall Space Flight Center

An environmentally-safe cleaning system jointly developed by NASA, the Air Force, and Martin Marietta uses solidified carbon dioxide pellets to blast the surface to be cleaned. The process can be automated using a programmable robot. Results from cleaning a variety of substrate materials has shown the system to be capable of reducing the amount of chlorofluorocarbon-based cleaning fluids and in some cases totally eliminating their use.

(Session E5)

Materials Science

Applications of Biologically-Derived Microstructures
Joel M. Schnur, Head, Molecular Science and Engineering Center, Naval Research Laboratory

Navy scientists have fabricated hollow 0.5 micron diameter cylindrical-shaped microstructures using modified lipids and the self-assembly provided by nature. Potential applications for the microstructures include controlled release of biocide for antifouling paint, composites for electronic and magnetic uses, and high-power microwave cathodes.

Structural Modification of Polysaccharides: A Biochemical/Genetic Approach
Roger Kern and Gene Peterson, Space Biological Sciences Group, Jet Propulsion Laboratory

This presentation will describe the development of unique biological techniques for adapting polysaccharides for use in electronic and optical devices. The ability to manipulate polysaccharides genetically and chemically will have an immediate impact on current commercial applications based on rheological properties, such as materials coatings, pharmaceutical delivery systems, and food additives.

Cryogenic Focusing, Ohmically Heated On-Column Trap
Stephen R. Springston, Department of Applied Science, Brookhaven National Laboratory

Mr. Springston will present a new method for thermally desorbing volatile solutes that have been cryogenically trapped within a capillary. Advantages of this trap for gas chromatographic analyses include fast response, simplicity, and elimination of connections. Other applications include physico-chemical studies, sample modulation chromatography, and restrictors for supercritical fluid chromatography.

Study of the Effect of Hydrocarbon Contamination on PFTE Exposed to Atomic Oxygen
Morton A. Golub and Theodore Wydeven, Research Scientists, Ames Research Center

As part of an effort to improve the surface properties of PFTE (commonly known as Teflon™), Ames researchers are using x-ray photoelectron spectroscopy analysis to study the effect of hydrocarbon contamination on PFTE exposed to an oxygen plasma. Their work will lead to the development of better surface-modified PFTE products for the medical and industrial markets.

(Session E6)

Medical Advances

Applications of the Strategic Defense Initiative's Compact Accelerator Technology
Nick Montanarelli, Deputy Direct, Office of Technology Applications, Strategic Defense Initiative Organization

The Strategic Defense Initiative's investment in particle accelerator technology for its energy weapons program has produced small and powerful accelerations with a variety of "spinoff" medical applications. These include a radio frequency quadropole linear accelerator for a cancer therapy unit, a compact induction linear accelerator to sterilize medical products, and accelerators to produce the radioactive isotopes used as radiopharmaceuticals for positron emission tomography.

Acoustically-Based Fetal Heart Rate Monitor
Allan J. Zuckerwar, Langley Research Center, and Dr. Donald A Baker, Baker Guardian Medical Labs

A new fetal heart rate monitor, using piezopolymer pressure sensors on a belt worn by the mother, can identify the fetal heart tone from among competing background signals and, through signal processing, yield a real-time evaluation of the fetal heart rate. The monitor is inexpensive and lends itself to an ambulatory mode of operation, whereby the mother can conduct fetal non-stress tests in her home.

Surgical Force Detection Probe
Ping Tcheng, Charles Scott, and Paul Roberts, Research Engineers, Langley Research Center

A precision electromechanical instrument detects and documents the forces and moment applied to human tissue during surgery. The pen-shaped probe measures just 6 inches long and features a tip with an interchangeable scalpel. A PC-based data system provides signal conditioning, data acquisition, and graphics display.

Dynamic Inter-Limb Resistance Exercise Device
A.R. Hargens, D.F. Schwandt, S.E. Parazynski, and D.E. Watenpaugh, Research Scientists, Ames Research Center

The presenters will show an exercise machine developed to help astronauts maintain muscle and bone strength in space. The invention offers applications in the sports fitness market and in rehabilitation.

Concurrent Government-Industry Workshops 4:30 pm—6:00 pm

(Presenters to be announced)
Agencies holding workshops during this period will include:

- Department of Defense
- Department of Health and Human Services
- Department of Veterans Affairs
- National Aeronautics and Space Administration

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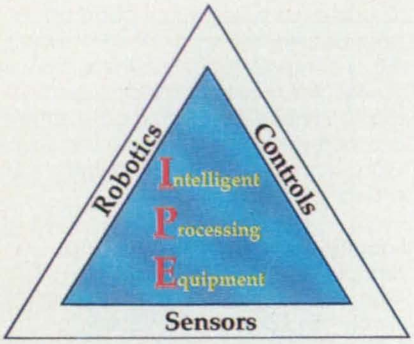


Advanced Manufacturing Technology

IPE Conference Program

The Intelligent Processing Equipment (IPE) Conference will focus on federally-developed innovations in robotics, sensors, and controls that industry can apply to a broad range of manufacturing processes, including machining, forming, welding, heat-treating, inspection, and assembly. Sixteen federal organizations will report on their present R&D efforts in intelligent processing during sessions held concurrently with Technology 2001 symposia in the San Jose Convention Center on Tuesday, Dec. 3 and Wednesday, Dec. 4.

On Thursday, Dec. 5, these presentations will be reviewed and discussed in panel sessions led by select industry leaders in manufacturing. A luncheon featuring a talk by a nationally-recognized expert in advanced manufacturing is also planned for Thursday in the convention center. Proceedings will be published and mailed to attendees after the conference.

The IPE sessions are open to all Technology 2001 registrants at no additional charge. Technology 2001 registrants are also invited to attend the Thursday luncheon, which will involve a small fee for food costs. Further information on the luncheon will be mailed to all Technology 2001 preregistrants prior to the show, and will also be available on-site at an information counter in the lobby.

The final program issued at the show will list all IPE Conference speakers and meeting room locations. The meeting rooms are in close proximity, making it easy for registrants to attend portions of both conferences.

IPE Conference Schedule:

Tuesday, December 3

**Technical Session
1:00 pm — 3:00 pm**

1:00 **Department of Agriculture**
Dr. Ruxton Villet, National Program Leader, Product Utilization, Agricultural Research Service

1:30 **Department of Commerce**
Ted Lettes, Director of Advanced Manufacturing, Office of Technology Commercialization

2:00 **Department of Energy**
Rick Peavy, Physical Scientist, Defense Programs Technology Transfer Div.

2:30 **Environmental Protection Agency**
Dr. Dan Greathouse, Operations Research Analyst

**Technical Session
4:30 pm — 6:00 pm**

4:30 **Federal Emergency Management Agency**
Anne Marie Surprise, Industrial Specialist

5:00 **Department of Interior**
Fred Schottman, Engineer, Div. of Minerals and Materials Science

5:30 **National Aeronautics and Space Administration**
Clyde Jones, Materials Engineer, Marshall Space Flight Ctr.

Wednesday, December 4

**Technical Session
8:30 am — 10:30 am**

8:30 **National Institutes of Health**
Dr. Caroline Holloway, Director, Office of Science and Policy

9:00 **National Science Foundation**
Dr. Suren Rao, Program Director, Div. of Design and Manufacturing

9:30 **Department of the Air Force**
Captain Paul Sampson, Program Mgr., Machine Tools, Processing and Fabrication Div.

10:00 **Department of the Army**
Amy Knutilla, PE, Assistant for ManTech, HQ US Army Material Command

**Technical Session
1:00 pm — 3:30 pm**

1:00 **Department of the Navy**
Dr. Phillip Nanzetta, Dept. of Commerce, NIST

1:30 **Defense Advanced Research Projects Agency**
Lt. Col. Eric Mettala, Deputy Director, Software and Intelligent Systems Office

2:00 **Defense Logistics Agency**
John Christensen, Industrial Engineer, Manufacturing Engineering Research Office

2:30 **Strategic Defense Initiative Organization**
Greg Stottlemyer, Director, Producibility and Manufacturing

3:00 **Manufacturing Technology Information Analysis Center**
Michal Safar, Director, MTIAC

Thursday, December 5

**Industry Review Panels
8:00 am — 11:00 am**

8:00 **Robotics Panel**
(Panelists to be announced)

9:30 **Controls Panel**
(Panelists to be announced)

**IPE Luncheon
11:30 am — 1:00 pm**

**Industry Review Panels
1:30 pm — 4:30 pm**

1:30 **Sensors Panel**
(Panelists to be announced)

3:00 **IPE Summary Session**
(Panelists to be announced)

For more information on the IPE Conf., call Robert Schwinghamer at (205) 544-1001.

Reserve Your Place At Technology 2001 Today

Save time and money: Preregister for Technology 2001 using the convenient form below. Mail the completed form with check payable to the Technology Utilization Foundation, or fax it with credit card information to (212) 986-7864 (VISA and Mastercard accepted). To register by phone, call (800) 944-NASA. Government organizations may register using a purchase order. **Deadline for preregistration is November 8.**

Choose from four types of registrations:

- Complete Registration—includes technical sessions, workshops, and exhibits for all three show days; tickets to the opening reception on Monday, Dec. 2 and the Technology Transfer Awards Dinner on Wednesday, Dec. 4; and a copy of the Technology 2001 proceedings.
- Symposia/Exhibits Registration—covers technical sessions, workshops, and exhibits for all three days.
- One-Day Symposia/Exhibits Registration
- One-Day Exhibits Only Registration

	By 11/8	On-Site
Complete Registration	$300	$325
Symposia/Exhibits Reg.	$200	$225
One-Day Symposia/Exhibits Reg.	$100	$125
One-Day Exhibits Only Reg.	$25	$30

Federal government employees are entitled to a 50 percent discount on above prices. Discounts are also available to groups of ten or more; call (212) 490-3999 for details.

Tickets to the Technology Transfer Awards Dinner may be purchased separately for $150 each using the preregistration form or by calling (212) 966-3100. Preregistrants can pick up their badges and reception/dinner tickets at the San Jose Convention Center, 150 West San Carlos St., during the hours listed below. Registration confirmations will be sent via mail.

On-Site Registration Hours

Monday, December 2	8:00 am - 5:00 pm
Tuesday, December 3	7:00 am - 4:00 pm
Wednesday, December 4	7:00 am - 4:00 pm
Thursday, December 5	7:00 am - 3:00 pm

The new San Jose Convention Center is situated in the heart of Silicon Valley.

Special Hotel Rates

Hotel space is limited, so act early to secure these special conference rates:

	Single	Double
Fairmont Hotel (headquarters hotel) (800) 527-4727	$105	$105
Hyatt San Jose (408) 993-1234	$85	$105
Red Lion (408) 453-4000	$80	$80
Hotel De Anza (800) 843-3700	$115	$130

The Fairmont and Hotel De Anza are within walking distance of the Convention Center; the Hyatt and Red Lion are approx. ten minutes away by Light Rail—San Jose's modern, efficient public transit system. When making reservations, you must mention Technology 2001 to obtain the special rates.

Transportation Discounts

Ground: Hertz Corp. is offering special discounted car rental rates with unlimited mileage. For reservations, call Hertz Meeting Services at (800) 654-2240 and identify yourself as an attendee of Technology 2001, meeting #9208.

Air: Discounted air fares are available to Technology 2001 attendees through American Airlines. Call American Airlines' Meeting Service Desk at (800) 433-1790 and ask them to display Star File #S01N1BG. Make reservations as the lowest applicable fare from your departure city and give your mailing address. Nepal Travel Bureau—the official travel agency for Technology 2001—will mail you the tickets. For follow-up inquiries about your tickets, call Nepal Travel at (800) 666-4519.

An Ideal Location

The Convention Center is located just three miles from San Jose International Airport, and offers plenty of indoor parking. At the heart of the downtown cultural center, the Convention Center is within easy walking distance of restaurants, shops, and entertainment. For information on cultural activities, attractions, and tours, call the San Jose Convention and Visitors Bureau at (408) 295-9600.

Questions? Call Joseph Pramberger or Justina Cardillo at (800) 944-NASA.

Technology 2001 Preregistration Form

Use a separate form or photocopy for each registrant. Type or print clearly.

Name ____________________

Title ____________________

Company ____________________

Address ____________________

City/St/Zip ____________________

Phone ____________________

❒ check enclosed charge my: ❒ VISA ❒ Mastercard

Account No.____________________

Expiration: Mo.______ Yr.________

Signature____________________

Registration Fees:

Complete Registration	$300	$ ____
Symposia/Exhibits Reg.	$200	$ ____
One-Day Symposia/Exhibits *(circle day: Tues. Wed. Thurs.)*	$100	$ ____
One-Day Exhibits Only *(circle day: Tues. Wed. Thurs.)*	$25	$ ____
Awards Dinner Only	$150	$ ____

Total: (Fed. govt. employees deduct 50%) $ ____

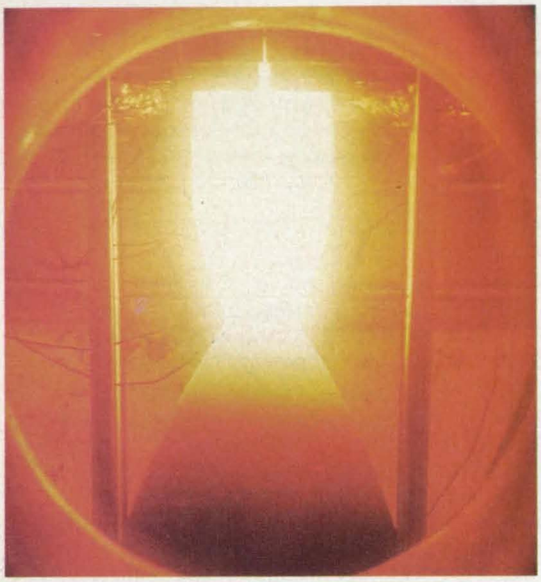
Registrations and awards dinner reservations are transferable, and may be cancelled until Nov. 8, 1991 subject to a $50 cancellation fee. After that date no cancellations will be accepted and no money refunded.

Return with payment to: Technology Utilization Foundation, 41 East 42nd St., Suite 921, New York, NY 10017

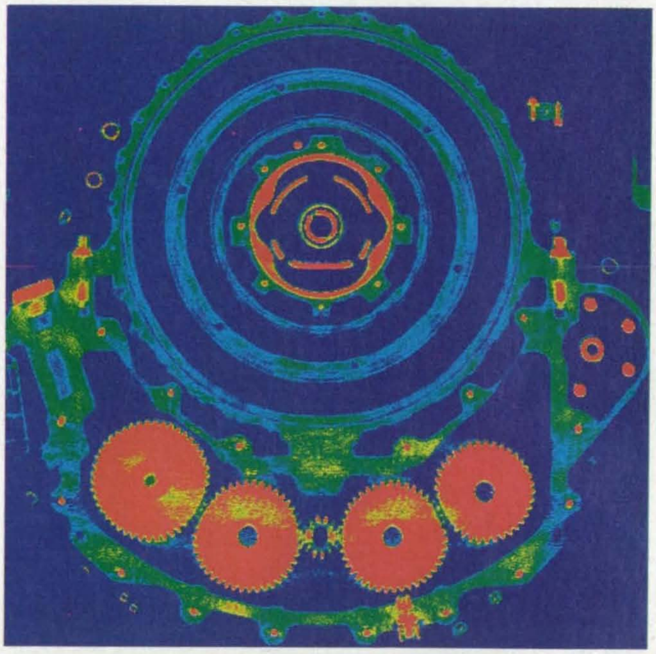
Explore The Cutting Edge

Technology 2001 symposia and exhibits will spotlight the best new inventions from federal laboratories, universities, and leading high-tech companies. Here's just a sample of the hundreds of innovations that await you.

The Ames Research Center exhibit will feature a virtual reality system that combines 3D sound and imagery to create "artificial worlds."

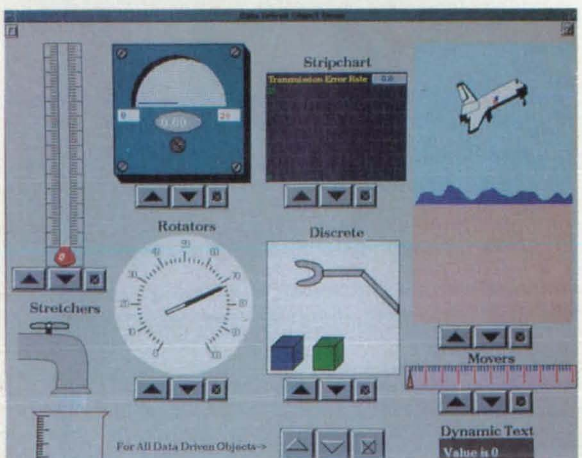


Ultramet will showcase an iridium/rhenium thrust chamber that has been called "the greatest advance in chemical rocket technology in three decades."

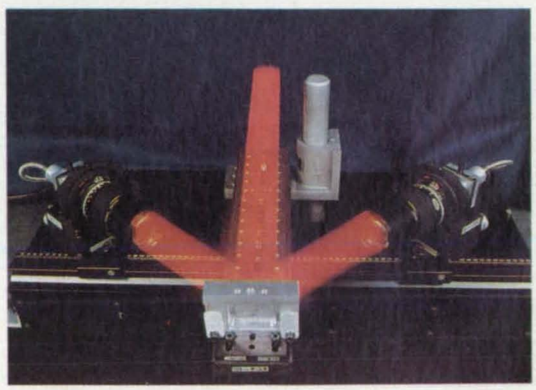


The Marshall Space Flight Center will demonstrate an advanced computed tomography system, shown here inspecting the gearing inside a Tomahawk Cruise Missile.

A patented recycling system to be displayed by Sorbilite Inc. converts paper, sawdust, and other waste products into high-quality 3D parts.



Goddard Center researchers will describe an innovative software tool for building and managing graphical user interfaces.



A major advance in the study and measurement of distortion, stress, and fracture will be shown by Idaho National Engineering Laboratory.

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Computer Programs

COSMIC: Transferring NASA Software

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

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

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

COSMIC is part of NASA's Technology Utilization Network

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Computer Programs

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

Physical Sciences

Contamination Analysis Program

This program models emission, reemission, deposition, and reflection of mass fluxes.

The Jet Propulsion Laboratory Contamination Analysis Program (CAP) is a generalized transient-executive-analysis computer code that solves realistic mass-transport problems in the free-molecular-flow environment. These transport problems involve mass fluxes from emission and reemission by sources on surfaces, venting, and emission by engines. If so required, CAP can also solve problems that include one-bounce mass reflections.

The solution procedure uses an enclosure method based on a lumped-parameter multinodal approach with exchange of mass between nodes. Transient solutions are computed by the finite-difference Euler method. First-order rate theory is used to represent surface emission and reemission (the user must take care to ensure that the problem is appropriate for such behavior), and all surface emission and reflections are assumed to be diffuse. CAP does not include the effects of postdeposition chemistry or interaction with the ambient atmosphere.

CAP reads in a mathematical model represented by an input stream of multiple blocks of data. CAP enables the user to edit the input stream and stack sequential editing operations (or cases) to make complex changes in behavior (surface temperatures, engine startup and shutdown, and the like) in a single run if desired. The eight data blocks that constitute the input data stream consist of problem-control parameters, nodal data (area, temperature, mass, and the like), engine or vent-distribution factors (based upon definitions of plumes), geometric configuration factors (diffuse surface emission), tables of surface capture coefficients, tables of rate constants for emission from sources, tables of rate constants for reemission, and the capability for partial node-to-body collapse (for deposition rates only).

The user must generate this data stream, inasmuch as neither the problem-specific geometric relationships, nor the constituents involved, nor the plume-distribution functions are parts of CAP. Instead, these are used to generate the data-stream model that CAP solves. Outputs vary from individual deposition rates of exchange on an internodal basis and on a constituent basis as a function of time, to deposition on each surface on a constituent basis as a function of time. By specifying control parameters, the user can specify the types of outputs. CAP enables the user to select output intervals within the solution interval and to generate restart nodal data blocks.

CAP is composed of several FORTRAN subroutines that serve specific functions and can be easily edited. It is written in relatively simple FORTRAN to be adaptable to a variety of computers and was implemented on a DEC VAX 780 computer. The code is relatively small (2,152 statements) and contains comment statements for all operations. The required virtual memory is 4.6 MB, which corresponds to the capacity for a model that contains 900 nodes. CAP was originally developed under contract for NASA/GSFC by JPL in 1979 and was subsequently modified as required to support projects at JPL. CAP is a copyrighted product of the California Institute of Technology.

This program was written by Jerry M. Millard and Carl R. Maag of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 114 on the TSP Request Card.*
NPO-17982

Mechanics

Improved Panel-Method/Potential-Flow Code

The size of the program can be adapted to the capacity of the computer.

Panel-method computer programs are software tools of moderate cost used for solving a wide range of engineering problems. The panel code PMARC (Panel Method Ames Research Center) can numerically simulate the flow field around complex three-dimensional bodies, such as complete aircraft models. PMARC is based on potential-flow theory. The code is written in standard FORTRAN 77, with the exception of the namelist extension used for input. The structure of PMARC facilitates the addition of new features to the code and the tailoring of the code to specific problems and computer hardware constraints.

In a panel method, the surface of the body over which the flow field is to be computed is represented by a set of panels. Singularities are distributed on the panels to perturb the flow field around the body surfaces. PMARC uses source and doublet singularities, distributed uniformly over each panel. Since the singularity strength is constant on each panel, the method is labeled a low-order panel method. Higher-order panel methods allow the singularity strength to vary linearly or quadratically across each panel. Experience has shown that low-order panel methods can provide nearly the same accuracy as higher-order methods over a wide range of cases, with significantly reduced computation times; hence, the low-order formulation was adopted for PMARC.

To avoid unnecessary duplication of previous work, existing software was utilized whenever possible to reduce the development time of PMARC. The basic potential-flow computational methods and techniques were patterned after the 1,000-panel version of VSAERO (developed by Analytical Methods, Inc.), which is currently available through COSMIC.

The flow problem is solved by modeling the body as a closed surface dividing space into two regions: the region external to the surface in which an unknown velocity potential exists representing the flow field of interest, and the region internal to the surface in which a known velocity potential (representing a fictitious flow) is prescribed as a boundary condition. Both velocity potentials are assumed to satisfy Laplace's equation. A surface integral equation for the unknown potential external to the surface can be written by applying Green's theorem to the external region. Using the internal potential and zero flow through the surface as boundary conditions, the unknown potential external to the surface can be solved for.

The management of the data within the PMARC code is highly optimized. All of the arrays within the code are adjustable arrays; thus, the size of the code (i.e., the number of panels that it can handle) can be changed very quickly. This allows PMARC to be sized to run on anything from a personal computer like a Macintosh to a supercomputer like the Cray Y-MP. The output and plot files from PMARC have been organized to maximize the amount of information they contain while minimizing their size.

The present version of PMARC includes several advanced features. The first is an internal-flow modeling capability that allows the analysis of closed ducts, wind tunnels, and similar internal-flow problems. When the internal-flow option is selected, the geometry is modeled such that the flow field of interest is inside the geometry and the fictitious flow is outside the geometry. Items such as wings, struts, or aircraft models can be included in the internal-flow problem.

A second feature is a simple jet model that allows the modeling of the gross effects of a jet in crossflow. The shape, trajectory, and entrainment velocities of the plume are computed by use of the Adler/Baron jet in crossflow code. This information is then passed back to PMARC. PMARC creates a plume using surface panels at the boundary of the plume as computed by Adler/Baron. Entrainment is modeled by specifying normal velocities on each panel making up the jet plume.

A third feature is a time-stepping wake model that gives PMARC the ability to model both steady- and unsteady-flow problems. The wake is convected downstream from the wake-separation line by the local velocity field. With each time step, a new row of wake panels is added to the wake at the wake-separation line. Time stepping can start from time $t = 0$ (no initial wake) or from time $t = t_0$ (an initial wake is specified).

The PMARC computer code is currently available through COSMIC. The default distribution media are three 3.5-in. standard Apple Macintosh diskettes (also available on VAX TK-50 tape cartridge or VAX 9-track tape if requested).

This program was written by Dale L. Ashby of **Ames Research Center**. *For further information, Circle 7 on the TSP Request Card.*
ARC-12642

Analyzing Control/ Structure Interactions

CO-ST-IN works in conjunction with other programs to enhance analysis of vibrations.

CO-ST-IN is a computer program developed for NASA to facilitate the study of control/structure interactions; that is, the dynamic coupling between control systems and flexible structures. As currently envisioned, structures for use in outer space are to be larger and more flexible than contemplated in previous designs. At the same time, increased demands are being placed on the performances of control systems. It is essential to analyze the interactions of control systems with the flexibilities of many such space structures. CO-ST-IN was designed to complement and enhance rather than to replace those software tools for the analysis of control systems and the dynamics of structures that are already available at NASA.

The functions performed by CO-ST-IN can be roughly divided into three areas: (1) transfer of data between structural-

Circle Reader Action No. 580

dynamics and control-systems software (CO-ST-IN currently supports MSC/NASTRAN, I-DEAS, EASY5, and MATRIXx to various degrees); (2) selection of vibrational modes at the component and system levels as a means of reduction of the mathematical model of a system; and (3) simulation of the coupled system (given simple controllers).

CO-ST-IN reduces the size of the mathematical model of the structure by selecting vibrational modes of the system on the basis of input/output coupling (three algorithms along with a number of other options are offered). This enables the analyst to use far fewer modes in the coupled analysis, inasmuch as the program selects those modes that are most closely coupled to the inputs to and outputs of the structure. Another special capability is the calculation of such outputs of the structure as forces and stresses in elements, using either the mode-acceleration or mode-displacement approach directly within the coupled simulation. This eliminates the need to return to MSC/NASTRAN for recovery of these data, shortening the time required to perform an analysis. CO-ST-IN also supports the transfer of input forces for analysis of transients in MSC/NASTRAN.

CO-ST-IN was implemented on a DEC VAX computer with the VMS operating system. This FORTRAN77 program requires a memory of 9.4 MB. CO-ST-IN was developed in 1989.

This program was written by K. Carney of **Lewis Research Center** *and P. Blelloch of SDRC, Inc. For further information, Circle 38 on the TSP Request Card.*
LEW-14904

Plotting Orbital Trajectories for Maneuvers

An interactive program helps in planning the maneuver of one spacecraft with respect to another.

The Interactive Orbital Trajectory Planning Tool (EIVAN) computer program is a forward-looking interactive orbit-trajectory-plotting software tool for use with proximity operations (operations occurring within a 1-km sphere of a space station) and other maneuvers. The results of vehicle burns on orbit are very difficult to anticipate because of nonlinearities in the equations that govern the motion of orbiting bodies. EIVAN was developed to plot resulting trajectories, to provide a better comprehension of the effects of orbital mechanics, and to help the user develop heuristics for planning missions on orbit.

EIVAN consists of a worksheet and a chart from Microsoft Excel on a Macintosh computer. Given burn inputs by the user, EIVAN plots the orbital path for an interval of time specified by the user. The use of fuel is also calculated. After the thrust parameters (magnitude, direction, and time) are entered, EIVAN plots the resulting trajectory. As many as five burns can be inserted at any time in the mission. Twenty data points are plotted for each burn, and the interval can be varied to accommodate any desired time frame or degree of resolution. Since the number of data points for each burn is constant, the duration of the mission can be increased or decreased by increasing or decreasing the interval.

The EIVAN program runs with Microsoft's Excel for execution on a Macintosh computer running Macintosh OS. A working knowledge of Excel is helpful, but not imperative, for interacting with EIVAN. The program was developed in 1988.

This program was written by Adam R. Brody of Sterling Software for **Ames Research Center**. *For further information, Circle 43 on the TSP Request Card.*
ARC-12365

Mathematics and Information Sciences

Software for Integration of EVA and Telerobotics

The TEJAS program facilitates discussion, communication, and analysis in the EVA and telerobotics communities.

The primary objective of space telerobotics as a research discipline is the augmentation and/or support of extravehicular activity (EVA) with telerobotic activity; this enables increased emplacement of on-orbit assets while providing for "in situ" management of them. The development of the requisite telerobot work system requires a well-understood correspondence between EVA and telerobotics that to date has been only partially established.

The Telerobotics/EVA Joint Analysis Systems (TEJAS) computer program is a hypermedia information software system that uses object-oriented programming to bridge the gap between crew-EVA and telerobotics activities. TEJAS Version 1.0 contains 20 HyperCard stacks that use a visual, customizable interface of icon buttons, pop-up menus, and relational commands to store, link, and standardize related information about the primitives, technologies, tasks, assumptions, and open issues involved in space-telerobot or crew-EVA tasks. These stacks are meant to be interactive and can be used with any data base system running on a Macintosh computer, including spreadsheets, relational data bases, word-processed documents, and hypermedia utilities. The software provides a means for managing volumes of data and for communicating complex ideas, relationships, and processes inherent to planning tasks.

The stack system contains 3 MB of data and utilities to aid reference, discussion, communication, and analysis within the EVA and telerobotics communities. The six baseline analysis stacks (EVATasks, EVAAssume, EVAIssues, TeleTasks, TeleAssume, and TeleIssues) work interactively to manage and relate basic information about the crew-EVA and telerobot tasks that one enters and that one wishes to analyze in depth. Analysis stacks draw on information in the reference stacks as part of a rapid point-and-click utility for building scripts of specific task primitives or for any EVA or telerobotics task. Any or all of these stacks can be completely incorporated within other hypermedia applications, or they can be referenced as is, without requiring data to be transferred into any other data base.

TEJAS is simple to use and requires no formal training. Some knowledge of HyperCard is helpful but not essential. All Help cards printed in the TEJAS User's Guide are part of the TEJAS Help Stack and are available from a pop-up menu any time one uses TEJAS. Specific stacks created in TEJAS can be exchanged between groups, divisions, companies, or centers for complete communication of fundamental information that forms the basis for further analyses.

TEJAS runs on any Apple Macintosh personal computer with at least 1 megabyte of random-access memory, a hard disk, and HyperCard 1.21 or a later version of HyperCard.

TEJAS is a copyrighted product of the California Institute of Technology. HyperCard and Macintosh are registered trademarks of Apple Computer, Inc.

This program was written by Michael L. Drews, Jeffrey H. Smith, Jay M. Estus, Cate Heneghan, Wayne Zimmerman, Paolo Fiorini, Paul S. Schenker, and Douglas A. McAffee of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 20 on the TSP Request Card.*

NPO-18220

Decomposing Systems Into Subsystems for Design

Interactions among systems are displayed in a concise format.

Many engineering systems are large, and multidisciplinary approaches are necessary to design them. Before the design of such a new, complex system as a large space platform can begin, the possible interactions among subsystems and the processes in them must be determined. The proposed system must be decomposed to identify its hierarchical structure. DeMAID (A Design Manager's Aide for Intelligent Decomposition) is a knowledge-based software system for automating the sequencing of the subprocesses in the design process and identifying a possible multilevel structure for the synthesis problem. Though DeMAID requires an investment of time to generate and refine the interactions among the processes in the equipment subsystems being designed, it could save a considerable amount of money and time in the total design process, particularly in new design problems in which the ordering of the subprocesses of the design process has not been defined.

The decomposition of a complex design system into subsystems requires the judgment of the design manager. DeMAID reorders and groups the modules of equipment being designed (and the processes in them) on the basis of the links (interactions) among the modules, helping the design manager make design decisions early in the design cycle. The modules are grouped into circuits (the subsystems) and displayed in an $N \times N$ matrix format. Feedback links, which indicate an iterative process, occur only within a circuit. Because there are no feedback links among the circuits, the circuits can be displayed in a multilevel format. Thus, a large amount of information is reduced to one or two displays that can be stored for later retrieval and modification. The design manager and leaders of the design teams then have a visual display of the design problem and the intricate interactions among the different modules.

A substantial amount of time could be saved during the design process if circuits on the same level of the multilevel structure were executed in parallel. DeMAID determines the time saved as well as the number of processors required. In addition to decomposing the system into subsystems, DeMAID examines the dependencies of the problem and creates a dependency matrix. This matrix shows the relationship among the independent design variables and the dependent objective and constraint functions. Because DeMAID relies on knowledge-based techniques, the addition of new capabilities is relatively easy.

The user begins the design process by determining those interactions among the various modules that might contribute to the solution of the design problem. The interactions are determined by examining the input and output of each module. A file of data on these modules is created for the main program. DeMAID then executes several functions through a system of menus. The user has the choice to plan, schedule, display the $N \times N$ matrix, display the multilevel organization, examine parallelism, or examine the dependency matrix. Each of these functions loads a rule file, asserts facts from a data file into the knowledge base, and applies the rules to the facts via the CLIPS inference engine.

DeMAID was written in FORTRAN 77 for a DEC VAX computer running the VMS operating system. The program runs with the VAX GKS graphics software system but can easily be modified to run with another graphics system. The CLIPS 4.2 run-time library is included with the program. DeMAID has a memory requirement of 200 KB and was developed in 1989.

This program was written by James L. Rogers, Jr., of **Langley Research Center**. *For further information, Circle 156 on the TSP Request Card.*

LAR-14210

HyperCLIPS

The Hypercard and CLIPS programs are combined into a program that offers the advantages of both.

The integration of the CLIPS computer program into the HyperCard computer program combines the intuitive, interactive user interface of the Macintosh computer with the powerful symbolic computation of an expert-system interpreter. HyperCard provides an excellent programming environment for quickly developing the front end of an application program with buttons, dialogs, and pictures, while the CLIPS interpreter provides a powerful inference engine for the analysis and solution of complicated problems.

To understand the benefit of the integration of the HyperCard and CLIPS programs, consider the following: HyperCard is an information-storage-and-retrieval software system that exploits the graphics and user-interface capabilities of the Apple Macintosh computer. The user can easily define buttons, dialog boxes, information templates, pictures, and graphical displays through the use of the HyperCard tools and scripting language.

What is generally lacking in this programming environment is a powerful reasoning engine for the solution of complicated problems, and this is where CLIPS plays a role. CLIPS (C Language Integrated Production System) was developed at the Johnson Space Center by the Artificial Intelligence Section for use in developing software systems for the NASA Mission Control Center. CLIPS includes a forward-chaining rule system with an expressive syntax that allows free-form patterns, single and multifield variable bindings across patterns, and other features. Inasmuch as CLIPS is implemented in the C language, it is highly portable. In addition, it is embeddable as a callable routine from a program written in another language such as Ada or FORTRAN. The integration of HyperCard and CLIPS makes advantages of both packages available for a wide range of uses: rapid prototyping of knowledge-based expert-systems software, interactive simulations of physical systems, and intelligent control of hypertext processes, to name a few.

HyperCLIPS requires an Apple Macintosh computer with at least 2 MB of random-access memory, Macintosh system 6.0.2 or greater, and HyperCard 1.2 or greater. For recompilation, Macintosh Programmer's Workshop (MPW) version 3.0, CLIPS 4.3 or greater, and the MPW C compiler are required. The program was developed in 1989 and is written in C language and Pascal. HyperCLIPS is a copyrighted product of the California Institute of Technology.

This program was written by Randall W. Hill, Jr., and William B. Pickering of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 118 on the TSP Request Card.*
NPO-18087

Expert Script Generator

This program provides an additional level of interface to facilitate use of a telerobotic system.

The Automation Technology Branch of NASA's Langley Research Center is employing increasingly complex degrees of operator/robot cooperation (telerobotics). A good relationship between the operator and computer is essential for smooth performance by a telerobotic system. ESG (Expert Script Generator) is a software package that automatically generates high-level task objective commands from the complex menu-driven language of the NASA Intelligent Systems Research Laboratory (ISRL).

ESG reduces errors and makes the telerobotics laboratory accessible to researchers who are not familiar with the comprehensive language developed by ISRL for interacting with the various systems of the ISRL test bed. ESG incorporates expert-system technology to capture the typical rules of operation that a skilled operator would use. The result is an operator interface that optimizes the ability of the system to perform a task remotely in a hazardous environment, in a timely manner, and without undue stress to the operator, while minimizing the chance for operator errors that may damage equipment.

The intricate menu-driven command interface that provides for various control modes of both manipulators and their associated sensors in the TeleRobotic System Simulation (TRSS) software has a syntax that is both irregular and verbose. ESG eliminates the following two problems with this command "language": (1) knowing the correct command sequence to accomplish a task and (2) putting in a known command sequence without typographical and other errors. ESG serves as an additional layer of interface, working in conjunction with the menu command processor, not supplanting it.

By specifying such task-level commands as GRASP, CONNECT, and the like, ESG generates the appropriate menu elements to accomplish the task. These elements are collected in a script file that can then be executed by the ISRL menu command processor. In addition, the operator can extend the list of task-level commands to include customized tasks composed of subtask commands. This mechanism gives the operator the ability to build a task-hierarchy tree of increasingly powerful commands. ESG also provides automatic regeneration of scripts based on what the system "knows" about updates on the telerobotic environment. The commands generated by ESG can be displayed at the terminal screen and/or stored.

ESG is implemented as a rule-based expert system written in CLIPS (C Language Integrated Production System). The system consists of a knowledge base of task heuristics, a static (unchanged during execution) data base that describes the physical features of objects, and a dynamic (may change as a result of fulfillment of tasks) data base that records changes in the environment. Capabilities are provided for the addition of new environmental objects and for the modification of existing objects and of data on configurations that are provided. Options for interactively viewing the values of both static and dynamic attributes of items in data bases are provided. Execution of the ESG can be suspended to allow access to functions at the system level.

ESG was implemented on a VAX 11/780 computer with the VMS 4.7 operating system, using a terminal compatible with a VT100. Its source code is 47 percent CLIPS and 53 percent C language, with a memory requirement of approximately 205 KB. The program was developed in 1988.

This program was written by Nancy E. Sliwa of **Langley Research Center** *and Eric G. Cooper of Planning Research Corp. For further information, Circle 9 on the TSP Request Card.*
LAR-14065

Mechanics

Grasping-Force Sensor for Robot Hand

Claws remain aligned during grasping.

NASA's Jet Propulsion Laboratory, Pasadena, California

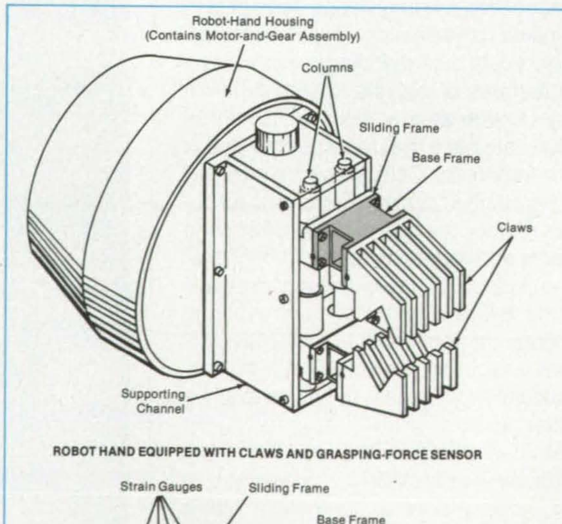
A grasping-force sensor is designed for use on a robot hand that includes interdigitating claws that are required to remain in alignment. Like other robotic grasping-force sensors, it relies on strain-gauge measurements of the deflection of part of the grasping mechanism. However, the design of the grasping-force sensor is integrated with that of the grasping mechanism in such a way that unlike in prior designs, the deflection caused by the grasping force does not disturb the angular alignment of the claws.

The figure shows the claw assembly mounted within a supporting channel. A motor-and-gear assembly mounted on a resilient base (not shown) moves the claws toward or away from each other along two columns. The claws are mounted on elastic base frames (the deflecting elements), which, in turn, are mounted on sliding frames that move along the columns. Unlike in prior designs, the claws can be installed, removed, or interchanged with other end effectors without having to disassemble the actuating mechanism.

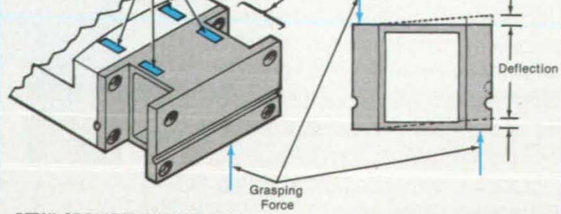
The hollow rectangular cross sections of the base frames make the frames act similarly to parallelogram linkages when they are subjected to the grasping force directed along their vertical (as shown in the figure) sides. The horizontal (as shown in the figure) sides bend in the manner of cantilever beams, while the vertical sides remain parallel. The claws and the sliding frame, which are attached to the vertical sides, therefore remain aligned. The distortion of the base frame causes a very small horizontal translation of the claws toward the sliding frame, but both claws translate by the same amount and thereby remain horizontally translationally as well as angularly aligned. Even if one claw encounters an obstacle that the other does not encounter, there is only a small horizontal misalignment, but the claws remain angularly aligned.

Two strain gauges are mounted on the outer surface of each base frame, and two matching gauges are mounted on the sliding frame structure on which each base frame is mounted. These gauges are connected in a full-bridge configuration that measures the deflection along the axis

The **Grasping-Force Sensor** is an integral part of the grasping claw assembly on the robot hand. The base frames deflect elastically, partly in the manner of a cantilever beam and partly in the manner of a parallelogram linkage. Strain gauges measure the grasping forces by measuring the deflections.



ROBOT HAND EQUIPPED WITH CLAWS AND GRASPING-FORCE SENSOR



DETAIL OF BASE FRAME ON SLIDING FRAME, SHOWING STRAIN GAGES

DETAIL OF DEFLECTION OF BASE FRAME

of motion of the claws toward or away from each other (the vertical axis in the figure). The outputs of the strain-gauge bridge circuits are transmitted to the robot-control computer, which converts them into indications of the grasping force. With the help of this sensing system, the operator can feel the initial contact between the claws and an object and modify the motions of the robot arm, hand, and claws accordingly.

This work was done by Victor D. Scheinman, Antal K. Bejczy, and Howard K. Primus of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 117 on the TSP Request Card.*

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

Edward Ansell
Director of Patents and Licensing
Mail Stop 305-6
California Institute of Technology
1201 East California Boulevard
Pasadena, CA 91125

Refer to NPO-16647, volume and number of this NASA Tech Briefs *issue, and the page number.*

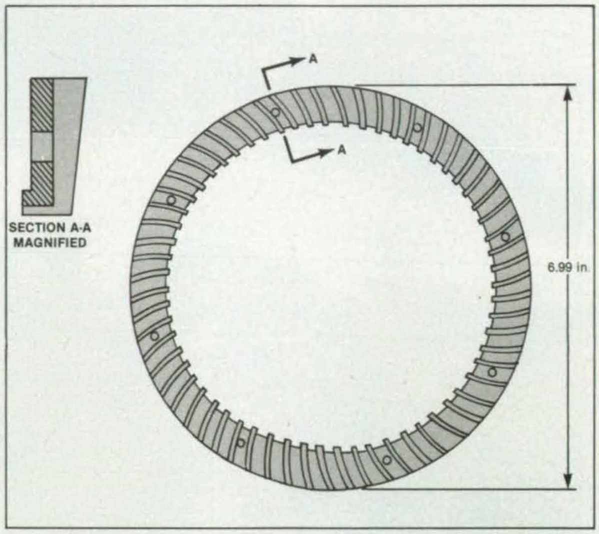
Low-Leakage Inlet Swirl Brake

Vanes change the direction of flow while giving rise to relatively low static pressure.

Marshall Space Flight Center, Alabama

An improved swirl brake offers both lower rotordynamic instability and lower static-pressure rise. In general, a swirl brake is a device that changes the direction of flow into a fluid seal in a turbomachine from circumferential to partly or entirely axial. Such a device is needed because high inlet circumferential velocities have been shown by experiment to give rise to rotor-destabilizing forces.

The problem in designing a swirl brake is to obtain a low whirl-frequency ratio without causing an excessive buildup of static pressure at the inlet. This problem arises because the ratio of destabilizing to stabilizing forces increases or decreases with the whirl-frequency ratio and because an increase in static pressure caused by diversion of the flow can give rise to an undesired increase in seal leakage. A two-dimensional finite-element solution of the Navier–Stokes equations was used to optimize the design. The angle of the turning vanes in the swirl brake (see figure) was chosen to eliminate the circumferential component of inlet flow. The turning vanes cause the flow to converge so that the increased velocity of flow results in a lower static pressure.



Sixty-Four Vanes are evenly spaced around a ring. The vanes convert inlet flow from circumferential to axial.

This work was done by Joseph K. Scharrer of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information, Circle 12 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 16]. Refer to MFS-29608.

Spectral Method for Simulation of Vortex Rings

Computations yield accurate results for long times.

Ames Research Center, Moffett Field, California

A method of computation that relies on spectral basis functions has been developed especially for the simulation of axisymmetric vortex rings in an incompressible, viscous fluid with a quiescent far field. From experience in the study of other flows, properly formulated spectral methods are known to yield exponential convergence to accurate solutions. The present spectral method contributes to our understanding of the flows in and around vortex rings (e.g., smoke rings) during long propagation times, including such theoretically and practically important phenomena as the drift and expansion of a ring, "leapfrogging" and coalescence of two rings, and the shedding of vorticity into the wake of a propagating ring.

The physics of the flow are represented by the Navier–Stokes equations for an incompressible fluid. Because the domain of flow is unbounded and vortex rings are known to diffuse and translate, the equations are expressed in a translating, expanding spherical coordinate system. The transformation to this coordinate system leaves the boundary conditions invariant and has minimal impact on the algorithm used to solve the Navier–Stokes equations. The expansion is chosen to match that of the viscous length scale, while the translation is chosen to minimize the dependence of the solution on time in the transformed coordinates.

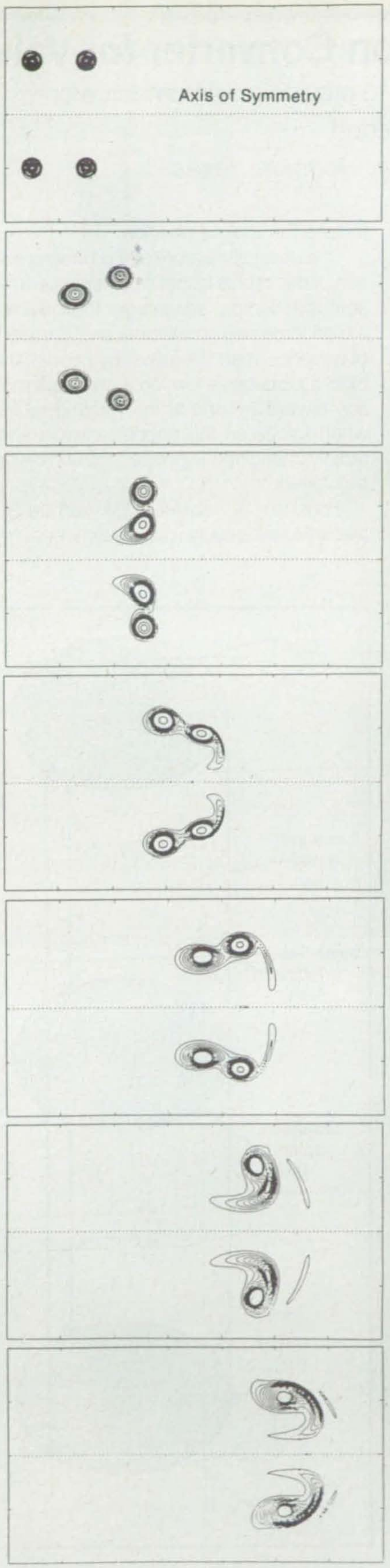
The flow field is represented by a weighted sum of spatially dependent functions that constitute the basis vectors for the solution space. The weighting coefficients depend on time and specify the evolution of the flow field. The angular dependence is specified in the basis functions by vector spherical harmonics. The semi-infinite radial domain $0 \le r < \infty$ is transformed further to a finite domain, $0 \le \xi < 1$, and the radial dependence of the velocity and vorticity is then specified in the basis functions by Jacobi polynomials.

The divergence of the velocity field is made zero (as it must be in incompressible flow) by choosing a divergence-free subset of the basis functions. By appropriate choice of the basis functions, the pressure term disapears when the basis functions are inserted in the Navier–Stokes equations, which are in turn multiplied by each basis function separately and integrated over the complete domain. Through this process, the Navier–Stokes equations reduce to a set of coupled ordinary differential equations that are numerically integrated in time from an initial flow field.

Flow fields, each characterized by one or two vortex rings, were simulated by this method for various Reynolds numbers from 0.001 to 1,000. At long times, every such flow was observed to approach a Stokes solution (a slowly decaying analytical solution) that depends only on the total hydrodynamic impulse, which is conserved for all time. At small times, the propagation speeds of initially infinitely thin vortex rings agree with a previous asymptotic theory. Following a single ring, with a Reynolds number of 500, the vorticity contours indicate shedding of vorticity into the wake and a settling of an initially circular core to a more elliptical shape, similar to that of a previous calculation for steady inviscid vortexes. A computation of "leapfrogging" vortex rings at a Reynolds number of 1,000 shows severe straining of the inner vortex core in the first pass and merging of the two cores during the second pass (see figure).

This work was done by S. K. Stanaway and B. J. Cantwell of Stanford University and P. R. Spalart of **Ames Research Center**. *Further information may be found in NASA TM-101041 [N89-23820], "A Numerical Study of Viscous Vortex Rings Using a Spectral Method."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.
ARC-12639



Two "Leapfrogging" Vortex Rings in a viscous flow (Reynolds number 1,000) were simulated numerically by the method described in the text. The lines represent contours of equal vorticity. The coalescence of vortexes and the shedding of vorticity into the wake are not predicted by simpler methods based on inviscid flow.

Rotary-to-Axial Motion Converter for Valve

The mechanical advantage varies to provide maximum force or translation where each is most needed.

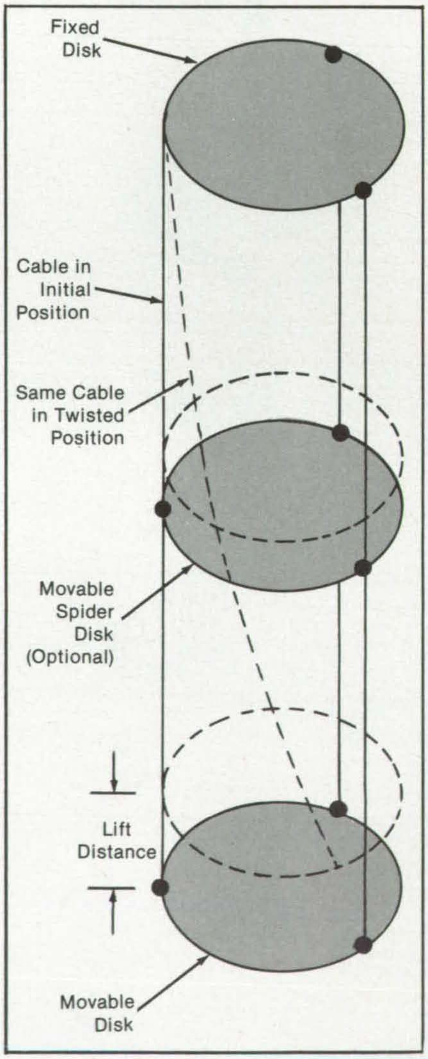
Lyndon B. Johnson Space Center, Houston, Texas

A nearly frictionless mechanism converts rotary motion into axial motion. The mechanism was designed for use in an electronically variable pressure-regulator valve. It changes the rotary motion imparted by a motor into translation that opens and closes the valve poppet. The mechanism requires no lubrication and is insensitive to contamination in the fluid flowing through the valve.

The mechanism includes two disks of equal diameter joined by a set of flexible bands or cables (see figure). One of the disks is fixed, while the other is axially and rotationally movable. Initially, when the valve is closed, the cables are parallel. When a motor rotates the movable disk, the cables twist, pulling the movable disk toward the fixed disk. This action also pulls the poppet, which is attached to the movable disk, out of its seat. When rotation of the motor is reversed, the cables unwind and lower the movable disk and poppet toward the closed position.

One desirable feature of the twisting action of the cables is that it produces a variable mechanical advantage. It produces a high force and small motion at the start of twisting, when forces on the poppet are high. It produces a low force and large motion toward the end of the twisting cycle, when forces on the poppet are low and rapidly changing the poppet position helps regulation.

Optionally, a "spider" disk can be attached to the cables midway between the



Cables Spaced Equidistantly around the edge of a fixed disk support a movable disk. As the movable disk is rotated, the cables twist, lifting it. When the movable disk is rotated in the opposite direction, the cables untwist, lowering it. The spider disk helps to prevent the cables from tangling.

fixed and movable disks to prevent the cables from closing in and wrapping around each other. It also increases the lift at the end of the twisting cycle.

This work was done by Robert H. Reinicke and Rafic Mohtar of Eaton Corp. for **Johnson Space Center**. *For further information, Circle 104 on the TSP Request Card.*

MSC-21697 and MSC-21698

Adjustable Support for Instrument Package

A structure can be adapted to a variety of configurations.

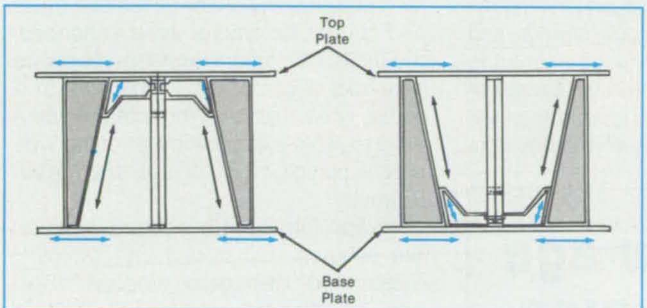
Goddard Space Flight Center, Greenbelt, Maryland

A strong, lightweight structure is designed to support an instrument package. The structure provides a choice of attachment locations to accommodate a variety of sizes and shapes. This structure is being used for the submillimeter-wave astronomy satellite.

The structure is a bridge composed of seven webbed metal parts (see figure). Honeycomb panels (not shown) cover the vertical sides of the structure. The instrumentation package, such as a telescope or infrared sensor, is bolted to the top of the structure. The accompanying electronics boxes are mounted on the inside surfaces of the panels. The weight of the instrumentation is carried in direct paths through the webbed members to the base plate.

Slots or sets of holes in the top and base plates provide a range of bolting locations. In each of these plates, the package can be bolted at any four locations equidistant from the axis of symmetry. If the bolt circle of the package is exceptionally large, the bridge can be inverted to extend the bolting range. The direct load paths to the base plate are retained.

This work was done by Gary Sneiderman of **Goddard Space Flight Center**. *For further information, Circle 113 on the TSP Request Card.* GSC-13381



The **Members of the Structure Are Adjustable** to accommodate various sizes and bolthole locations. The structure can be inverted to accommodate a wider bolt circle on the top plate.

Polymers and Riblets Reduce Hydrodynamic Skin Friction

Polymers injected into riblet grooves could dramatically reduce the polymer flow rate required for drag reduction.

Langley Research Center, Hampton, Virginia

The use of long-chain polymer molecules to reduce turbulent skin friction has been shown to produce reductions in drag consistently — up to 80 percent in some cases. However, the use of polymers on marine vehicles has been limited by the impracticality of injecting polymers into the water at the rates needed to maintain sufficiently high concentrations of polymers close to the surfaces of the vehicles. Turbulent diffusion in a boundary layer rapidly disperses the polymer after it is injected, causing much of the polymer to leave the region of the boundary close to the surface, where the polymer drag-reduction effect occurs.

The distributed injection of a polymer over the entire surface of a vehicle can produce, at much-lower total mass-injection rates, local concentrations of polymer sufficient to result in large reductions in drag; but this approach requires a porous surface over the entire vehicle, making it infeasible to apply to such large vessels as ships and submarines.

In previous studies of the injection of polymers, the surfaces of the test vessels were covered with longitudinal grooves, or riblets, but these studies indicated only additive effects between the polymers and riblets. No attempts were made to inject polymers into the grooves to control the diffusion of polymers into the boundary layers.

In the current technique, the surface contains many rows of side-by-side, evenly spaced longitudinal grooves, and the rate of diffusion of the polymer from the surface is controlled by injecting the polymer into the grooves. The depth and width of each groove must be chosen according to the local scale length for viscosity, which is a function of the velocity of the vehicle and its position on the surface.

The polymer solution is injected into the valleys of the grooves through an array of holes or slots angled downstream to keep the injected streams within the grooves. Injection has to be repeated some distance downstream because the volumes of the grooves are finite and the polymer becomes depleted as it is slowly pulled from the groove by turbulence. The polymer must reach the "outer layer" just above the riblet surface to reduce the turbulent skin friction effectively.

The rate of injection and the concentration of the polymer solution also depend on the local viscous scaling. Once in a groove, the polymer diffuses into the boundary layer at a rate controlled by the dimensions of the groove. Correct scaling of a groove causes the polymer to be distributed slowly over a certain length in the same fashion as, and with the same advantage of low mass-flow requirement as, that of distributed injection, without the need for a porous surface over the entire vessel.

The use of this technique has the potential to reduce skin-friction drag at mass-injection rates less than one-tenth those of previous methods. The technique can be especially important for oil tankers as a means of markedly reducing the cost of fuel and could be used extensively on submarines, other ships, and other marine vehicles. However, these applications will require considerable further development.

This work was done by Dennis M. Bushnell of **Langley Research Center** *and Jason C. Reed of Old Dominion University Research Foundation. No further documentation is available.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 16]. Refer to LAR-14271.

Digital Image Velocimetry

Magnitudes and directions of velocities are determined unambiguously.

Ames Research Center, Moffett Field, California

Digital image velocimetry is a technique for extracting the two-dimensional (in the image planes) velocities of objects from multiple photographs or video images of the objects. Digital image velocimetry was devised to overcome the disadvantages of particle-image velocimetry and laser-speckle velocimetry, both of which involve the use of illuminated seed particles to make flows visible. The sizes of the seed particles and speckle images limit the dynamic ranges of measurable speeds, and elaborate optical systems are needed to eliminate the ambiguities in the senses of the velocity vectors. In digital image velocimetry, the directions of velocity vectors are determined unambiguously, and the dynamic range is limited only by the speed of the camera or, equivalently, by the speed of the stroboscopic illumination.

In digital image velocimetry, a high-speed video or film camera first records a time sequence of images of moving objects in its field of view; in effect, it makes a short movie. The images are digitized, then processed digitally to remove noise and correct distortions. Thus enhanced, the individual images are superposed to construct a composite image that, in a sense, is equivalent to (but not the same as) a multiple-exposure image of the type used in particle-image or laser-speckle velocimetry.

In addition, each enhanced image in the sequence is divided into sampling areas called "interrogation windows," within each of which the gradient of velocity is assumed and required to be negligible. Depending on the details of the velocity field under study, it may be necessary to vary the sizes of the windows to satisfy this requirement.

The sampled individual images and the composite image are digitally Fourier-transformed. The Fourier transforms of the individual images are also used to construct a mathematical filter to deblur the composite image. The speed, which is assumed to be constant within each interrogation window, is easily computed: it is inversely proportional to the time between exposures, to the magnification of the camera lens, and to the widths of stripes that appear in the Fourier transform of the composite image. The direction of the velocity is determined from phase information in the Fourier transform of the composite image divided by the Fourier transform of one of the individual images. The collection of velocities thus computed in all the windows constitutes the velocity field of the objects in the field of view.

This work was done by Y.-C. Cho of **Ames Research Center**. *For further information, Circle 14 on the TSP Request Card. ARC-12774*

Books and Reports

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

Transonic Flows About a Fighter Airplane

Navier-Stokes calculations simulate complicated flow fields and interactions.

A report describes a computational study of transonic flows about an airplane having a shape similar to that of the F-16A fighter. This study is an example of the use of techniques of computational fluid dynamics to simulate complicated flows of practical importance. Computational fluid dynamics has become indispensable to the design of advanced aircraft, turbomachinery, valves, and other equipment that involve fast flows, because it enables designers to visualize quickly the effects of changes in design, without having to perform an expensive and time-consuming wind-tunnel experiment or a dangerous flight test to evaluate every such change.

This study focused on the effects of the separations of flow at the angles of attack that the F-16A was designed to sustain. One of these separations is a controlled effect of the strake, which is designed to cause a strong primary vortex on the inboard wing/fuselage. The "nonlinear" lift generated by this effect of the strake keeps the airplane controllable long after a conventionally designed airplane would have stalled.

Another separation of interest is that often induced on the rear of the wing by shocks in transonic flight. This separation is also controlled in the sense that the supercritical wing was designed to delay the shocks that trigger that separation as far aft as possible. Wing-tip separation is expected where the wing-tip vortex causes inboard flow at high angles of attack. At higher angles of attack, separated flow also gives rise to a vortex at the leading edge of the wing. The ability to simulate these effects is important because all modern fighters, especially those being considered for the Advanced Tactical Fighter(AFT) competition, will be designed to use nonlinear lift generated by strakes, chines, canards, or leading-edge extensions.

The flow fields were simulated by finite-difference solution of the Euler equations and the thin-layer approximation of the Navier-Stokes equations, by use of the Transonic Navier-Stokes (TNS) computer program. The computational grids about the wing and fuselage were generated by a computer program called "ZONER," which subdivides a coarse grid about a fighterlike aircraft body into smaller zones that are tailored to local grid requirements. These zones can be either finely clustered for capture of viscous effects or coarsely clustered for inviscid portions of the flow field.

Different sets of equations can be solved in the different zones. This modular approach also affords the opportunity to modify a local region of the grid without recomputing the global grid, thereby speeding the design optimization process when quick modifications are desired. The algorithm embodied in TNS is implicit and is capable of capturing pressure gradients associated with shocks. An algebraic eddy-viscosity model of turbulence was used and proved adequate for viscous interactions with moderate separation.

Viscous effects were computed normal to all aircraft surfaces; in wake zones, including regions behind the trailing edge of the wing; and in regions outboard of the tip. Laminar solutions were generated for qualitative comparison with water-tunnel flow-visualization experiments and for analysis of critical points. Turbulent solutions were generated at moderate angles of attack for quantitative comparison to wind-tunnel data and for qualitative comparison to wind-tunnel flow-visualizations.

Extensive use of video graphic simulation was made to analyze the particle-trace behavior of several of the solutions. Comparisons of computed data with experimental data, including flow visualizations, showed good quantitative and qualitative agreement.

This work was done by Steve Reznick and Jolen Flores of **Ames Research Center**. *Further information may be found in NASA TM-*

100009 [N88-22010], "Transonic Navier-Stokes Computations of Strake-Generated Vortex Interactions for a Fighter-Like Configuration."

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. ARC-12304

Pressure Fluctuations in Simulated Turbulent Channel Flow

Statistical analysis of data shows significant trends.

A report presents a study of the structures of fluctuations in pressure in a numerically simulated incompressible, turbulent channel flow. The study, which is based on statistical analyses of the pressure and velocity fields, is part of the continuing effort to understand the relationships among pressures (especially those measured on the walls of channels or aerodynamic bodies), velocities, vorticities, kinetic energies, and other features of turbulent flows in the vicinities of walls.

The simulation represented the flow in a channel between two parallel plates with a computational grid of 128 by 129 by 128 points in the x, y, and z directions (streamwise, perpendicular to the walls or plates, and spanwise directions, respectively). The Reynolds number, based on the half width of the channel and the velocity at the centerline, was 3,300. Once the simulated velocity field reached the statistically steady state, it was recorded at about 100 consecutive instants, and the resulting data were used in the statistical analysis.

For the purposes of this study, the pressure was split into two components: one that varies rapidly (the "rapid pressure") and corresponds to the linear source term in the Poisson equation that expresses the relationship between the pressure and velocity fields; and one that varies slowly (the "slow pressure") and corresponds to the nonlinear term in this Poisson equation. Contrary to the common belief that the rapid pressure is the dominant component, it was found that the slow pressure is comparable near the wall and larger away from the wall. The corresponding source terms also showed the same trend.

The probability-density distributions showed that the pressure fluctuations are much more intermittent than are velocity fluctuations, and large negative fluctuations contribute substantially to the mean-square fluctuation. Many of these negative pressure fluctuations are correlated with high vorticity fluctuations. Power spectra and two-point correlations showed that there is little difference between the rapid and the slow pressure near the wall, but that they differ considerably from each other away from the wall. The behavior of the two-point correlation of the rapid pressure at the wall was found to agree well with that obtained from the rapid-distortion theory, suggesting the usefulness of the linear theory.

A Green's-function representation was used to demonstrate the global dependence of pressure fluctuations. It was shown that instantaneous pressure at one wall is influenced significantly by the source terms from near the other wall. However, the use of the same representation for the mean-square fluctuation showed that although the instantaneous pressure has a global dependence, most contributions to the mean-square fluctuation are local. This indicates that the influence from far away is averaged out with small net effects. Contributions to the pressure-strain correlations are apparently local near the wall, but global away from the wall. This nonlocal character of the contributions to the pressure-strain correlations raises an important question of whether one can model them in terms of local variables, as is done currently.

Examination of contours of constant pressure gradients showed that those associated with $\partial p/\partial y$ and $\partial p/\partial z$ (where p = pressure) are somewhat elongated in the streamwise direction, but not those associated with $\partial p/\partial x$. Examination of vorticity ω and gradients of pressure at the wall, which control the diffusion of vorticity from the wall, showed a strong correlation between ω_x and $\partial p/\partial z$, but no apparent correlation between ω_z and $\partial p/\partial x$.

This work was done by John Kim of **Ames Research Center**. *Further information may be found NASA TM-101084 [N89-22860], "On the Structure of Pressure Fluctuations in Simulated Turbulent Channel Flow."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. ARC-12597

Numerical Aerodynamic Simulation Program

Computers simulate a variety of complicated flow phenomena.

A report describes the developments that occurred at the National Aerodynamics Simulation (NAS) facility at Ames Research Center during the years 1987 and 1988. This facility was established to advance computational fluid dynamics, providing the capability to simulate rapidly the details of flows about aircraft of complicated shapes over the complete range of operating conditions.

The main body of the report begins with a description of the NAS processing network, which is a large network of computers. This is followed by a summary of the early achievements of the NAS program and the advanced features of the NAS network, including the installation of supercomputers, the installation of a standard operating system and communication software on all processors, accessibility to users at remote facilities across the United States, and emphasis on the development of graphics workstations to display the results of numerical simulation.

The following section of the report discusses the role of the NAS program in providing the technological basis for continuing research. The discussion focuses on communication between facilities in the network and the replacement of older with newer and more-capable computing equipment. This is followed by a section that describes the present and potential future characteristics of the majority of users of the NAS system.

The next three sections describe the state-of-the-art CFD software and examples of the use of the capabilities of the NAS system to predict the fundamental physics of fluids, to complement and supplement experiments, and to aid in the design of aerospace vehicles. The examples of prediction are vortical flow over a double delta wing, Navier-Stokes simulation of a turbulent boundary layer, and jet-induced loss of lift on the wing of a vertical/short-takeoff-and-landing aircraft. The examples of complementing and supplementing experimentation are applications to an ogive cylinder at a large angle of incidence, transonic flow over a wing/body model, and experiments on turbulence and boundary layers. Examples of aiding the design process are provided by the proposed National Aero-Space Plane, the Space Shuttle Main Engine, and the separation of the Space Shuttle booster.

The next section discusses the mathematical models of physical systems and the computing equipment that determine the pace of advance of CFD. The report concludes with a section that describes the likely future developments in CFD and the NAS system.

This work was done by F. R. Bailey and Paul Kutler of **Ames Research Center**. *To obtain a copy of the report, "NAS — The First Year," Circle 5 on the TSP Request Card. ARC-12245*

Computed Flow About the Integrated Space Shuttle

The goal is to understand and predict flight during ascent.

A report discusses numerical simulations of the flow of air about the integrated Space Shuttle (the complete Space Shut-

tle assembly, including the orbiter, the solid rocket boosters, and the external tank) in ascent. The goal of these and related studies is to improve the understanding of, and the ability to predict, how the integrated Space Shuttle will perform during both nominal and aborted ascent under various conditions. These and other numerical simulations are intended both to supplement wind-tunnel data, which are corrupted to some extent by scaling and wall-interference effects, and to compensate for the scarcity of valid flight data, the safe collection of which is difficult.

It was necessary to reduce the complexity of the problem and thereby reduce the simulation task to one within the capability of available computational resources while preserving the ability to extract useful engineering data. Accordingly, the mathematical model of the integrated Space Shuttle was formulated with some approximations and simplifications. Specifically, a solid-body sting was made to protrude to the rear from the major component bodies to represent wakes and rocket-engine plumes; attaching hardware, fuel and oxidizer lines, and other protuberances were neglected; the elevons of the orbiter were set to zero deflection; and the vertical tail of the orbiter was removed. This configuration was initially used for supersonic free-stream simulations in the expectation that errors resulting from sting models, lack of the tail, and incorrect deflections of the elevons would not propagate significantly upstream in the supersonic flow.

A composite computational grid was formed by use of overset grids fitted to the main component bodies. Altogether, about 750,000 grid points were distributed among 5 grids. The flow in this body-conforming coordinate system was assumed to be governed by the three-dimensional, thin-layer Navier–Stokes equations. The equations were solved on this grid by an approximately factored, finite-difference, implicit numerical-integration scheme.

The results of the computation were found to agree fairly well with wind-tunnel and flight-test data. However, additional grid resolution or a numerical-integration scheme that is accurate to higher order was found to be needed, especially in regions where the flow expands. It was also observed that the grid did not have sufficient resolution to resolve the skin friction correctly. The report concludes by recommending refinements to overcome these inadequacies, to model the effects of attaching hardware and other protuberances more accurately, and to represent the effects of plumes more realistically.

This work was done by P. G. Buning, I. T. Chiu, S. Obayashi, Y. M. Rizk, and J. L. Steger of **Ames Research Center**. *Further information may be found in AIAA paper 88A-50602, "Numerical Simulation of the Integrated Space Shuttle Vehicle in Ascent."*

Copies may be purchased [prepayment required] from AIAA Technical Information Services Library, 555 West 57th Street, New York, New York 10019, Telephone No. (212) 247-6500. ARC-12685

Computed Turbulent Flow in a Turnaround Duct

Kinetic energy of turbulence near the wall is predicted accurately.

A report describes the numerical simulation of two-dimensional turbulent flow in a duct that has a 180° bend. The sharp curvature at the bend complicates the simulation of turbulence, and the particular significance of this study is that it addresses that complication with some success. This kind of study contributes to the fund of information needed to design advanced engines that contain turbulent flows.

A low-Reynolds-number algebraic model of turbulence is introduced. This model is of the k–ϵ type, where k is the time-averaged local kinetic energy of turbulence and ϵ is the time-averaged local rate of viscous dissipation of kinetic energy. The model has been used in the computer program KEM, which implements a finite-difference solution to the three-dimensional equations for the transport of k and ϵ in generalized coordinates and can be used with any compressible- or incompressible-flow-simulating computer program to compute the turbulent flow of interest.

The model is formulated to yield accurate predictions of k near the wall. It is derived partly from knowledge gained in earlier direct simulations of turbulence near walls. Very near the wall, limiting behavior on the turbulence kinetic energy and the length scale is imposed. This minimizes the sensitivity of the model to the inflow length scale and, therefore, to the inflow boundary condition on ϵ, which is not easily prescribed. The dissipation-rate equation is modified near the wall so that the molecular diffusion and the destruction terms balance each other uniformly as the wall is approached. A new $f\mu$ function is prescribed. (The function $f\mu$ is a factor in the equation for the turbulent viscosity; it specifies the variation, with distance from the wall, of a coefficient of proportionality at low Reynolds numbers.) This function is consistent with the limiting behavior of k and ϵ near the wall. Alternate boundary conditions on ϵ and a spatially varying correction for curvature are also derived.

The k–ϵ equations in generalized coordinates are integrated by an implicit, noniterative finite-difference method. First, the calculations are performed for a straight duct to validate the turbulence model. The calculations are carried out by prescribing the fully developed mean-velocity profile from experiment throughout the solution domain and by solving only for the turbulence quantities. The predictions of the model are found to agree well with the experimental data. The experimental peak in the kinetic energy is matched exactly. The predictions also agree reasonably well with the results of a previous direct simulation.

The turbulence model with a correction for curvature appropriate to flow over a spinning cylinder is used in the simulation of the two-dimensional flow in the turnaround duct, which is given the same radii of curvature as those of the turnaround duct in the main engine of the Space Shuttle. The predictions are compared with limited available experimental data, with the caveat that the two-dimensional simulation is an approximation to the problem of the axisymmetric experimental turnaround duct.

This work was done by Upender K. Kaul of Sterling Federal Systems for **Ames Research Center**. *Further information may be found in NASA CR-4141 [N89-24579], "Turbulent Flow in a 180° Bend: Modeling and Computations."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.
ARC-12552

Speeding Convergence in Simulations of Hypersonic Flow

A Richardson-type overrelaxation method is applied.

A report describes a study aimed at accelerating the rates of convergence of iterative schemes for the numerical integration of the equations of hypersonic flow of viscous and inviscid fluids. The need for faster convergence on the solution is particularly severe in such cases as simulation of hypersonic flow about an airplane, which could involve as many as 5,000 iterations of a Navier–Stokes code that take 25 h a supercomputer.

The Euler equations (of inviscid flow in the bulk of the fluid) are presented and treated via the Steger–Warming flux-vector-splitting approach. The flux-vector-split thin-layer Navier–Stokes equations (of viscous flow in the boundary layer) are obtained by adding an explicit boundary-layer term to flux-vector-split Euler equations. First-order differencing is applied, and the resulting large sparse system of equations is put in matrix form and solved numerically by an iterative approximate-factorization technique.

To accelerate the convergence of the numerical simulation, Richardson's overrelaxation method (the "RF" method) and Wynn's ϵ-algorithm (a technique for acceleration in iterative vector and matrix problems) are invoked. These techniques have been used successfully in previous studies to accelerate convergence in simulations of inviscid and viscous flows in the subsonic and transonic regimes of flow. First, a simple successive-overrelaxation technique is used to accelerate the convergence of the Steger–Warming flux-vector-splitting code in the case of two-dimensional flow over a blunt-ended wedge — a simplified model of a blunt-ended cone. This overrelaxation technique is found to reduce the computing time by half. The convergence is even faster when both the overrelaxation technique and Wynn's ϵ-algorithm are used.

Next, an overrelaxation factor for a nonlinear iterative procedure is introduced, applied in several computations, and examined experimentally. When it is applied along with Wynn's ϵ-algorithm in the three-dimensional Navier–Stokes simulation of the flow over a blunt cone, the number of iterations needed to achieve a specified level of convergence is reduced by more than 40 percent.

This work was done by J. Flores of **Ames Research Center** *and S. Cheung, A. Cheer, and M. Hafez of the University of California. Further information may be found in AIAA paper 89A-42100, "Convergence Acceleration of Viscous and Inviscid Hypersonic Flow Calculations.*

Copies may be purchased [prepayment required] from AIAA Technical Information Services Library, 555 West 57th Street, New York 10019, Telephone No. (212) 247-6500.
ARC-12601

Analyzing Takeoffs of Powered-Lift Aircraft

Engine and nozzle settings for minimum takeoff roll are predicted.

A report describes additions to the ACSYNT aircraft-synthesis computer code to reflect analyses of the takeoff performances of ejector/augmentor and vectoring-nozzle short-takeoff airplanes. The new computer code predicts the engine and nozzle settings that minimize the takeoff roll (the horizontal distance traveled on the ground during takeoff).

In a powered-lift aircraft, a portion of the engine thrust can be deflected at various angles to the fuselage. This feature enables the aircraft to take off at lower speeds and with shorter takeoff rolls; it also complicates the analysis of performance because in addition to the unknowns of conventional aircraft (takeoff velocity, flap settings, tail settings, and rotation speed), it presents the additional unknowns of the front thrust-vector angle, rear thrust-vector angle, and thrust split (the allocation of the total engine thrust to the front and rear nozzles).

For purposes of the analysis, a number of simplifying assumptions are invoked, including the following:

- The effects of a reaction control system are not considered.
- Moments of inertia are neglected, and the aircraft is treated as a point mass located at its center of gravity.
- All aerodynamic moments are treated as negligibly small, relative to thrust moments.
- The variation of forward thrust is taken as linear with respect to the thrust split.
- Ground effects are ignored.
- Only single-engine aircraft are considered.

In the calculations, only the front and rear thrust vectors are used in balancing the aircraft. The user specifies such quantities as the angle range of the forward nozzle, the limit on the thrust split, the flightpath angle, the acceleration along the flightpath at takeoff, and the initial nozzle and flap angles for the takeoff roll.

Three equations are used to predict the forward-nozzle angle, aft-nozzle angle, and thrust split that minimize the takeoff roll. The first equation states that the sum of moments about the center of gravity created by the ram drag, front thrust, and rear thrust must equal zero to balance the aircraft. The second equation states that the sum of forces perpendicular to the flightpath (principally thrust, lift, and weight) must equal zero at takeoff. The third equation expresses the sum of forces along the flightpath as the value that gives the specified takeoff acceleration.

These equations cannot be solved explicitly. Instead, initial values of the front-nozzle angle and the takeoff velocity are guessed, and an iterative procedure is used to arrive at the settings that produce the minimum takeoff velocity. The takeoff roll is then calculated by integrating the velocity during the interval required to accelerate to the minimum takeoff velocity.

In a test, the new computer program predicted takeoff rolls and nozzle settings for the YAV-8B Harrier airplane that were close to actual values. In another use, an analysis of performance for ejector/augmentor and vectoring-nozzle designs indicated that the takeoff roll can be decreased by horizontally moving the rear thrust vector closer to the center of gravity, by increasing the vertical position of the ram-drag vector, or by moving the rear thrust vector farther below the center of gravity.

This work was done by Andrew S. Hahn of **Ames Research Center** *and Douglas A. Wardwell and Doral R. Sandlin of California Polytechnic State University. To obtain a copy of the report, "Takeoff Predictions for Powered-Lift Aircraft," Circle 70 on the TSP Request Card.*
ARC-11784

Aerodynamics of Missiles: Present and Future

Recent developments and opportunities for future work are surveyed.

A paper reviews a variety of topics in the aerodynamics of missiles. The paper describes recent developments and suggests areas in which future research may be fruitful. Emphasis is on stability and control of tactical missiles. Aerodynamic problems are discussed in general terms without reference to particular missiles.

Among the topics covered are the following:

- The Tri-service/NASA data base, which illustrates many nonlinear aerodynamic phenomena. The data base was compiled from systematic tests on a cylindrical body with an ogive nose. The data base is used to predict the aerodynamic characteristics of cruciform missiles and is incorporated into a computer code, Missile III.
- Wing/body interference, which has been an important subject of study for decades and for which the Tri-service/NASA data base provides considerable information at high mach numbers. More work is needed, however to answer the following: What is the effect of a long afterbody on body lift interference, and where is the center of pressure for the carryover of lift from fins to the body?
- Nonlinear control effects, which can be substantial at hypersonic speeds with all-movable controls, wraparound fins, and retractable fins.
- Transitions from laminar to turbulent flows in hypersonic missile boundary layers, which are not accurately predictable. Work is needed to correlate wind-tunnel data with flight data.
- Vortex interference, which can cause a variety of control problems. Little is known about the strengths and positions of vortices at hypersonic speeds.
- Air-breathing propulsion systems, which offer high specific impulses at hypersonic speeds but pose special problems. In particular, the technology of inlets is ripe for innovation. Computational fluid dynamics will help in the design of inlets.
- Problems posed by the release of missiles from aircraft. For example, at high transonic speeds, missiles can become unstable when released, possibly even striking the releasing aircraft.
- Computational fluid dynamics codes, of which there are several for determining the pressure and flow fields about a complete missile or about a missile and an aircraft.
- Engineering prediction computer codes,

which supplement computational fluid dynamics codes but are simpler. These incorporate empirical, semiempirical, and theoretical equations.

- New concepts, which include waveriders, flat-top monoplanar missiles, missiles designed for supersonic combustion ram (scram) jets, and missiles designed for particular missions.

This work was done by Jack N. Nielsen of **Ames Research Center**. *Further information may be found in NASA TM-100063 [N88-29773], "The Present Status and the Future of Missile Aerodynamics."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.
ARC-12188

Particle-in-Cell Simulation of Explosive Flow

A cell can contain more than one material.

A report describes the use of a second-order particle-in-cell method to compute the two-dimensional hydro/elastic/plastic flow of a hemispherical copper shell after the detonation of an axisymmetric explosive charge. This flow is difficult to compute because the equation of state of the high-pressure gas from the explosion is complicated; because the mechanical properties of the copper and the remaining solid explosive depend on pressure, temperature, and previous deformations; and because changes of state (e.g., chemical reactions and melting of the copper) must be taken into account.

The governing equations include the equations of conservation of mass, momentum, and energy in cylindrical Eulerian coordinates; and the equations of state, including hydrostatic-pressure stresses in the elastic and plastic regimes. The set of governing equations is split in the axial and radial directions. A separate calculation is performed in each direction. The order of this calculation is alternated for each time advancement to maintain the accuracy of the one-dimensional procedure.

Based on known quantities at the nth time step, Lagrangian quantities at the $(n \pm 1)$th time step are computed. After the Lagrangian phase calculation, one has the velocity, energy density, and stress in each cell. Consistent with these, temporary values of momentum and internal energy are assigned to each cell.

For a cell containing only one type of material, the fluid-volume-transport calculations are used without introducing any particles. If a cell contains 2 or more materials, then a total of 64 particles are created for each material in the cell. The particles are considered to be transported with an average velocity. Particles of each material (e.g., copper or explosive) are created or destroyed to maintain the proper dynamic balances in each cell. Each particle carries with it a fraction, proportional to its mass, of dynamic and state quantities.

The results of the particle-in-cell computation are presented in the form of pictures of the shape of the copper shell at various times, a plot of the velocity of the shell as a function of position along the axis at a particular instant of time, and a plot of the cumulative mass of the copper jet as a function of its velocity. The latter plot is shown to agree well with a plot of experimental values, and the computed velocity of the tip is shown to differ from the experimental value by only ~1.9 percent.

This work was done by Dochan Kwak of **Ames Research Center** *and Wen Ho Lee of Los Alamos National Laboratory. To obtain a copy of the report, "PIC Method for a Two-Dimensional Elastic-Plastic-Hydro Code," Circle 63 on the TSP Request Card.*
ARC-12543

Computed Hypersonic Flow About a Sharp Cone

The laminar–turbulent transitional flow with particular reference to heat transfer is studied.

A report describes a mostly computational study of the hypersonic flow about a sharp cone. This and other related studies are parts of a continuing effort to understand and predict complicated aerodynamic and heat-transfer phenomena in the flows over the forebodies of such hypersonic vehicles as the Space Shuttle and the proposed National Aerospace Plane. This study focuses on the transition from laminar to turbulent flow, with particular reference to the heat-transfer predictions. Phenomena, such as skin friction and heat transfer to the cone, and the interactions among them all become significant in a hypersonic flow, because in such a flow, a considerable portion of a typical forebody is engulfed in the transition region.

The report includes an introduction that discusses the factors that influence the laminar-to-turbulent transition and summarizes previous theoretical and experimental research on this topic. Next, it describes numerical simulations, via the Parabolized Navier–Stokes (PNS) computer code, of flows of mach 7 to mach 10 about cones of 5°, 8°, and 10° half angle, at angles of attack of 0° and 4°. In these simulations, turbulent viscosity was calculated by use of the Baldwin–Lomax model, and laminar viscosity was calculated via the Sutherland law. The model for the transition was based on the intermittency-function of Dhawan and Narashima.

The numerical results are presented as plots of the Stanton number (*St*) versus distance (*x*) along the conical surface from the apex and plots of $StRe^{1/2}$ versus *Re* (where Re = Reynolds number). The locus of the computed onset of transition on the cone, calculated by use of various correlations, is plotted and compared with the locus given by experiment. Some observations are made on the basis of this comparison. The results at angles of attack of 0° and 4° are discussed, and it is concluded that none of the correlations used to obtain the transition-onset location applies satisfactorily at an angle of attack. A transition-onset-location criterion based on the ratio between the Reynolds number (calculated from the momentum thickness) and the mach number has been shown to be a reasonable alternative at small angles of attack. Also, a need for a mach-number-based modification of the intermittency function is indicated.

This work was done by Upender K. Kaul of Sterling Software for **Ames Research Center**. *To obtain a copy of the report, "Laminar-Turbulent Transition Calculations of Heat Transfer at Hypersonic Mach Numbers Over Sharp Cones," Circle 8 on the TSP Request Card.*
ARC-12675

Navier–Stokes Simulation of Wind-Tunnel Flow

Numerical integration is performed by the LU-ADI factorization algorithm.

A report describes a three-dimensional Navier–Stokes simulation of the transonic flow past a model wing in a wind tunnel and in free air. The simulation shows the effects of the walls of the tunnel.

The Navier–Stokes equations of viscous, compressible flow of an ideal gas are written in three-dimensional, Reynolds-averaged thin-layer, conservation-law form in generalized coordinates. The viscosity coefficient is taken to be the sum of the actual viscosity plus the turbulent-eddy viscosity computed from the algebraic Baldwin-Lomax eddy-viscosity model with length scales modified for the thin layers near the surfaces of the wing and the walls.

The equations are integrated numerically by the Lower/Upper-Alternating Direction Implicit (LU-ADI) factorization algorithm, which is a compromise between the LU and ADI algorithms in which each ADI operator is decomposed into the product of lower and upper bidiagonal matrices by a flux-vector-splitting technique and a diagonally dominant factorization. Steady-state solutions are obtained for the wing in the wind tunnel at angles of attack of 0° and 2°, and for the wing in free air at angles of attack of 0°, 2°, 5°, and 8°. The free-stream mach and Reynolds numbers used in the numerical simulations are those of a previously reported experiment.

The lift coefficients predicted by the wind-tunnel simulation are lower than those predicted by the free-air simulation. The results indicate that the technique for the simulation of the transition from laminar to turbulent flow and the technique for the generation of the computational grid will have to be developed further. The results also indicate that the available experimental data are not precise enough to establish boundary conditions for the computations.

This work was done by S. Obayashi and K. Fujii of **Ames Research Center** *and S. Gavali of Amdahl Corp. Further information may be found in NASA TM-100042 [N88-17584], "Navier–Stokes Simulation of Wind-Tunnel Flow Using LU-ADI Factorization Algorithm."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.
ARC-12193

Machinery

Redundant Robot Can Avoid Obstacles

Configuration control would exploit the extra degrees of freedom.

NASA's Jet Propulsion Laboratory, Pasadena, California

A relatively simple and direct control scheme has been proposed to enable a redundant robot to avoid obstacles in its workspace. A redundant robot — typically, a manipulator arm with multiple joints and links — has more degrees of freedom than are needed to make the end effector follow the desired trajectory. The extra degrees of freedom are available for use in satisfying additional task objectives; in this case, they are used to satisfy the additional objective of reaching around, or otherwise avoiding collision with, obstacles.

Heretofore, the majority of research on simultaneously obtaining the desired end-effector trajectory while avoiding obstacles has taken a high-level path-planning approach, in which the paths of the end effector and other parts of the robot are planned a priori to avoid collisions with obstacles. This approach involves a focus on the path-planning portion of the robot-control problem, the classical solution of which is time-consuming.

In the proposed scheme, which is called "configuration control," the degrees of freedom would be used to configure the robot to satisfy a set of inequality constraints that represent the avoidance of obstacles, while simultaneously making the end effector follow the desired trajectory (see Figure 1). For each obstacle, there would be defined a convex volume or "space of influence" consisting of the object plus an imaginary thick shield around it. If any point on the robot entered such a space of influence (entry would manifest itself as a violation of one or more of the inequality constraints), the degrees of freedom would be used to inhibit the motion of that point toward the obstacle.

Configuration control would utilize on-line adaptation to eliminate the need for a complicated mathematical model and parameter values of the dynamics of the robot. Configuration control could be implemented at the low level of the servocontrol loops of the robot, in contrast with prior schemes in which the avoidance of obstacles is implemented at the high-level task-planning stage. This feature would provide the capability to avoid obstacles in a dynamically varying environment (e.g., where the obstacles are moving), where a-priori planning of tasks is not feasible. The relative simplicity and computational efficiency would make it possible to implement real-time obstacle-avoidance control loops with high sampling rates.

Configuration control of a four-link planar robot (see Figure 2) was tested in computer simulations. The problems studied included reaching around a stationary round obstacle, simultaneous avoidance of two stationary round obstacles, reconfiguration of the robot to avoid a moving round obstacle, and avoiding a stationary rectangular obstacle. The simulations showed that the end effector tracked the desired trajectories closely, and the robot succeeded in avoiding the obstacles.

This work was done by Homayoun Seraji, of Caltech and Richard Colbaugh and Kristin Glass of New Mexico State University for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 97 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 16]. Refer to NPO-17852.

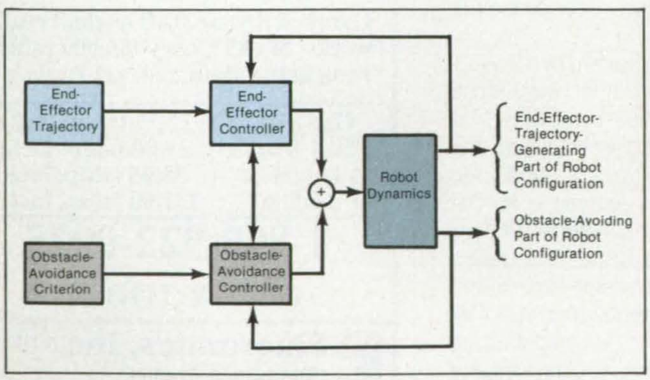


Figure 1. In **Configuration Control**, extra degrees of freedom—those not needed to make the end effector of a robot follow the desired trajectory—would be used to make the robot avoid obstacles.

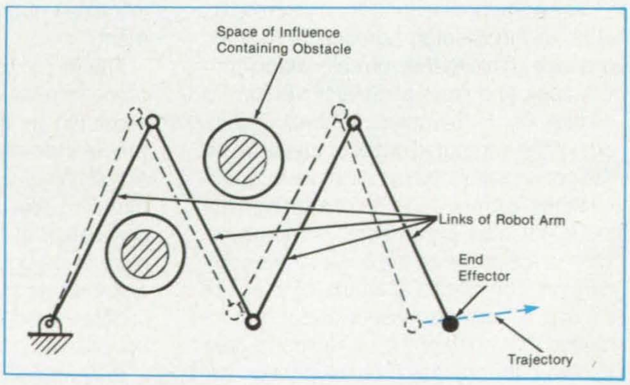


Figure 2. A **Four-Link Robot in a Horizontal Plane**, equipped with configuration controller, was studied by computer simulation. The results of the simulation showed that the robot could avoid obstacles while its end effector closely tracked the desired trajectory.

Viselike Robotic Gripper

A split-rail/roller bearing system minimizes both friction and jamming under side loads.

Goddard Space Flight Center, Greenbelt, Maryland

A viselike, high-performance, general-purpose robot hand is being developed for use in both industry and outer space. This device, called a "split-rail parallel gripper," is simple, compact, inexpensive, rugged, light enough [10 lb (4.5 kg)] to be used on small robots, strong enough to be used on large robots to lift loads up to 100 lb (45 kg), and capable of gripping objects up to 7 in. (17.8 cm) wide.

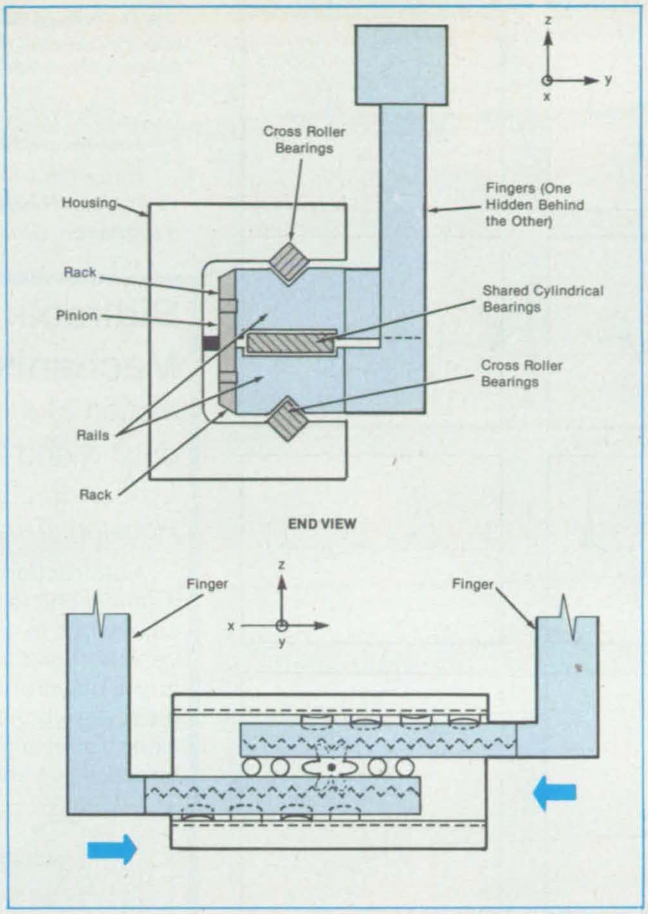
The gripper has a unique "split-rail" configuration (see figure) in which a finger reminiscent of a vise jaw is attached to each of two rails. The rails move along each other on preloaded roller bearings that minimize the friction between the rails and between each rail and a housing. Because the motion is rolling rather than sliding, there is little wear, and the gripper can, therefore, be used in workspaces where contamination must be minimized.

Rack gears mounted on the rails mesh with a pinion gear that rotates about an axis fixed to the housing. This gear system forces the rails and fingers to move equal distances in opposite directions and to remain at equal distances from the midpoint where they meet. Therefore, the gripper can be driven via either the pinion or one of the rails by any of a variety of rotary or linear motors, actuators, or transmission systems. When one of the rails is driven, the fingers press on the grasped object with half the driving force.

The rails and housing are made of 6061-T6 aluminum. They are machined by simple straight cuts; no grinding or polishing is necessary. The machined surfaces are hard-anodized to reduced wear and prevent indentation by the bearings under high loads. The racks, pinion, and roller bearings are made of stainless steel and are available commercially.

In tests, the motion of the prototype gripper was repeatable with an error of less than 0.001 in. (0.025 mm). Such a high degree of repeatability is possible because the backlash exists only in transition between opening and closing motion, and either motion automatically removes the backlash. The preloaded bearings eliminate the repeatability errors in directions perpendicular to the rails. The tests showed that the gripper responds to a driving force of less than 1 lb (4.5 N). The test also showed that the gripper resists jamming under side loads, continuing to open and close smoothly when subjected to side torques as large as 200 lb•in. (22.6 N•m).

This work was done by John M. Vranish of **Goddard Space Flight Center**. *For further information, Circle 134 on the TSP Request Card.* GSC-13323



The **Split-Rail/Roller Bearing System** reduces friction and backlash. The cylindrical roller bearings between the rails rotate but, because of the opposing motions of the rails, do not translate. The cross roller bearings (which are short cylindrical bearings) rotate, and each translates one-fourth the change in distance between the fingers.

Hidden-Markov-Model Analysis of Telemanipulator Data

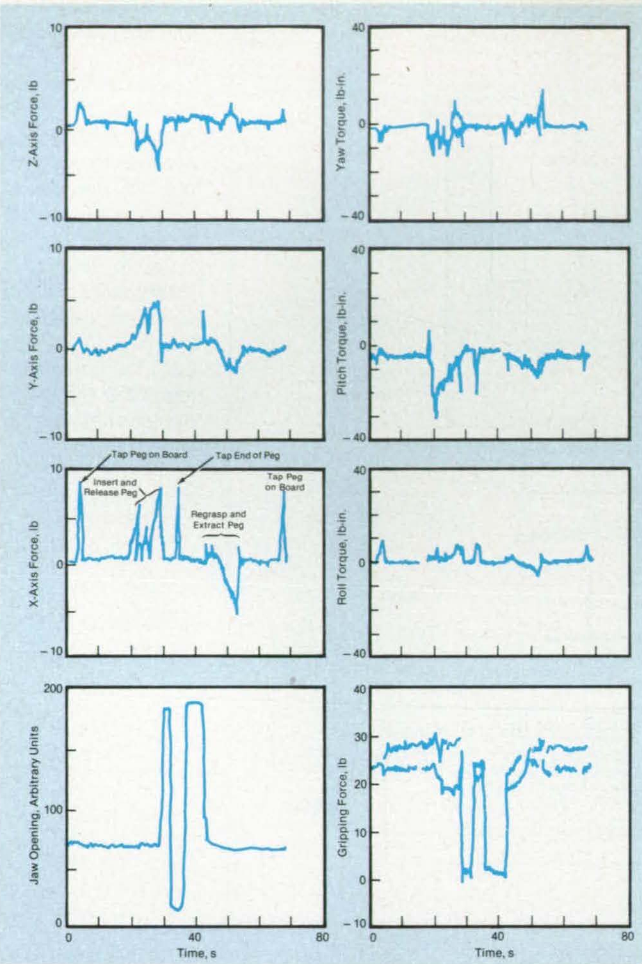
Forces and torques are analyzed by extension of a method previously applied to speech.

NASA's Jet Propulsion Laboratory, Pasadena, California

A mathematical model and procedure based on the hidden-Markov-model concept are undergoing development for use in the analysis and prediction of the outputs of force and torque sensors of telerobotic manipulators (see figure). A hidden Markov model is a mathematical model of a Markov process (a type of stochastic process) that cannot be observed directly. Each state of a hidden Markov model specifies a probability density from which such observations as sensor outputs are generated. In a nontrivial case in which the probability densities overlap, the problem of determining the sequence of states in the underlying Markov model becomes one of optimally combining the information on state-transition probabilities with state-dependent observation densities and observations at particular times.

The hidden-Markov-model concept has previously been applied to the recognition of speech signals, which are similar to robotic force/torque signals in that they are noiselike and represent hidden mental states of human operators or internal states of electronic controllers. In the developmental hidden Markov model, an overall task is broken down into subgoals, and transition probabilities encode the ease with which the operator completes each subgoal. The Markov-process portion of the model encodes the task-sequence/subgoal structure, and the probability-density functions for the forces and torques associated with each state of manipulation (subgoal/state) encode the sensor signals that one expects to observe at the subgoal. The parameters of this model are constructed from engineering knowledge of the task.

Three problems arise: to compute the probability of a sequence of observed sensor outputs given a particular hidden Markov model, to compute the most likely sequence of states from a sequence of observed sensor outputs and the hidden Markov model, and to identify the hidden Markov model from a sequence or set of sequences of observed sensor outputs. The first problem corresponds to the computation of a "*P*-value" (a recursive sum of products that include transition probabilities) for the entire sequence of sensor data. For example, if evaluated against a hidden Markov model of normal execution of the task, the *P*-value" indicates to what extent the operation is proceeding according to plan. The second problem is solved by using the Viterbi algorithm, which also computes the probability of the most likely sequence of states. The third problem is solved by use of the Baum–Welch algorithm, which is an incremental-optimization algorithm that is guaranteed to change the



The **Outputs of Sensors** on a robot performing a precise peg-in-hole task are noisy but also contain information that can be interpreted with the help of knowledge of the task.

hidden Markov model in such a way as to improve the *P*-value for a given set of sensor data.

This work was done by Blake Hannaford and Paul Lee of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 2 on the TSP Request Card. NPO-18000*

Bidirectional Drive-and-Brake Mechanism

Motion of a single lever provides both driving and braking.

Lyndon B. Johnson Space Center, Houston, Texas

A bidirectional drive-and-brake mechanism is part of a small vehicle that is driven manually along a monorail somewhat in the manner of a railroad handcar. The vehicle looks and functions like a hybrid of a handcar and a bicycle (see Figure 1). The vehicle and mechanism were conceived for use by an astronaut traveling along a structure in outer space, but the basic concept could be applied on Earth, for example, to make very small railroad

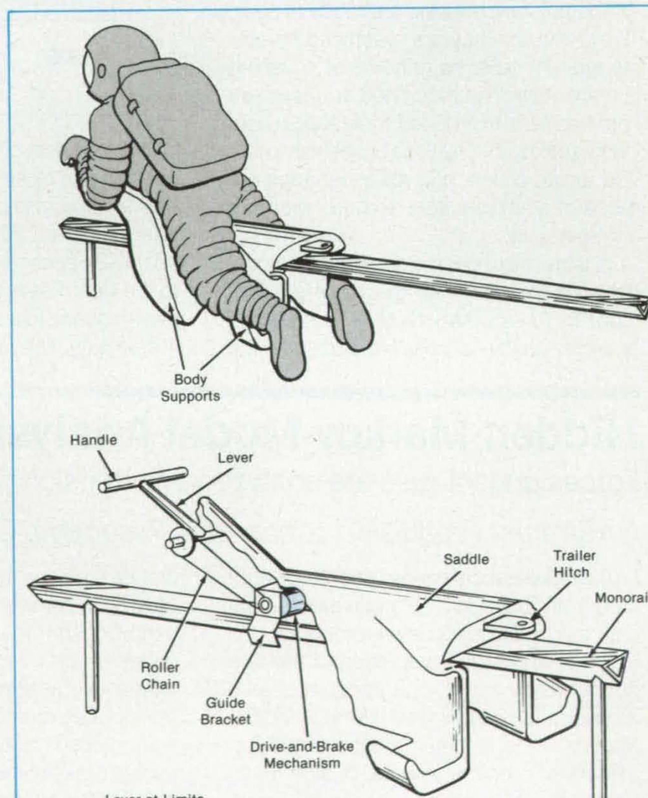


Figure 1. A **Vehicle That Crawls Along a Monorail** combines features of both a bicycle and a railroad handcar.

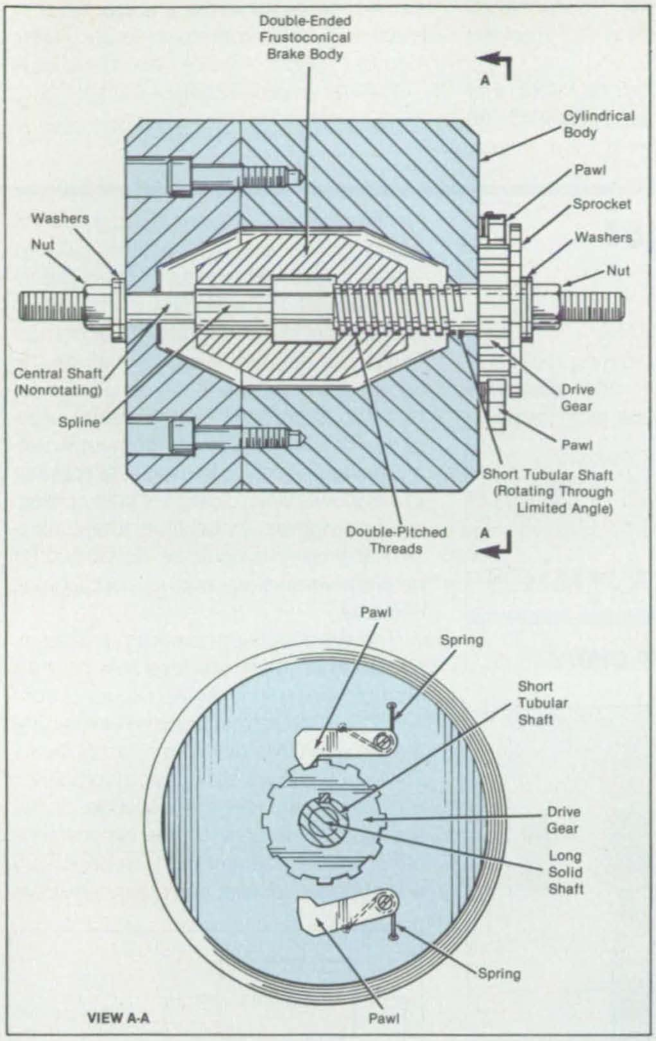


Figure 2. The **Bidirectional Drive-and-Brake Mechanism** includes a selectable-pawl-and-ratchet overrunning clutch (the drive mechanism) and mating stationary and rotating conical surfaces that can be pressed against each other (the brake mechanism). The mechanism operates similarly to a bicycle drive-and-brake mechanism except that it limits the rotation of the sprocket in both directions and brakes at both limits.

handcars or crawling vehicles for use on large structures, in pipelines under construction, or underwater.

As in the case of a bicycle crank with pedals, the motion of a single lever with a handle actuates both the driving and braking functions, and the range of motion determines which function is selected. As on a handcar rather than on a bicycle, even when driving, the lever is moved reciprocally through a limited arc. A bicycle-like combination of roller chain and sprockets transmits the motion of the lever to the drive-and-brake mechanism.

Shown in more detail in Figure 2, the mechanism includes a cylindrical body that drives and brakes the vehicle by rotating in frictional contact with the monorail. A nonrotating central shaft with threaded ends is mounted on guide brackets that hold the vehicle on the monorail.

The sprocket on the mechanism is attached to a drive gear and a short tubular shaft that rotates about the central shaft. During the forward or reverse stroke of the lever, one of two manually selectable spring-loaded pawls transmits forward or reverse driving torque, respectively, from the drive gear to the cylindrical body. The pawls are arranged so that only the one for the selected direction of drive can engage the drive gear.

A portion of the short tubular shaft includes double-pitched outer threads that mate with similar threads in a double-ended frustoconical brake body. As the motion of the lever causes this shaft to rotate, the action of the threads causes the brake body to slide along the central shaft. Splines on the central shaft and brake body allow the brake body to slide lengthwise but prevent it from rotating. At the extremes of the arc of lever motion, beyond the limits of the driving arc, the brake body makes contact with conical inner surfaces of the rotating cylindrical body, and the friction of this contact brakes the motion of the vehicle. Thus, for example, when the forward-driving pawl is selected, one can brake the vehicle as one brakes a bicycle: by moving the lever to the limit of its travel in the reverse-torque

direction. However, unlike on a bicycle, even when forward drive is selected, one can also brake the vehicle by moving the lever to the limit of its travel in the forward-torque direction.

This work was done by Scott A. Swan of **Johnson Space Center**. *For further information, Circle 39 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 16]. Refer to MSC-21540.

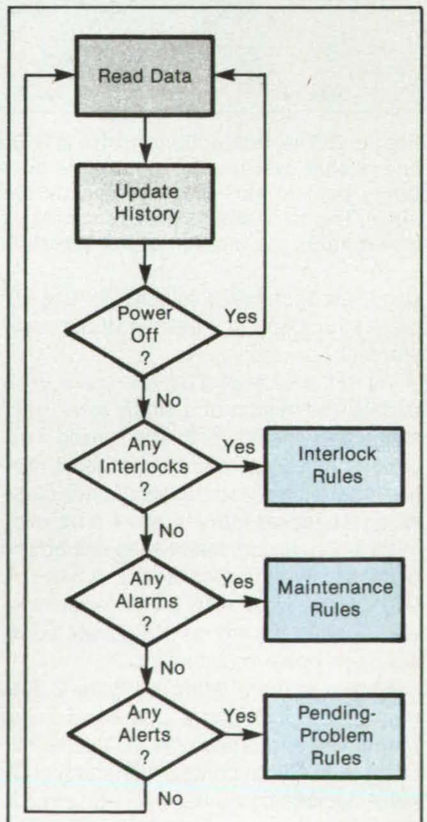
Expert System for Heat Exchanger

Diagnosis is simplified for non-engineers.

NASA's Jet Propulsion Laboratory, Pasadena, California

A developmental expert-system computer program assists an operator in controlling, monitoring the operation, diagnosing malfunctions, and ordering repairs of a heat-exchanger system that dissipates heat generated by a 20-kW radio transmitter. This system includes not only a heat exchanger but also pumps, fans, sensors, valves, a reservoir, and associated plumbing. Because this assembly of equipment and its modes of operation are complicated, the operator needs to call on the knowledge and experience of an engineer to respond properly to unforeseen problems. The expert-system computer program was conceived to assist the operator in this way while avoiding the cost of keeping an engineer in full-time attendance. Similar programs could be developed for heating, ventilating, and air-conditioning systems.

The expert-system program resides in a computer that monitors the heat-exchanger system via digitized signals from sensors. It performs four main tasks, the first of which is to detect and locate faults. For this purpose, the program incorporates an expert engineer's knowledge of the symptoms of failures (e.g., sensor readings out of specified ranges) and the necessary adjustments, repairs, and other corrective



The **Knowledge Base** of the expert system is organized in a set of "if...then" rules regarding flow interlocks (e.g., to order a shutdown if flow of coolant is blocked in a critical component), maintenance, and pending problems.

responses. This expertise is encoded in the form of "if...then" rules (see figure); for example, "if level of liquid in tank is less than level of liquid in tank 10 minutes ago, then coolant may be leaking."

In addition to the expert knowledge base encoded in "if...then" rules, the expert system includes an "inference engine" that derives conclusions about the status of the heat-exchanger system from sensor outputs and from rules furnished by the expert. For example, where the knowledge base contains the rule "if A then B" and a sensor reports that A is true, then the inference engine deduces that B is also true. The assertion that B is true might trigger other rules of the form "if B then C," and so on. The execution of the program entails a sequence of such forward chaining, which persists until either no more rules are executed or a halt is commanded. At each cycle, all rules, the preconditions of which are satisfied by the contents of working memory, are determined. If more than one rule is activated, one is selected by means of a suitable conflict-resolution strategy. All the actions associated with the selected rule are then performed, and the data base is changed accordingly. Alternatively, if B is suspected to be the cause of a problem, then, armed with a rule of the form "if A then B," the inference engine may work backward and ask the sensor system to provide any evidence that could confirm the existence of A.

The second main task is to provide reports on the statuses of important components of the system. These include which components like pumps or fans are on at the moment, whether they are operating correctly, and the like. Other data include operating hours, reports of momentary faults, past failures, and records of repairs.

The third main task is to furnish the operator with alternatives when faults are detected. For example, if one of several fans malfunctions but the remaining fans are sufficient to handle the current heat load, the system so advises the operator.

The fourth main task is to acquire and analyze data continuously during operation so as to detect trends (e.g., slow leakage of coolant) that may lead to failures and to advise the operator of the need to make repairs before those failures occur. This involves the application of least-squares regression analyses to selected sensor outputs. The expert system first alerts the operator to the existence of a potential problem and then, by comparing the trends in current sensor outputs with certain prespecified parameters, predicts a time when those trends would become critical. This action mimics that of an attentive engineer.

The expert system provides for interactive displays on the video terminal of the computer to assist the operator in using it. Expert information (including alarms) is presented in the form of text, graphs, and icons. In addition, printouts are available and are produced automatically in response to some alarms to instruct the operator about corrective actions.

This work was done by D. Gordon Bagby and Reginald A. Cormier of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 108 on the TSP Request Card.* NPO-17991

Books and Reports

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

Separation of Liquid and Gas in Zero Gravity

Tanks would double as cyclone separators.

A pair of reports describe a scheme for separating a liquid from a gas so that the liquid could be pumped. The scheme is designed to operate in the absence of gravitation.

A jet of liquid, gas, or liquid/gas mixture would be fed circumferentially into a cylindrical tank filled with the liquid/gas mixture. The jet would start the liquid swirling. The swirling motion would centrifugally separate the liquid from the gas. The liquid could then be pumped from the tank at a point approximately diametrically opposite the point of injection of the jet.

The vortex phase separator would replace such devices as bladders and screens. It would require no components inside the tank. Pumps for gas and liquid would be outside the tank and thus would be easily accessible for maintenance and repairs.

This work was done by Frank S. Howard of **Kennedy Space Center** *and Wilson S. Fraser of Johnson Space Center. To obtain copies of the reports, "Vortex Motion Phase Separator for Zero Gravity Liquid Transfer" and "Preliminary Results for a Vortex Induced, Liquid Handling and Accountability Procedure at Zero Gravity," Circle 69 on the TSP Request Card.*

This invention has been patented by NASA (U.S. Patent No. 4,848,987). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Kennedy Space Center [see page 16]. Refer to KSC-11387.

Fabrication Technology

Lighted, Folding Inspection Mirror

This compact, inexpensive tool can be used in place of expensive borescopes.

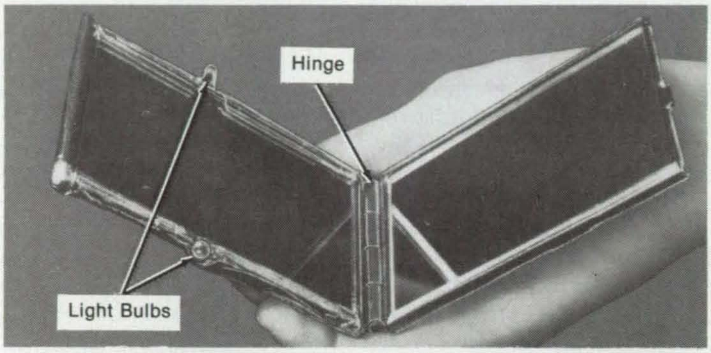
Marshall Space Flight Center, Alabama

A compact, cheap tool (see figure) is used in place of an expensive (about $200,000) borescope for inspecting and photographing interior surfaces of the cases of the redesigned solid rocket motors of the Space Shuttle for salt-water corrosion, fretting, or other damage. Previously, examination of these surfaces had been tedious because of the lack of adequate tools. This new tool, which can be carried in an inspector's pocket, greatly shortens the inspection/photographing process. This tool will be useful in the assembly of segments of the solid rocket motors as well as in postflight assessment, engineering evaluation, and refurbishment. It can be applied in general to the inspection and photographing of inner sealing surfaces to which access is difficult.

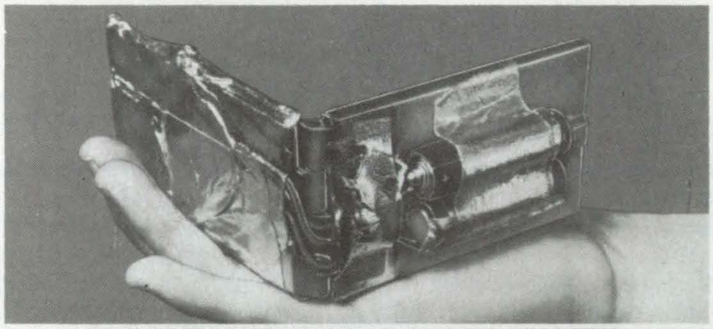
The tool includes two small metal or glass mirrors hinged together (see figure). Two 3-V light bulbs are attached along the edges of one mirror and connected to a battery of two cells. The cells are attached to the back side of one of the mirrors. For inspection of the clevises or tangs of the solid rocket motors, the size of each mirror is about 3 in. (7.6 cm) × 2 in. (5.1 cm). The lighted mirror is inserted into the narrow opening of the clevis or tang, and the surface can be viewed and photographed in the opposite mirror.

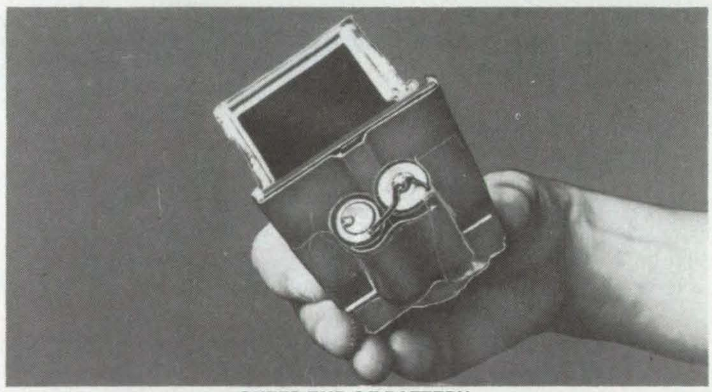
This work was done by Brian E. Roepe of Thiokol Corp. for **Marshall Space Flight Center**. *No further documentation is available.*
MFS-28457

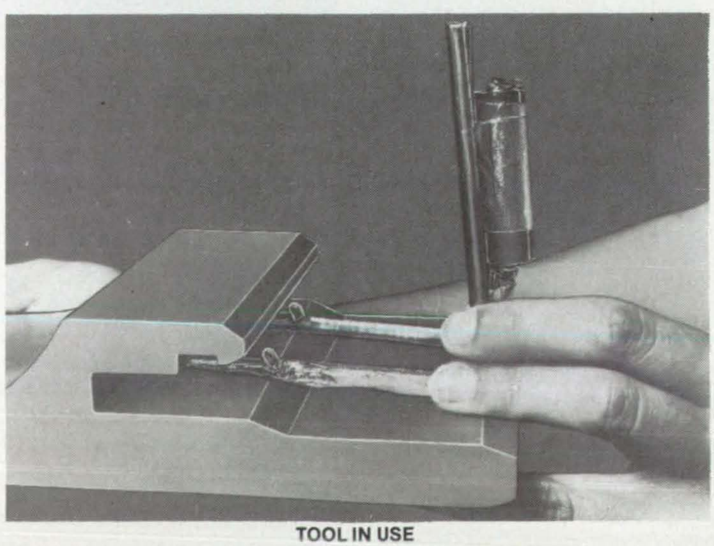
This **Inexpensive Tool** replaces a borescope for the inspection and photographing of surfaces that are otherwise difficult to view.



TOOL PARTLY UNFOLDED FOR USE, SHOWING REFLECTING SURFACES


BACK SIDES OF TOOL, SHOWING INNER END OF BATTERY


OUTER END OF BATTERY


TOOL IN USE

Vacuum Powder Injector

Neat resin coats are applied uniformly to bundles of fiber tow.

Langley Research Center, Hampton, Virginia

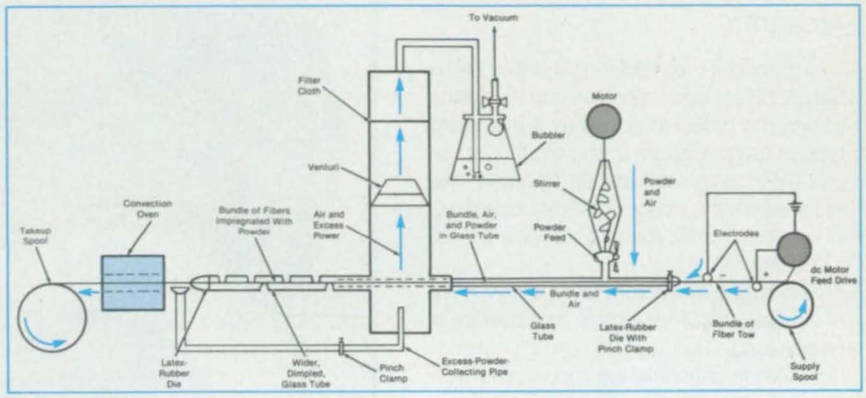
A method has been developed to provide uniform impregnation of bundles of carbon-fiber tow with low-solubility, high-melt-flow polymer powder materials to produce composite prepregs. Because of the interactions among various low-viscosity, high-melting-point polymers, the methods available for coating of carbon-fiber tows with these polymers are limited and of marginal value for the production of prepregs of high quality. The inability to remove solvents and carrier materials to acceptable levels and the inability to cause the polymer films to infiltrate the fiber bundles totally have proved to be significant barriers to the production of uniformly impregnated prepregs of high quality.

In the new method (see figure), a bundle of fiber tow is unwound from a supply spool by an electric motor. The circuit that supplies power to the motor is completed when the bundle is pulled against the electrodes, causing the motor to advance until the circuit is broken again. The bundle is then pulled through a latex-rubber die, which includes a pinch clamp that regulates the intake of air into the bundle. The bundle passes along a glass tube, along with the air drawn in by a vacuum system. The polymer powder is mechanically dispensed into the tube and, like the air, it is pulled into the tube by the vacuum.

While the flow of air is spreading the fibers in the bundle in the tube, the powder material is mixed into the bundle. The larger particles of powder are carried into a wider glass tube dimpled to half its diameter, wherein these particles are combed into the bundle. At the entrance to the larger glass tube, the vacuum changes the direction of flow of air, and the air is no longer traveling with the fiber. A rubber die at the exit end of the larger glass tube near a convection oven stops the air from entering from that end. The die also constricts the fiber for the final entrapment of the polymer.

The excess powder that is stripped from the fiber before it leaves the vacuum is first accelerated through a venturi, then dispersed through a filter, causing an overall loss of energy that, in turn, causes the powder to collect in a pipe at the bottom. Those smaller particles that are not stopped by this loss of energy are collected in the liquid of a bubbler. A very fine filter at the outlet of the bubbler provides final protection for the vacuum system.

This system provides for control of the amount of polymer on the bundle (≤65 percent). The crystallinity of the polymer can be maintained by a controlled melt on the takeup system. All the powder is entrapped, and most is collected for reuse. The process provides an inexpensive and efficient method for making composite materials. It allows for the coating of any bundle of fine fibers (wire, cloth, graphite, glass, and the like) with powders (paints, dyes, insulating materials, and the like). The method shows high potential for making prepregs of improved materials and for preparation of high-temperature, high-modulus, reinforced thermoplastics.



The **Vacuum Powder Injector** expands the bundle of fiber tow, applies polymer powder to it, then compresses the bundle to hold the powder.

This work was done by Dennis C. Working of **Langley Research Center**. *No further documentation is available.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center *[see page 16]**. Refer to LAR-14179.*

Repairing a Shaft Prone to Fatigue

The shaft of a hydraulic motor now outlives its bearings.

Marshall Space Flight Center, Alabama

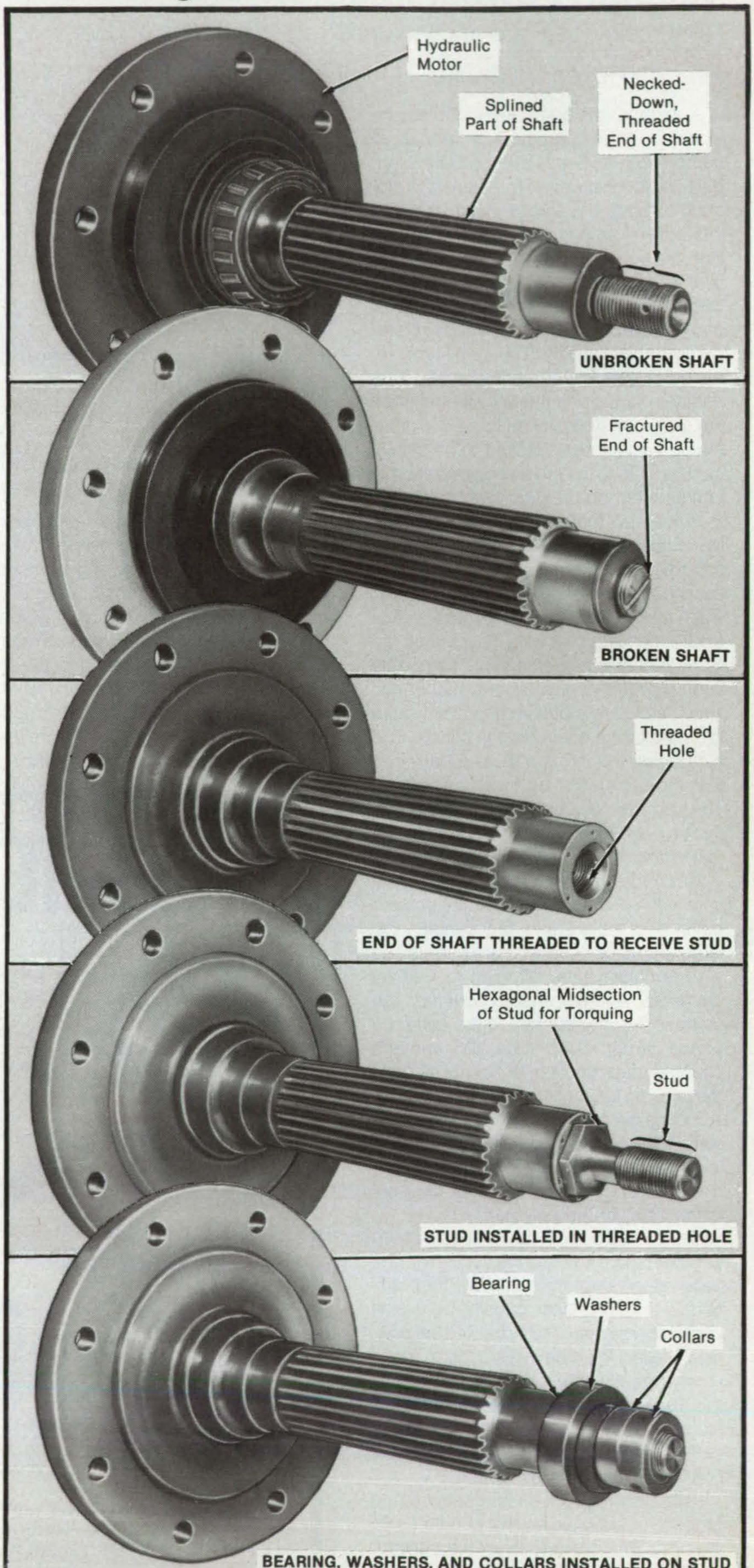
A procedure for repairing a John Deere Series 50 (or equivalent) hydraulic motor solves the problem posed by a common type of fatigue failure of the shaft. The repair extends the service life 10 times; the repaired shaft outlasts the motor bearings, which have an expected service life of 1,000 hours.

The hydraulic motors drive the wheels of a slowly moving vehicle that carries a heavy load. The motors are low-speed, high-torque units that are mounted directly on the transporter axle-and-wheel assemblies. Pressurized hydraulic fluid turns a splined shaft that has a necked-down threaded end (see figure). The end is subject to bending and fatigue; when it fails, it breaks away from the motor, hydraulic fluid leaks, and the vehicle can no longer move.

The repair procedure can be summarized as follows:

1. Completely remove the remaining part of the broken necked-down section.
2. Bore and internally thread a hole in the end of the remaining shaft.
3. Apply an adhesive to the threads on the inner end of a special stud. Insert the threaded end of the stud in the hole in the end of the shaft. By use of the hexagonal-nut-like midsection of the stud, torque the stud into the threaded hole.
4. Replace the bearings and seals in the motor.
5. Place a special machined washer, a self-aligning washer, locking collars, and an end cap on the outer end of the stud.

The locking collars provide the necessary end play of 0.003 in. (0.08 mm). They replace a nut that was secured by a cotter pin extending through a diametral hole in the necked-down section. Similarly, the machined washer and self-aligning washer replace an eccentric washer that was secured by a roll pin through a hole in the shaft. Because the holes through the necked-down section are no longer needed in the stud that replaces it, the stud is stronger and more resistant to fatigue. These qualities are enhanced by the stud material (4340 steel), which is tougher than is the original shaft material, and by the use of rolled (instead of cut) threads on the stud.



The **Necked-Down End of the Shaft** is prone to fatigue failure, in which the threaded end is sheared off. Repair includes forming an internally threaded hole in the end of the shaft, inserting a double-threaded end stud, and adding washers and collars.

It is not necessary to wait until a failure occurs to carry out the repair procedure. It can be performed as a retrofit procedure to ensure reliable operation.

This work was done by Roger A. Sharp, David V. Larsen, and Garold A. Bates of Thiokol Corp. for **Marshall Space Flight Center**. *For further information, Circle 130 on the TSP Request Card. MFS-28518*

Filament Winding of Carbon/Carbon Structures

An improved technique has potential for automation.

NASA's Jet Propulsion Laboratory, Pasadena, California

An improved method of winding carbon filaments for carbon/carbon composite structures is less costly and labor-intensive than are prior methods and produces more consistent results. The improved method involves the use of a roller squeegee to ensure that filaments are continuously wet with resin during winding. The method also involves control of the spacing and the resin contents of plies to obtain strong bonds between carbon filaments and the carbon matrices. The method lends itself to full automation and involves the use of filaments and matrix-precursor resins in their simplest forms, thereby reducing costs.

Carbon/carbon composites offer high strength at high temperatures. They resist thermal shock and erosion. They are used to make such structures as throats and exit cones of rocket engines.

The roller-squeege eliminates buildup of resin on the guide rollers, which eventually tears the filaments, as seen with previous conventional techniques. The buildup occurs due to the tackiness and high viscosity of the phenolic resin (the high viscosity of the resin is attributed to the addition of 6 to 16 weight percent of carbon filler, which increases the total char yield of the structure). The roller-squeegee continuously applies resin to the dry fibers as they are wound onto the part being fabricated and works the resin into the outer layers.

Another feature of the new method prevents the wrinkles that usually form in older methods because of polymerization and shrinkage during curing. The wrinkles are prevented by controlling the interlaminar resin content and curing in a vacuum bag under atmospheric pressure only.

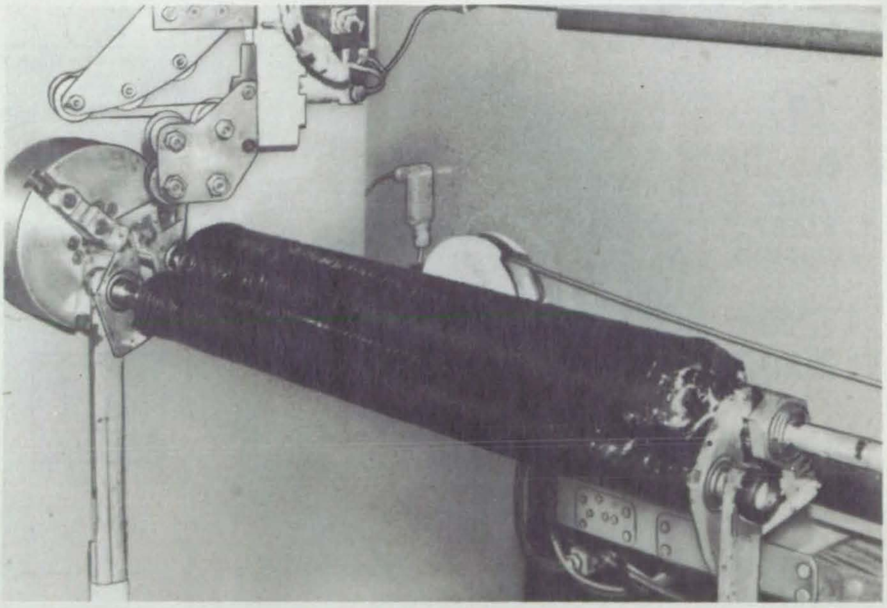
In a demonstration of the method, several carbon/carbon tubes, 4 in. (10 cm) in diameter, were fabricated by alternately winding four fiber bundles at an angle of ±30° off axis on an aluminum mandrel coated with a release chemical. The roller squeegee worked the carbon-filled resin into the bundles as they were laid down. The roller squeegee was spring-loaded against the surface. A servosystem controlled the tension on the filaments.

After winding, the tubes were vacuum-bagged and cured at a temperature of 165 °C under atmospheric pressure. They were carbonized in nitrogen at a temperature that was gradually increased to 816 °C, then graphitized at 2,200 °C. Finally, some tubes were densified by chemical-vapor deposition, while others were densified by impregnation with pitch. The material produced by chemical-vapor deposition was found to be stronger and to have a matrix that was more nearly uniform than that produced by impregnation with pitch. Chemical-vapor deposition gave better adhesion between matrices and fibers, thereby imparting better transfer of loads and increased shear strength.

The roller-squeegee method has also been used to fabricate prototype rocket nozzles. In the prototypes, the winding angle was varied between 30° and 60° to create constant thicknesses of material along the axes of the nozzles. After winding, the filament-wound nozzles were processed similarly to the tubes. These rocket nozzles were successfully test-fired to show structural integrity..

This work was done by Paul J. Jacoy, Wesley P. Schmitigal, and Wayne M. Phillips of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 52 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 16]. Refer to NPO-18163.



The **Roller Squeegee** presses against filaments as they are wrapped on a mandrel on a servo-controlled winding machine. The filaments are thereby coated uniformly with the correct amount of carbon-filled resin.

Acoustic Levitator With Furnace and Laser Heating

The levitated sample can be heated to more than 1,500 °C.

NASA's Jet Propulsion Laboratory, Pasadena, California

An acoustic-levitation apparatus incorporates an electrical-resistance furnace for uniform heating up to a temperature of about 1,000 °C. Additional local heating by a pair of laser beams can raise the temperature of the sample to more than 1,500 °C. The apparatus is designed for use in the containerless processing of materials in microgravity or in normal Earth gravity.

The apparatus (see Figure 1) includes a round cylindrical quartz tube surrounded by a quartz mandrel that supports the heating wire. Sound at a frequency of 20 kHz is generated by a piezoelectric transducer and coupled via a horn and a driver rod into the quartz tube. The dimensions of the tube are chosen so that at the 20-kHz frequency, the sound waves excite an acoustic resonance that provides stable levitation of the sample at the center

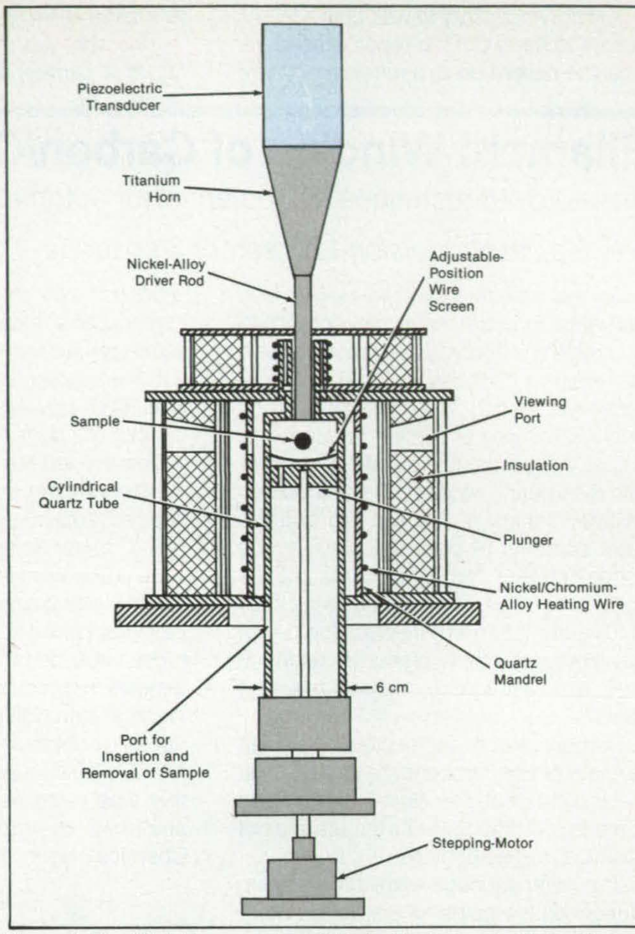


Figure 1. The **High Temperature Single-Mode Acoustic Levitator** generates a cylindrical-mode acoustic resonance that levitates a sample. The levitation chamber is enclosed in an electrical-resistance furnace.

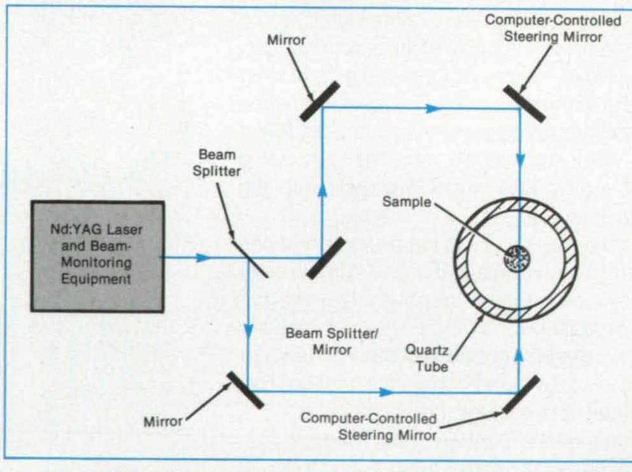


Figure 2. **Infrared Beams** from an Nd:YAG laser provide additional local heating of the sample. This is a simplified diagram: the equipment also includes lenses, collimators, additional beam splitters, and a helium/neon laser used in alignment.

of the tube. Because the resonant length of the tube at a fixed frequency varies with the speed of sound (which increases with temperature), an adjustable quartz plunger driven by a stepping motor is used to adjust the length to maintain the resonance during heating.

To prepare for ground-based levitation, the plunger is lowered below a port near the bottom of the quartz tube, and the sample is inserted through the port onto a wire screen. The screen is then raised to bring the sample up to the initial levitation position, and the plunger is raised to the position that corresponds to the initial resonant length. Once the sound begins to support the sample, the screen is lowered out of contact with the sample. The sample is removed from the chamber by reversing this procedure.

The levitation chamber and furnace include viewing ports for observation of the sample. Two additional ports (not shown) are used to direct the laser heating beams at the sample from two opposite directions. The beams are generated by splitting the beam from a neodymium:yttrium aluminum garnet (Nd:YAG) laser of 100-W power and 1.06-µm wavelength and are aimed at the sample by a pair of computer-controlled steering mirrors (see Figure 2). The temperature of the sample is measured optically (in terms of radiance and surface reflectance) by use of a 0.904-µm laser pyrometer.

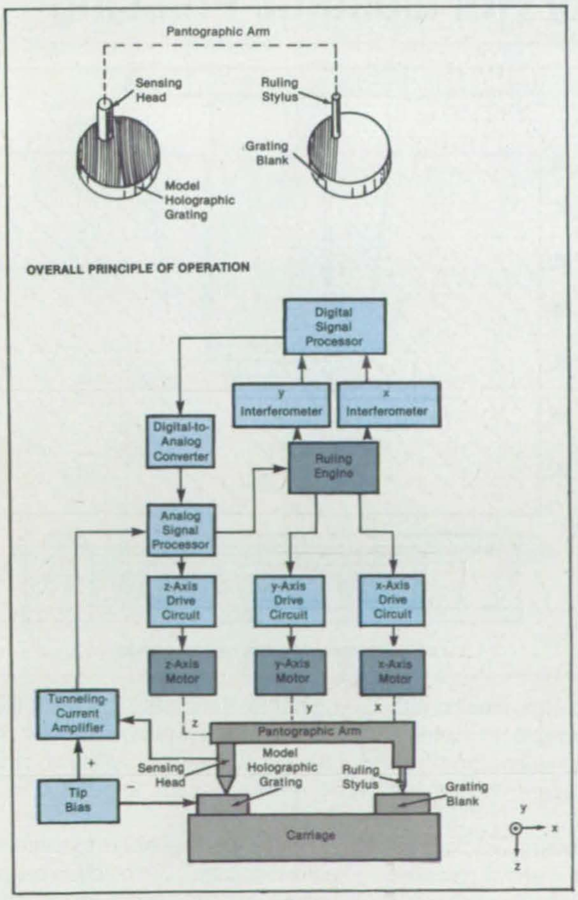
This work was done by Martin B. Barmatz and James D. Stoneburner of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 77 on the TSP Request Card. NPO-18035*

Ruling Blazed, Aberration-Corrected Diffraction Gratings

Advantages of holographic and ruled gratings are combined.

Goddard Space Flight Center, Greenbelt, Maryland

A proposed optoelectromechanical apparatus that functions partly as a ruling engine and partly as a pantograph would rule blazed, aberration-corrected diffraction gratings. Heretofore, gratings blazed on conventional mechanical ruling engines have been subject to phase errors, with consequent undesired ghost images and scattering of light, caused by periodic and



The **Sensing Head** traces the grooves in a model holographic grating, causing the ruling stylus to form similar grooves in a grating blank.

random mechanical errors in the ruling engines. Conventional mechanical ruling engines are also limited in that they rule only nominally straight grooves, whereas specially curved grooves are needed in some cases to compensate for optical aberrations elsewhere in the systems in which the gratings are to be used. Although gratings can be made holographically with grooves in precise registration, with little or no phase error, and corrected for aberrations, the grooves in such gratings have smoothly undulating cross sections with rounded edges, which have low diffraction efficiency. Gratings with grooves of triangular or "sawtooth" cross sections (blazed gratings) are needed for high efficiency in the designed order of diffraction.

The new apparatus (see figure) makes it possible to combine the precision of an aberration-corrected, holographically produced grating with the diffraction efficiency of a blazed grating by using the holographically produced grating as a model or master pattern that controls the ruling engine that makes the blazed grating. The surface of the model holographic grating is scanned by a sensing head mounted on a pantographic arm. A ruling stylus is mounted on the other end of the pantographic arm with its tip in a grating blank.

The sensing head is a scanning-tunneling-microscope probe mounted on a pantographic arm. The probe tapers to a sharp tip, and a bias voltage is applied between the tip and the model holographic grating. The vertical (*z*-axis) position of the pantographic arm is controlled by a scanning-tunneling-microscope feedback servo-control loop in response to the quantum-mechanical-tunneling electron current that flows between the tip and the surface. This current depends on the distance of the tip above the surface of the grating, and the servomechanism maintains the tip at a fixed distance as small as a few nanometers.

A ruling engine commands the horizontal (*x*- and *y*-axis) motion of the pantographic arm via *x*- and *y*-axis drive circuits and motors. (Alternatively, the pantographic arm can be moved in *y* only, and the carriage can be translated in *x*.) The ruling engine includes *x*- and *y*-axis interferometers that measure the horizontal position. The outputs of the interferometers are processed digitally, and the resulting signal is converted into one of the analog inputs to the *z*-axis servocontrol loop.

The net effect of the interaction among the *x*-, *y*-, and *z*-axis control loops is the following: The ruling engine commands the pantographic arm to scan in *y* along a groove, which lies substantially along the *y* axis. The *z* motion of the pantographic arm and the x motion of the pantographic arm or carriage are controlled together in such a way as to make the tip of the probe trace a path a few nanometers above the top of one of the grooves on the model. (This path can deviate slightly from a straight line parallel to the *y*-axis because of the aberration-correcting curvature.) The ruling stylus on the other end of the pantographic arm follows a parallel path, thereby embedding the pattern of the holographic grating in the grating blank.

An alternate apparatus would have a photolithographic recording device such as an electron spot instead of a ruling stylus. The end product would be a recording mask defining groove layout in etched grating processes.

This work was done by Douglas B. Leviton of **Goddard Space Flight Center**. *For further information, Circle· 6 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 16]. Refer to GSC-13240.

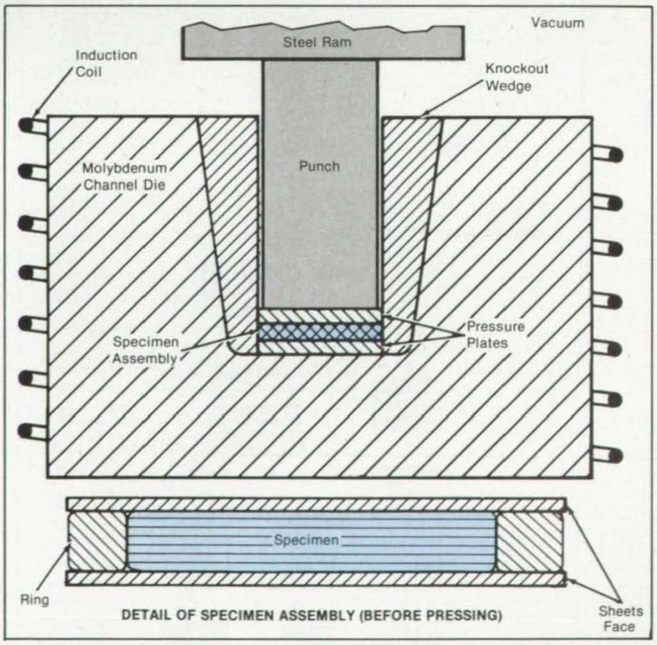
Crack-Free, Nondistorting Can for Hot Isostatic Pressing

Outgassing and warping are reduced.

Lewis Research Center, Cleveland, Ohio

A new method of canning specimens made of composites of arc-sprayed and plasma-sprayed tape reduces outgassing and warping during hot isostatic pressing. The method produces a can that has a reliable, crack-free seal and thereby helps to ensure a pressed product of high quality.

In the new method, a specimen is placed in a ring of refractory metal between two face sheets, also of refractory metal (see figure). This assembly is placed in a die in a vacuum hot press, where it is simultaneously heated and pressed until the plates become diffusion-welded to the ring, forming a sealed can around the specimen. The specimen also becomes partially densified, and thus fits snugly within the can. The specimen is then ready for further densification by hot isostatic pressing.



The **Specimen Assembly** in the die lies under a punch driven by a steel ram in a vacuum hot press. An induction coil around the die supplies heat for solid-state diffusion welding. The specimen assembly consists of the composite specimen layup between refractory-metal plates in a refractory-metal ring.

Previously, the specimen was placed in a lidded refractory-metal container that was then sealed in a vacuum by electron-beam welding. Because the vacuum was sealed in the can at room temperature, the specimen did not have the opportunity to release gases until it was subjected to hot isostatic pressing, at which point the sealed-in gases could not escape. The resulting gas bubbles prevented proper densification, and the gases often reacted with the specimen, weakening it. In the new hot-sealing method, gases are driven off during the sealing process, before hot isostatic pressing.

Moreover, electron-beam welding according to the previous method can lead to cracks when the molten refractory metal recrystallizes in the weld zone, and cracks prevent the specimen from densifying during hot isostatic pressing. With the solid-state diffusion weld in the new method, however, there is no melting and therefore no recrystallization and the consequent cracking.

Finally, it is impossible to achieve a perfectly fitting can with electron-beam welding according to the previous method. Unequal stresses in the specimen during hot isostatic pressing therefore tend to warp it. However, the heat and pressure of the sealing process in the new method squeeze the specimen into contact with the entire inner surface of the can, so that thereafter, the specimen does not warp when pressed.

This work was done by John J. Juhas of **Lewis Research Center**. *For further information, Circle 71 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, Lewis Research Center [see page 16]. Refer to LEW-14990.

Heavy-Workpiece Handler for Vacuum Plasma Spraying

Massive parts are manipulated for uniform coating.

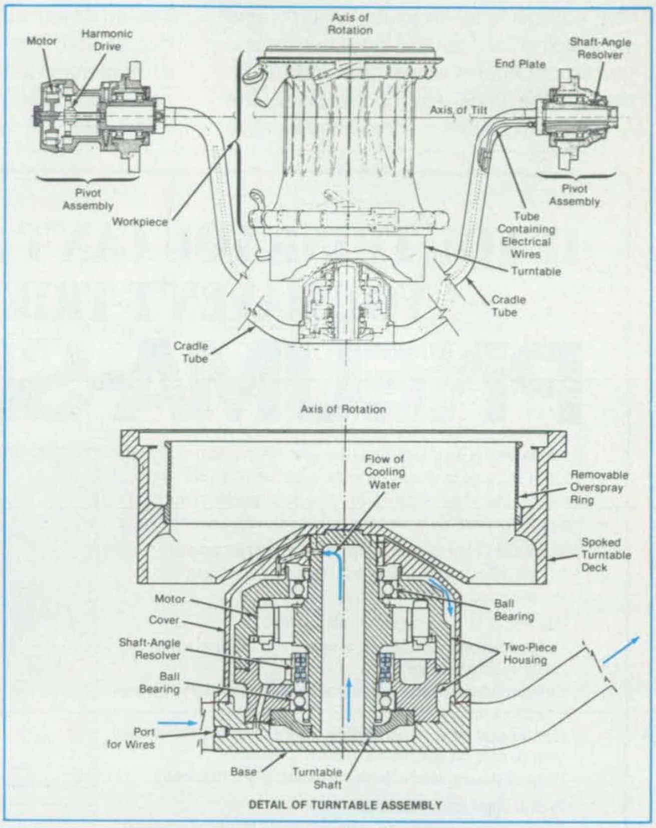
Marshall Space Flight Center, Alabama

A handling device manipulates a heavy, hollow workpiece for plasma spraying in a vacuum chamber. The device rotates and tilts the workpiece, keeping it approximately perpendicular to the plasma-spray nozzle, so that the nozzle deposits a uniform layer on the interior surface of the workpiece. It can accommodate workpieces as heavy as 1,000 pounds (450 kilograms) and is compatible with the heat and vacuum of the spraying process.

The device includes a turntable mounted on a cradle made of tubes (see figure). The cradle tilts on a pair of pivot assemblies. A motor in the base of the turntable drives a spoked turntable deck that holds a removable ring, called the "overspray ring," that supports the workpiece. A motor and harmonic drive in one of the pivot assemblies tilts the cradle.

The workpiece is placed on the overspray ring. The plasma-spray gun is inserted in the workpiece from the top. The overspray ring provides a margin at the lower limit of the vertical travel of the plasma-spray gun; it protects the interior surface of the spoked turntable deck from the plasma spray. It has a thin cross section to minimize the transfer of heat to the spoked turntable deck. During spraying, the overspray ring becomes attached to the workpiece via the deposited layer. Therefore, the overspray ring is designed to be easily removable from the turntable.

The turntable motor rotates the workpiece during spraying. A shaft-angle resolver in the turntable housing provides position feedback, and Hall-effect devices in the motor provide rate feedback for automatic control of the rotation of the turntable. Simultaneously, the motor and harmonic drive in one of the pivot assemblies keep the contoured internal surface perpendicular to the axis of the spray. The harmonic drive multiplies the torque of the pivot motor 200 times so that the massive workpiece can be tilted. A shaft-angle resolver in the opposite pivot assembly provides position feedback for the control system, which is programmed to coordinate the tilt of the cradle with the position and orientation of the gun and the rotation of the turntable.



A **Heavy Workpiece** is mounted on a turntable. The turntable rotates the workpiece about one axis while the cradle tilts the turntable and workpiece about an orthogonal axis. A plasma-spray gun is inserted in the workpiece. A removable ring, shown in cross section, supports the workpiece and shields part of the turntable from the spray.

Cooling water enters the motorized pivot and flows along the pivot shaft, the adjacent cradle tube, the turntable, and around the turntable motor. The cooling water leaves the turntable through the opposite cradle tube and pivot.

Tubes carrying water and power and control cables enter the vacuum chamber through dual-sealed ports. The seals are pressurized with argon gas.

The cradle completes the electric circuit from the plasma gun through the casting. It is insulated from the wall of the vacuum chamber by nonmetallic bushings between the pivot bearings and their housings.

This work was done by William N. Myers of **Marshall Space Flight Center**. *For further information, Circle 31 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 16]. Refer to MFS-28522.

Books and Reports

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

Effects of Heat Sinks on VPPA Welds

Predicted heat-sink effects are consistently less than measured ones.

A report describes a theoretical and experimental study of the absorption of heat by metal blocks in contact with a metal plate while the plate is subjected to variable-polarity plasma-arc (VPPA) welding. The plate and the blocks served as simplified models of workpieces to be welded and the fixtures that hold the workpieces, respectively. The purpose of the study was to contribute to the development of a comprehensive mathematical model of temperature in the weld region; this model would be incorporated into an algorithm for automatic control of the welding process. The study is also relevant to the welding of thin sheets of metal to thick blocks of metal, the heat treatment of metals, and hotspots in engines.

The theoretical part of the study is based on a simplified mathematical model of thermal conditions in the plate. The plate is treated as having uniform thermal diffusivity throughout, convective cooling of the surface is ignored, the temperature in regions of the plate far from the welding heat source is taken to be uniform, and the welding heat source is treated as line source of uniform power per unit length through the thickness of the plate. The welding heat source is considered to move along the plate in the x direction at a steady speed V and to have been operating long enough so that in the coordinate system moving with the source, the distribution of temperature in the plate is constant in time. Under these conditions, the steady-state distribution of temperature in the moving coordinate system is given by an equation derived by D. Rosenthal and published in 1946.

The heat-sinking effect of a block is treated as a disturbance of the Rosenthal distribution: The basic premise is that if a small mass initially at the ambient temperature and fixed to the plate were to interact with the moving temperature field, it would draw, from the plate, the amount of heat necessary to raise its temperature to that prescribed for its position by the Rosenthal distribution. In the frame of reference moving with the welding heat source, the heat-sinking effect of a mass fixed to the plate is equivalent to that of a moving heat sink (equivalently, a negative heat source) of variable strength. Then by use of an equation for the effect of a moving source and the use of Ahamel's theorem, the temperature at a given position on the plate as a function of time is expressed by an integral equation as, in effect, the sum of many instantaneous sources occurring between an initial time and the present time.

The integration is performed numerically, and the maximum temperature depression in the weld zone because of the block is determined. Then the temperature field is shifted from the Rosenthal distribution by the amount of the depression, and the shift in the melting isotherm is estimated to estimate the consequent decrease in the width of the weld bead, for comparison with the width of the bead without the block.

In the experiments, aluminum blocks were bolted to aluminum plates at various positions with respect to the path of the welding torch, and bead-on-plate welds were performed. In every case, the experimental decrease in width of the weld bead near the blocks was less than that predicted by the theory. However, the theory was found to agree qualitatively with experimental trends.

This work was done by Arthur C. Nunes of **Marshall Space Flight Center** *and Paul O. Steranka, Jr., of Wichita State University. To obtain a copy of the report, "Heat Sink Effects on Weld Bead — VPPA Process," Circle 58 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 16]. Refer to MFS-27240.

Development of Composite Panels for Telescope Mirrors

Methods of design and fabrication are discussed.

A report describes a continuing program for the development of lightweight hexagonal graphite/epoxy composite panels intended to support precisely curved mirror surfaces that can be assembled into a large telescope mirror. The telescope is to be flown in orbit around the Earth to observe at wavelengths down to 30 μm. The report discusses development requirements, technical decisions, fabrication methods, measurements of properties of materials, analytical simulation, and thermal vacuum testing.

Each panel includes a face sheet that consists of layers of epoxy reinforced with graphite fibers, with fibers in the different layers oriented in different directions. The face sheet is built up on an aluminum honeycomb core. The panel is designed to bend uniformly about any lateral axis and to conform to the required curved mirror surface.

The panels are designed on the basis of a mathematical model that takes into account thermal, structural, and optical properties of the materials. They are fabricated on thermally stable ceramic tooling and cured in an autoclave according to a temperature-control algorithm that minimizes residual thermal strain.

In the initial phase of the program described in the report, a panel measuring 0.9 m and a panel measuring 0.5 m on a side were fabricated. The reflecting surface of the 0.9-m panel was found to differ from the specified surface figure by 10 μm root mean square (rms), while that of the 0.5-m panel was found to differ by 4 μm rms. It was estimated that when the temperature is reduced from room temperature to 200 K, the rms difference between the actual and specified surface figures should not exceed 10 μm and 5 μm, respectively. The areal densities of the panels are only 6.5 and 3.5 kg/m^2, respectively.

Recent developments by this program have resulted in 0.9-m panels with 2 μm rms as manufactured surfaces. The measured change of surface precision when the temperature is reduced from room to 200 K was 4 μm rms.

This work was done by Robert E. Freeland and Paul M. McElroy of Caltech and Robert D. Johnston of Hexcel Corp. for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Technical Approach for the Development of Structural Composite Mirrors," Circle 3 on the TSP Request Card.*
NPO-17895

Designing Applications for Fasteners

This book assists the engineer in the seemingly simple — but really difficult — selection of fasteners.

The *Fastener Design Manual* was written to provide design engineers with a single source that assists them in choosing appropriate fasteners for their designs. It gives practical information on the selection of fastener materials, platings, lubricants, galvanic corrosion, embrittlement by hydrogen, locking methods, inserts, washers, types and classes of threads, fatigue loading, and fastener torque. A section on design criteria discusses the derivation of torque formulas, loads on a group of fasteners, combining shear and tension loads, pullout loads for tapped holes, grip lengths, head styles, and strengths of fasteners.

The second half of the manual is devoted to the design and selection of rivets and lockbolts. Although the emphasis is on aerospace rivets and lockbolts, some industrial types are included. The manual contains 54 illustrations and 11 tables on various fasteners, components, and assemblies, so that the engineer can usually see a picture of the item being described.

This work was done by Richard T. Barrett of **Lewis Research Center**. *Further information may be found in NASA RP-1228 [N90-18740], "Fastener Design Manual."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.
LEW-15081

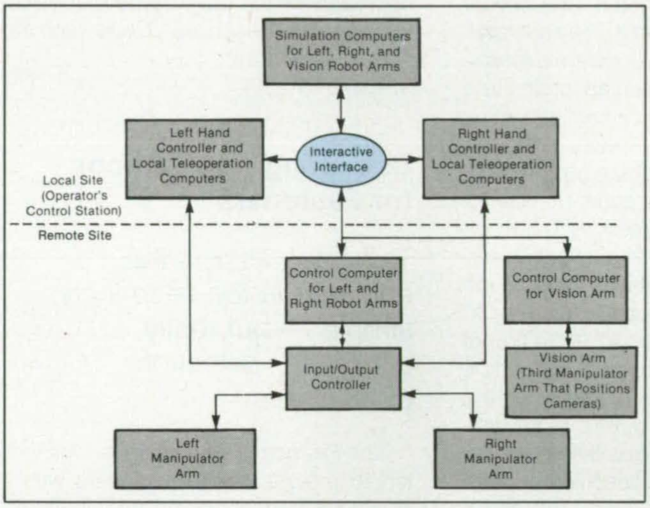
Mathematics and Information Sciences

Software for Supervisory and Shared Control of a Robot

The operator can choose various combinations of manual and automatic control.

NASA's Jet Propulsion Laboratory, Pasadena, California

The User-Macro-Interface computer program provides an interactive interface that enables a human operator to plan tasks for a multiple-arm telerobot, cause the robot to execute the tasks, and monitor the robot (see figure). UMI enables the operator to specify that the robot execute various tasks and subtasks under various mixtures of manual or automatic control. As such, it is well suited for use where the environment of the task is poorly modeled or unplanned or the task is unexpected.



UMI Provides an Interactive Interface that makes all the capabilities of a complicated, advanced multiple-arm telerobot available to a human operator, but it does so in a way that simplifies the description of robotic tasks and eases the operator's burden.

To explain the UMI concept, it is necessary to define the following specialized terms:

- Guarded motion — motion that follows a specified nominal trajectory until the task is interrupted.
- Compliant motion — motion that may nominally follow a specified trajectory but that is perturbed by sensory feedback.
- Shared control — control in which inputs from both the human operator and an autonomous control subsystem are mixed.
- Supervisory control — control in which the operator specifies the parameters for autonomous execution of the task and can stop the execution at any time.
- Task primitive — a subtask that consists of a guarded motion, a compliant motion, a grasping motion, or a teleoperation (which could be under manual or shared control).
- Execution environment — those aspects of the robotic system, other equipment, and workspace that are relevant to the task execution, to all the task primitives, and to the background monitoring function and that are specified via a number of input parameters.

UMI provides graphical status displays and a hierarchical menu that simplifies the operator's work by taking advantage of the shared-control and supervisory-control features of the robotic system. The operator interactively sets up the execution environment and specifies additional input parameters for a variety of available task primitives. Several task primitives can be stored as a task sequence for later execution. The primitives or sequences can be simulated graphically or executed by the telerobot, which includes two task-execution manipulator arms, one manipulator arm that positions cameras, and two 6-degree-of-freedom force-reflecting hand controllers used in the shared and manually-controlled-teleoperation modes of execution.

In supervisory control, the operator sets up a task primitive or a sequence of primitives, and the task is then executed autonomously. In manually controlled teleoperation, the operator specifies desired initialization parameters and controls the arms via the hand controllers. In shared control, teleoperated inputs from the hand controllers are merged during execution with inputs from user-parameterized autonomous primitives.

In all modes of operation, UMI periodically updates a display of the status of execution and enables the operator to stop execution at any time.

Safety is a primary concern in UMI. Protection against invalid or dangerous commands is achieved by executing tasks at the remote site by use of general but well tested task primitives. The operator's control station specifies inputs to these primitives. At the remote site, the input parameters to the task primitives are tested to be within bounds, and, as much as possible, the behaviors of the primitives with the given input parameters are determined to be safe or not. If a behavior is determined not to be safe, an error signal is returned to the operator's control station site.

This work was done by Paul G. Backes and Kam S. Tso of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 24 on the TSP Request Card.*

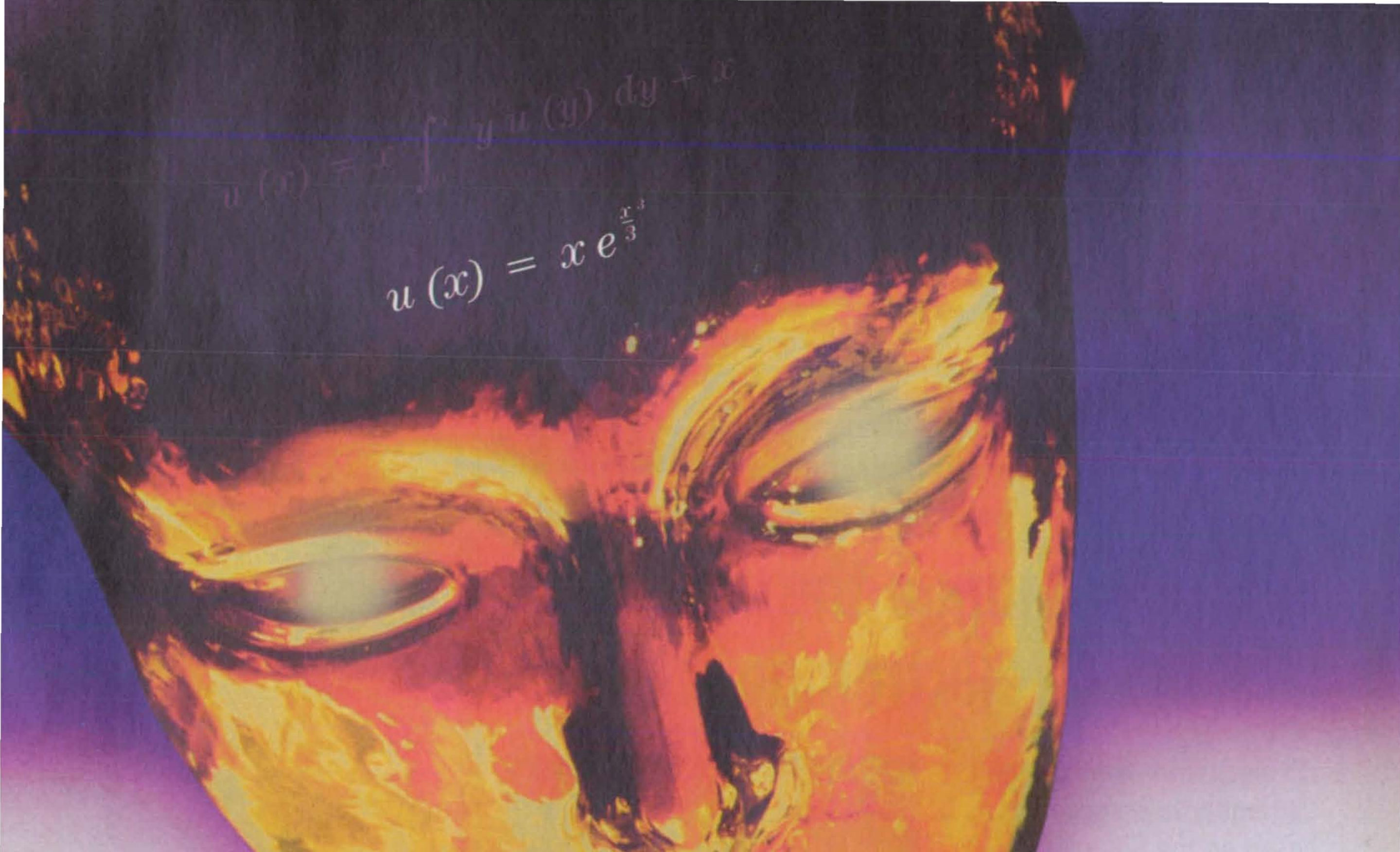
Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 16]. Refer to NPO-18116.

Estimating SAR Doppler Shifts From Homogeneous Targets

Optimal estimates make better use of returns from both stationary and moving targets.

NASA's Jet Propulsion Laboratory, Pasadena, California

An algorithm that processes some of the information in synthetic-aperture-radar (SAR) echoes from homogeneous targets yields optimal estimates of Doppler frequency shifts. In so doing, the algorithm helps in further processing to extract as much information as possible about the targets. The algorithm can be used to im-



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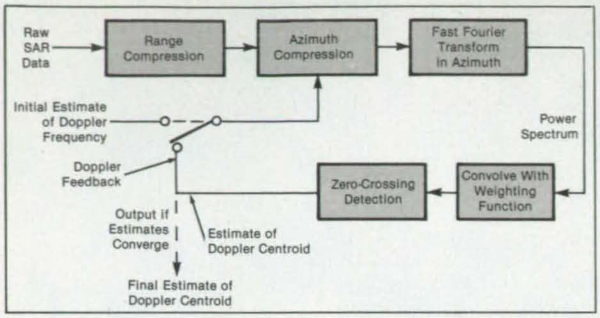


This **Iterative Algorithm** minimizes the error in the estimated Doppler centroid of SAR echoes from a homogeneous target area.

prove radiometric calibrations, to estimate the direction of the radar antenna, and to determine the speeds of moving targets more accurately. The algorithm could be helpful in measurements of the speeds of ocean currents and of wind shears at airports.

The Doppler frequency shift and the rate of change of Doppler frequency shift ("Doppler rate," for short) constitute a complete set of parameters that characterize the history of the distance (range) between the radar apparatus and a target. Accurate values of these parameters are necessary to obtain SAR images of high quality. Typically, the estimated Doppler parameters are based on the Doppler centroid, which, for the purposes of this method, is regarded as the Doppler frequency at the instantaneous energy centroid of the radar beam. An error in the estimated Doppler centroid degrades both the signal-to-noise ratio (SNR) and the signal-to-azimuth-ambiguity ratio (SAAR). An error in the estimated Doppler rate broadens the main lobe and increases the side lobe of the SAR impulse-response function.

In the derivation of the algorithm, the target area (e.g., the surface of the ocean) is considered to be homogeneous in a statistical sense: it is rough and mathematically modeled as being covered with many scattering sites, the positions and radar reflectivities of which are distributed statistically. The derivation also involves simplifying assumptions about the scattering properties of the target (e.g., that it is isotropic) and about the characteristics of typical SAR signals. Analysis of the resulting mathematical model of the SAR echoes leads to the following iterative procedure for optimal estimation of the Doppler centroid (see figure):

1. The basic inputs are the raw SAR data and the initial estimates of the Doppler parameters based on the known motion of the radar apparatus.
2. Generate a complex (amplitude and phase) SAR image by first compressing the raw SAR data in range, then compressing them in azimuth using the initial Doppler estimates.
3. Fast-Fourier-transform the complex SAR image in the azimuth direction and use the transform to compute the power spectral density of each azimuth line.
4. Convolve the power spectrum with a linear-estimator weighting function. The frequency bin that minimizes the value of the convolution becomes the new Doppler estimate.
5. Repeat the procedure to refine the estimate until the difference between two consecutive estimates lies within a preset tolerance.

This algorithm is optimal in the sense that it attains the Cramer–Rao bound, which is a theoretical lower bound on the variance of the error. The algorithm has proven successful in tests on SAR imagery from SEASAT and from the Shuttle Image Radar B (SIR-B). The algorithm can be generalized for use in sea altimeters and radar-echo trackers.

This work was done by Michael Y. Jin and C. Y. Chang of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 89 on the TSP Request Card.* *NPO-17869*

Estimating SAR Doppler Shifts From Quasi-Homogeneous Targets

A linear-estimator subalgorithm is optimized for the local terrain.

NASA's Jet Propulsion Laboratory, Pasadena, California

An algorithm processes some of the information in synthetic-aperture-radar echoes from quasi-homogeneous targets, yielding optimal estimates of Doppler frequency shifts. The algorithm differs from the one described in the preceding article, "Estimating SAR Doppler Shifts From Homogeneous Targets" (NPO-17869), though it offers similar advantages for the measurements of wind shears and the speeds of ocean currents.

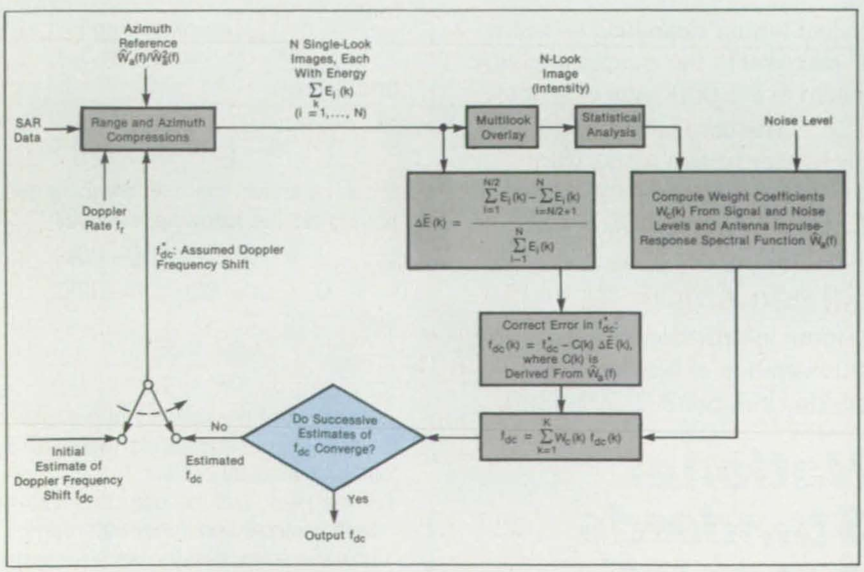
The derivation of this algorithm involves some of the same terminology and simplifying assumptions described in the preceding article. However, in this case, the target area is considered to be quasi-homogeneous in the sense that it consists of a patchwork of subareas, each of which is a homogeneous target that differs from its neighbors. This assumption is more realistic than is the assumption of homogeneity.

The steps of the algorithm can be summarized as two overall steps: the first is to obtain a set of optimal preliminary estimates of Doppler centroids from the subareas; the second is to obtain an optimal final estimate of the Doppler centroid f_{dc}. On the basis of a maximum-likelihood criterion, the optimal final estimate is a weighted sum of the preliminary estimates in which each weight is inversely proportional to the variance of each preliminary estimate.

The algorithm can be developed from a frequency-domain approach, but a time-domain approach is easier to implement. In the latter approach, one begins by processing the SAR echo response into N independent single-look images, each with $1/N$ of the total processing bandwidth, where N is an even number and the spectra of these images are consecutive. These single-look images are weighted in the frequency domain, with $\hat{W}_a'(f)/\hat{W}_a^2(f)$, where f is a Doppler frequency shift, $\hat{W}_a(f)$ is an impulse-response spectral function related to the response of the antenna in the time domain, and $\hat{W}_a'(f)$ is the derivative of $\hat{W}_a(f)$ with respect to f, by incorporating this weight function in the reference function. Then $\Delta\bar{E}$ is computed according to the equation shown in the figure and is used to compute the correction to the assumed Doppler frequency. This procedure is repeated until the difference of two successive Doppler centroid estimates is less than a predetermined error bound.

In this algorithm, it is not necessary to determine the boundaries of the subareas. Instead, one uses the intensity histogram of the multilook image. The procedure includes the following: The multilook summation is performed to generate the N-look image (to reduce speckle uncertainty) and its histogram. The intensity range covering more than 99 percent of the picture elements total image pixels is divided into K intensity intervals. Preliminary Doppler estimates are then obtained from subsets of picture elements that lie in the same intensity interval.

This work was done by Michael Y. Jin of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 128 on the TSP Request Card.*
NPO-17905



This **Iterative Algorithm** minimizes the error in the estimated Doppler centroid of SAR echoes from a quasi-homogeneous target area.

R-Parameterization of Linear Feedback Systems

Necessary and sufficient conditions for stability can be examined via Q and R.

Ames Research Center, Moffett Field, California

A classification of all the compensators that stabilize a given plant in a linear, time-invariant, multiple-input/multiple-output feedback system has been developed. This classification, along with the necessary and sufficient conditions for the stability of the system, is achieved through the introduction of the R-parameterization, which is dual of the previously developed Q-parameterization. The classification is made according to the stability conditions of the compensators and the plant by themselves, while the necessary and sufficient conditions are based on the stabilities of Q and R by themselves.

The system (see figure) receives a command input $\mathbf{u}_1$. The output $\mathbf{y}_2$ of the plant is subtracted from the command input, and the resulting error signal $\mathbf{e}_1$ is fed to the compensator. A disturbance input $\mathbf{u}_2$ is added to the output $\mathbf{y}_1$ of the compensator, and the resulting signal $\mathbf{e}_2$ is fed into the plant. The transfer functions of the plant and compensator are denoted by $P(s)$ and $C(s)$, respectively, where s is the Laplace-transform complex frequency. It is assumed that (1) $C(s)$ and $P(s)$ are in general proper, (2) neither the plant nor the compensator has unstable hidden modes, and (3) the mathematical model of the system is well posed. The transfer matrices from $\mathbf{u}$ to $\mathbf{y}$ and from $\mathbf{u}$ to $\mathbf{e}$ are given by

$$H_{\mathbf{yu}} = \begin{bmatrix} C(I+PC)^{-1} & -CP(I+CP)^{-1} \\ PC(I+PC)^{-1} & P(I+CP)^{-1} \end{bmatrix}$$

and

$$H_{\mathbf{eu}} = \begin{bmatrix} (I+PC)^{-1} & -P(I+CP)^{-1} \\ C(I+PC)^{-1} & (I+CP)^{-1} \end{bmatrix},$$

respectively.

The Q-parameterization involves the use of the matrix Q, which is the transfer function from $\mathbf{u}_1$ to $\mathbf{y}_1$ or from $\mathbf{u}_1$ to $\mathbf{e}_2$. The transfer matrices can be expressed as

$$Q = C(I+PC)^{-1} = (I+CP)^{-1}\,C,$$

and

$$C = Q(I-PC)^{-1} = (I-QP)^{-1}\,Q,$$

$$H_{\mathbf{yu}} = \begin{bmatrix} Q & -QP \\ PQ & P(I-QP) \end{bmatrix},$$

$$H_{\mathbf{eu}} = \begin{bmatrix} I-PQ & -P(I-QP) \\ Q & I-QP \end{bmatrix}.$$

The new R-parameterization involves the use of the transfer matrix R, which relates the output $\mathbf{y}_2$ of the plant to the disturbance input $\mathbf{u}_2$. R is expressed as

$$R = P(I+CP)^{-1} = (I+PC)^{-1}\,P$$

from which it can be shown that

$$P = R(I-CR)^{-1} = (I-RC)^{-1}\,R.$$

Then

$$H_{\mathbf{yu}} = \begin{bmatrix} C(I-RC) & -CR \\ RC & R \end{bmatrix}$$

and

$$H_{\mathbf{eu}} = \begin{bmatrix} I-RC & -R \\ C(I-RC) & I-CR \end{bmatrix}$$

It can be shown that the foregoing equations yield the following identities:

$$R = P(I-QP) = (I-PQ)P,$$

$$Q = C(I-RC) = (I-CR)C,$$

and

$$PQ = RC,$$

$$QP = CR$$

Analysis of the stability of the system in the R-parameterization leads to the following stability criteria:

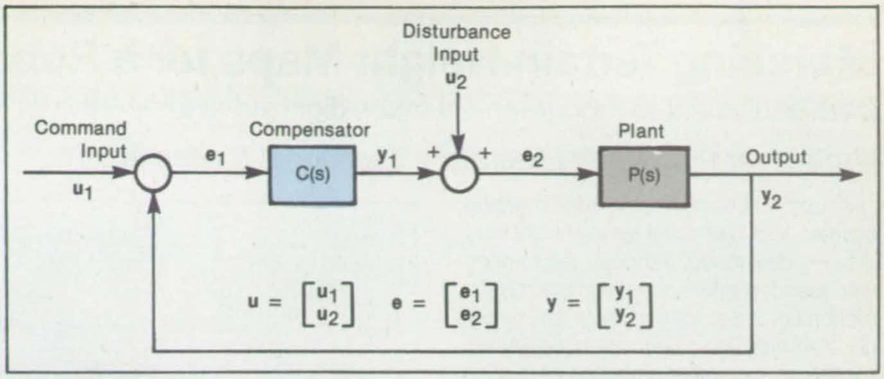
1. If the plant and the compensators are both unstable and if they have common unstable poles, then the feedback system is stable if and only if (a) Q and R are stable and (b) $(I-4RQ)^{1/2}$ and $(I-4QR)^{1/2}$ are stable.

2. If the plant and the compensators are both unstable but they do not have common unstable poles, then the feedback system is stable if and only if both Q and R are stable.
3. If the plant is unstable but the compensators are stable, then the feedback system is stable if and only if R is stable.
4. If the plant is stable but the compensators are unstable, then the feedback system is stable if and only if Q is stable.
5. If the plant and the compensators are both stable, then the feedback system is stable if and only if either Q or R is stable.

This work was done by Robert T. N. Chen of **Ames Research Center**. *Further information may be found in NASA TM-101066 [N89-16844], "R-Parameterization and Its Role in Classification of Linear Multivariable Feedback Systems."*

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

ARC-12369



This **Feedback System** is amenable to analysis via the Q- and R-parameterizations.

Intelligent Computerized Training System

An expert system acts like an experienced, dedicated human trainer.

Lyndon B. Johnson Space Center, Houston, Texas

An intelligent computer-aided training system gives trainees much of the same experience that would be gained from the best on-the-job training. The automated system is designed to emulate the behavior of an experienced teacher devoting full time and attention to training a novice. Like such a teacher, the system proposes challenging training scenarios, monitors and evaluates the trainee's actions, makes meaningful comments in response to the trainee's errors, responds to the trainee's requests for information, gives hints when appropriate, and remembers the trainee's strengths and weaknesses so that it can design suitable exercises.

The system is used to train flight-dynamics officers in deploying satellites from the Space Shuttle. The system is, however, a general-purpose one. It can be adapted to training for a variety of tasks and situations, simply by modifying one or at most two of its five modules. The system thus will help to ensure a continuous supply of trained specialists despite the scarcity of experienced and skilled human trainers.

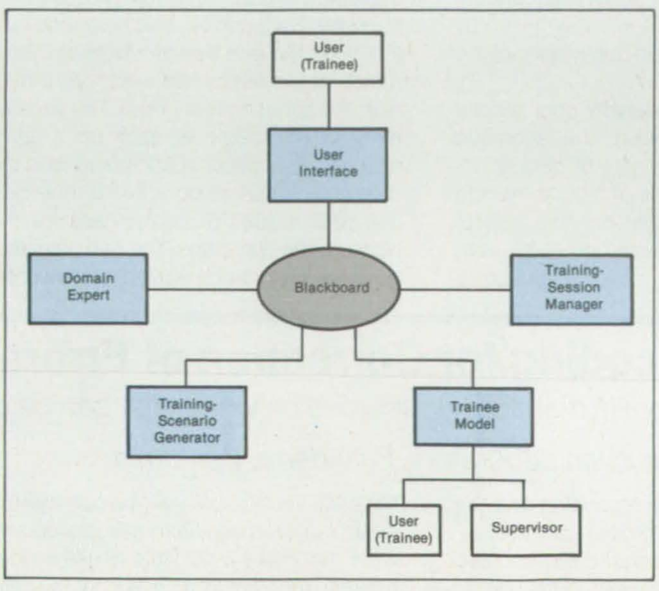
The system comprises the following modules (see figure).

- The user interface — usually a computer terminal — gives the trainee access to the same information that would be available in performing the actual task and enables the trainee to give commands and communicate with the training system.
- The domain expert is an expert system that carries out the task on its own, using the same information available to the trainee. The expert-system software also knows the errors commonly made by trainees. The domain expert can therefore detect an error, diagnose its nature, and provide information for the training system to correct the misconception or lack of knowledge that led the trainee to commit the error.
- The training-session manager compares the assertions of the domain expert with the actions of the trainee and generates error messages appropriate to the stage of development of the trainee. For example, a first-time user may need a lengthy explanation, while an experienced trainee may have momentarily forgotten a procedure and needs only a terse reminder.
- The trainee model stores information from the training-session manager about the trainee's actions. For the current training session, the trainee model contains a complete record of correct and incorrect actions. At the end of a training session, the model updates a summary of the trainee's progress.
- The training-scenario generator uses a data base of task problems to develop unique exercises for the trainee. It adapts the exercises to the progress of the trainee and to the particular errors to which the trainee is prone, giving the trainee extra practice where it is needed.

The modules communicate through a common data base, called a "blackboard." The training-session manager, the trainee model, and the training-scenario generator are general modules in the sense that they are not limited to a particular task. The user interface may require some modification for new tasks. The domain expert must be developed anew for each training task.

This work was done by Lui Wang and Paul Baffes of **Johnson Space Center**, *R. Bowen Loftin of the University of Houston, and Grace C. Hua of Computer Science Corp. For further information, Circle 28 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center [see page 16]. Refer to MSC-21381.



Five Modules Communicate through a so-called blackboard, a common base of facts. Modules look to the blackboard for facts to activate their built-in sets of rules. A human training supervisor can query the system for data on each trainee.

Matching Terrain-Height Maps for a Robotic Vehicle

Data equivalent to topographical maps digitized at different intervals are merged.

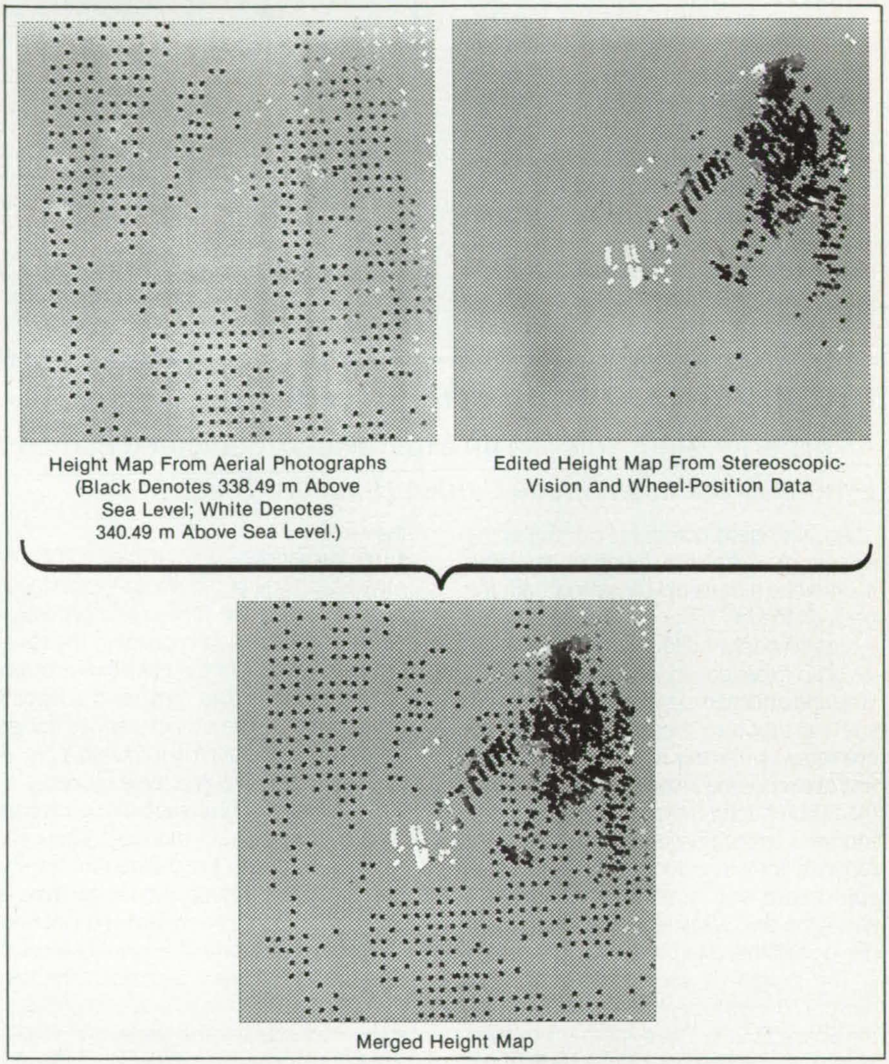
NASA's Jet Propulsion Laboratory, Pasadena, California

A computational method for merging coarser- and finer-scale terrain-height data is being developed. Although the method was intended initially for use in guiding the motions of the proposed Mars rover vehicle, the underlying concept is clearly applicable to such other problems as guiding semiautonomous robotic land vehicles in general and merging different topographical maps that may contain partly conflicting and/or partly unreliable data on the same terrain.

The basic idea is to refine the estimate of the position of the vehicle by matching two sets of data that are equivalent to two topographical maps of different scales (see figure). One set includes the terrain-height-vs.-horizontal-position data estimated from the outputs of its stereoscopic vision subsystem and from the result of a dead-reckoning calculation based on the outputs of its wheel-position sensors. The terrain-height data points in this set can be located at unequal horizontal intervals. The other set consists of more nearly conventional topographical data derived from a camera in orbit around Mars (or from, say, aerial photography in a terrestrial application).

Because of the uncertainty in matching the local map generated by the vehicle systems with the most global map generated remotely in advance (e.g., made by telescope on Earth in advance of the exploration of Mars or made by aerial photography of a local area on Earth), it could be desirable to use a hierarchy of merged maps, with a more complete merging of new local, old local, and global data. However, in the present experimental terrestrial version, only one match of new local data with global data from aerial photographs is performed for each new view taken by the stereoscopic vision subsystem of the vehicle (see figure).

Because of the relatively poor resolution of the aerial imagery, the technique for matching the two sets of data is designed to make full use of the information in them. Assuming that the two sets of data are at least oriented correctly with respect to each other, the terrain-matching algorithm steps in equal increments through a 3×3 grid of vehicle positions until it finds the one that produces the best match of the vehicle-derived height map with the aerial-imagery map. The assessment of the match at each point takes quantitative account of uncertainties in the data (expressed as covariance matrices) and probabilities of correctness for the points in the two maps. The grid point that gives the best match is used as the center of another 3×3 search at half the previous increment. This procedure is repeated, doubling the spatial resolution each time, until the finest desired horizontal resolution is reached.



Terrain-Height Data from aerial photographs are merged with similar data on a finer scale estimated from stereoscopic-vision and wheel-sensor outputs on a robotic vehicle.

This work was done by Donald B. Gennery of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 61 on the TSP Request Card. NPO-17856*

Matrix Encoding for Correction of Errors

Some burst errors in digital data recorded on video tape can be corrected.

NASA's Jet Propulsion Laboratory, Pasadena, California

A method of matrix encoding and the associated decoding provides for the correction of errors in digital data recorded on magnetic tape. The method is intended specifically for use with a commercial control circuit board and associated software that make it possible to use a video cassette recorder as a backup for the hard-disk memory of a personal computer. In this equipment, errors in recording and playback tend to occur in bursts that can span several contiguous bytes of data. The controller detects, but does not correct, such errors.

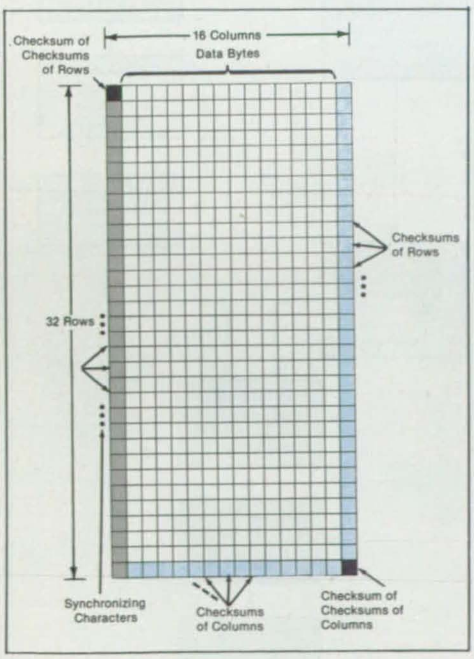
The encoding/decoding method described here can correct bursts of up to 15 consecutive 8-bit bytes (120 bits) of erroneous or missing data, provided that only one such burst occurs in each block of 512 bytes. The method is implemented in software, requiring no changes in the existing hardware. The decoding scheme is recursive; that is, it provides for potentially many different attempts to correct the data — something that most hardware correction schemes do not do.

During recording onto the video tape, check bytes are recorded along with data bytes. The check bytes are interspersed with the data bytes to reduce the probability of corrupting more than one check byte at a time. Seventy-eight of the 512 bytes in each block are used in this way, reducing the available data storage by 15 percent.

Within each block, the data and check bytes can be regarded as being arranged in chronological order into 32 rows and 16 columns that define a matrix (see figure). At the beginning of each row except the first, there is a check byte that serves as a synchronizing character; it consists of all "one" bits (chosen because the controller circuit board is more susceptible to errors when there are long strings of "zero" bits). At the end of each row is a character that contains the checksum of all other characters (except the synchronizing character) in that row. Every character at every 1 of the 14 data-byte positions in the last row contains the checksum of all the other characters in its column. Two other checksum characters help ensure the integrity of the checksum characters themselves: The first character of the first row contains a checksum of all except the last place in the last column (the checksum characters for each row). The last character of the last row contains the checksum of all except the first and last places in the last row (the checksum characters for each column).

This simple 8-bit sumcheck scheme is not the most rigorous, but it offers the advantages of requiring very little computational time, requiring a small amount of space in the matrix, and making it possible to determine what any single missing or corrupted character or string of characters should have been in any row or column. The two redundant sumchecks of each data character (both rows and columns) usually make it possible to determine which character in a row or column has to be corrected. By checksumming the checksums, one can sometimes even correct the checksums if one can determine which one of them is erroneous.

The decoding program first tries to determine whether the data are aligned by inspecting the synchronizing characters and checksums. If the data are not aligned (i.e., there is a total dropout of one or more characters), it attempts to realign the data. If this fails, no further attempts are made to correct data.



Check Bytes that serve as synchronizing and checksum characters are interspersed among the data, and the total of 512 bytes in each block are arranged in a matrix like this one.

Next, the checksums are examined, and attempts are made to correct the erroneous ones. Then a pass is made over the data to try to correct them. Occasionally, everything is found to be correct even though the controller has indicated an error. In such a case, the internal code used by the controller is probably corrupted.

This work was done by Ronald S. Dotson of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 93 on the TSP Request Card.*

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

Edward Ansell
Director of Patents and Licensing
Mail Stop 305-6
California Institute of Technology
1201 East California Boulevard
Pasadena, CA 91125

Refer to NPO-17834., volume and number of this NASA Tech Briefs *issue, and the page number.*

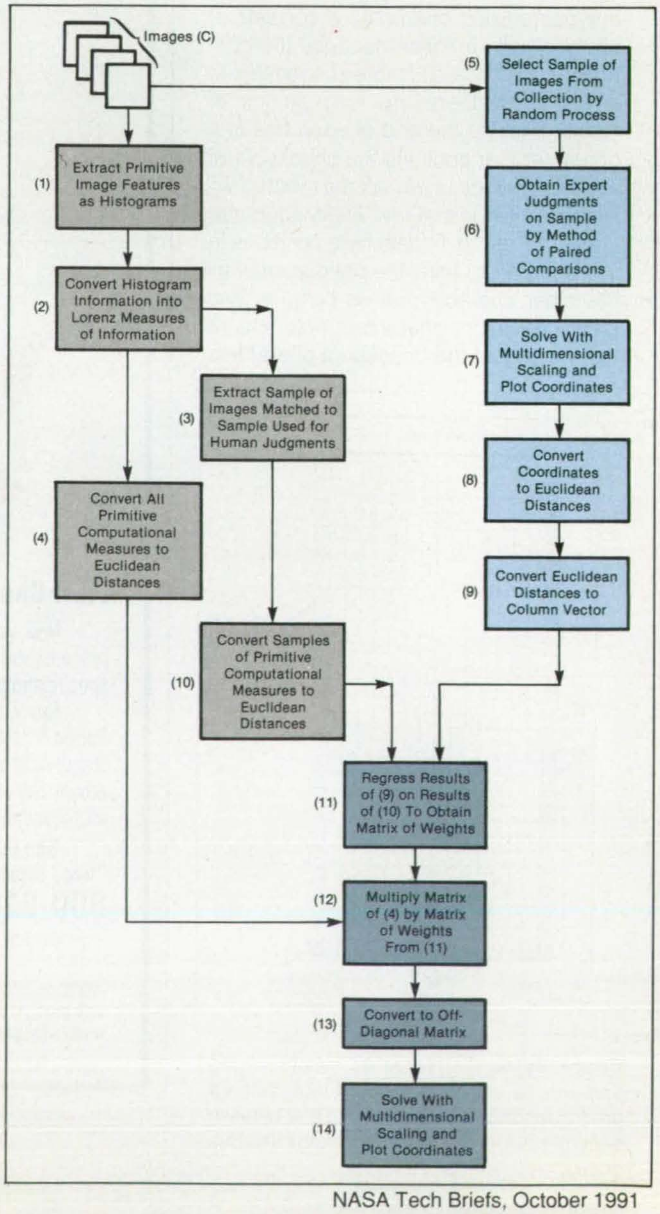
Human Expertise Helps Computer Classify Images

The computational abstraction of image data is related to human classification via a mapping.

Lyndon B. Johnson Space Center, Houston, Texas

The two-domain method of computational classification of images requires less computation than do other methods for the computational recognition, matching, or classification of images or patterns. It does not require explicit computational matching of features, and it incorporates human expertise without requiring the translation of the mental processes of classification into language comprehensible to a computer. The method was conceived to "train" a computer to analyze photomicrographs of microscope-slide specimens of leucocytes from human peripheral blood in such a way as to distinguish between specimens from healthy and specimens from traumatized patients.

As its name implies, the two-domain method involves the melding of analyses, in two domains, of the images in a collection (see figure). Let the collection be denoted as *C*. In one domain, a human expert examines all possible pairs of images in *C* and intuitively assigns a quantitative index of dissimilarity to every pair. These indices are processed in an abstract *n*-dimensional space by conventional multidimensional-scaling techniques to obtain a real-valued ordering of the images according to their dissimilarities. Let this ordering be denoted as Φ. In following this ordering procedure, it is unnecessary to know explicitly what features the expert examines or what rules the expert uses in judging dissimilarities: all aspects of the mental process of classification are already implicit in Φ.



The **Two-Domain Method** incorporates the judgment of a human expert into a quantitative analysis of selected features of images to "train" a computer to classify images.

In the other domain, the images in *C* are digitized and processed to extract a number of general primitive features rendered as histograms. In the original leucocyte-image application, the following six features are extracted: gray levels, intensities of edges, slopes of edges, lengths of lines, linear distances from the origin, and angular distances from the origin. Other features or numbers of features could be used. The histograms for each image are converted into Lorenz measures (which are based on statistics) of the information in them, and the Euclidean distances among all pairs over all such measures are computed to produce a matrix. This matrix, denoted as *M*, embodies the result of the primitive computational analysis.

The complicated problem of the classification of images then becomes one of finding a mapping from Φ to *M* under the assumption that the mapping can be used to classify images other than those in *C*. The process of finding the mapping begins with the extraction of the original measures from the primitive computational analyses of each pair of images judged by the human expert. Then Euclidean distances for both primitive computational measures and intuitively assigned dissimilarity indices are computed. Next, weights are derived via a multiple-regression calculation in which the Euclidean distances from the product of the multidimensional-scaling analysis of the human judgments are the dependent variables and the Euclidean distances among images according to the primitive computational analyses of them are the independent variables. The predicted values are resubmitted to the multidimensional-scaling process, and the final ordering, Φ', is produced in an *n*-dimenional space.

The two-domain method is general enough to be applicable to problems other than the classification of the leucocyte-slide images. For example, it could be used to search large data bases in which images are represented as feature components. In an application of this kind, the method would be applied iteratively to classes of images by segregating and mapping smaller classes of imagery. Such an application could be critical in the identification of desired sets of images that cannot be described linguistically because of intellectual or economic constraints.

This work was done by Mark E. Rorvig of **Johnson Space Center**. *For further information, Circle 72 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 16]. Refer to MSC-21737.

Relative-Error-Covariance Algorithms

Consistencies and inconsistencies between estimated states of systems can be quantified.

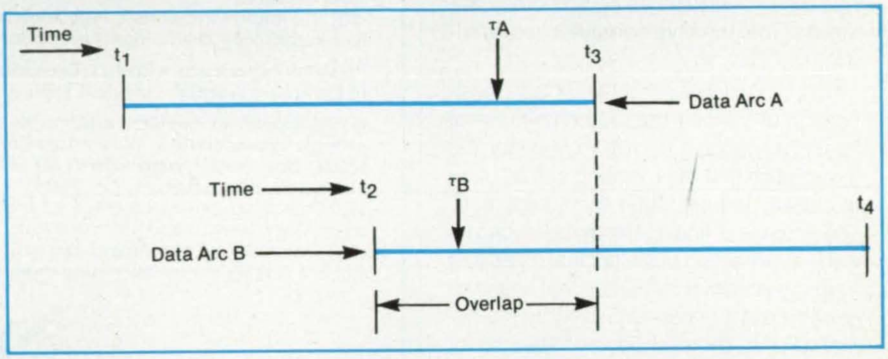
NASA's Jet Propulsion Laboratory, Pasadena, California

Two algorithms compute the error covariance of the difference between optimal estimates, based on data acquired during overlapping or disjoint intervals, of the state of a discrete linear system. This covariance, called the "relative-error covariance," provides a quantitative measure of the mutual consistency or inconsistency of the estimates of the states. The relative-error-covariance concept can be applied, for example, to (1) determine the degree of correlation between trajectories calculated from two overlapping sets of measurements (see figure) and (2) construct a real-time test of the consistency of state estimates based upon recently acquired data.

A covariance matrix, P, can be factored into the form $P = UDU^T$, where U is an upper triangular matrix with ones on the diagonals and D is a diagonal matrix with nonnegative entries. One of the algorithms is based on postprocessing of Kalman-filter gain profiles to compute sequentially the U and D factors of the covariance of the relative error. This algorithm can be used to compute the relative-error covariance for either filtered or smoothed estimates of the state of a system.

The other algorithm, based on previous square-root-information-filter (SRIF) algorithms, can be applied to relative-error analysis of least-squares parameter-estimation problems. This algorithm is restricted to nonstochastic state models, and for such problems it is computationally more efficient and more flexible than the Kalman-gain algorithm. The SRIF algorithm is extremely efficient for analyzing variations in a-priori statistics and variations of the dimension of the state vector. However, the Kalman-gain algorithm is more general and can generate relative-error covariances when the state dynamics are driven by process noise.

This work was done by Gerald J. Bierman and Peter J. Wolff of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, Circle 98 on the TSP Request Card.* NPO-17956



Overlapping Data Arcs — for example, data from overlapping portions of a trajectory — are used to generate optimal estimates of the trajectory at times τ_A and τ_B. Relative-error-covariance analysis provides a measure of the correlation between the two estimates.

Life Sciences

Hardware, Techniques, and Processes

Portable Water-Saving Shower for Emergencies

A stowable compact unit would spray from many directions.

Marshall Space Flight Center, Alabama

A proposed portable emergency fogging shower would rinse harmful chemicals from a person. Intended for use on the Space Station, it could be used in laboratories and factories on Earth. It might even be used for routine shower bathing in areas with limited water supplies.

The shower would include a double-walled transparent, approximately cylindrical curtain containing sets of interior nozzles on regularly spaced loops (see figure). The shower would be sealed at the top and bottom. The victim of contamination would enter through a longitudinal zippered opening. A pressurized mixture of air and water would flow through selected nozzles, creating a foglike spray that would scrub contaminants from the victim's skin and clothing.

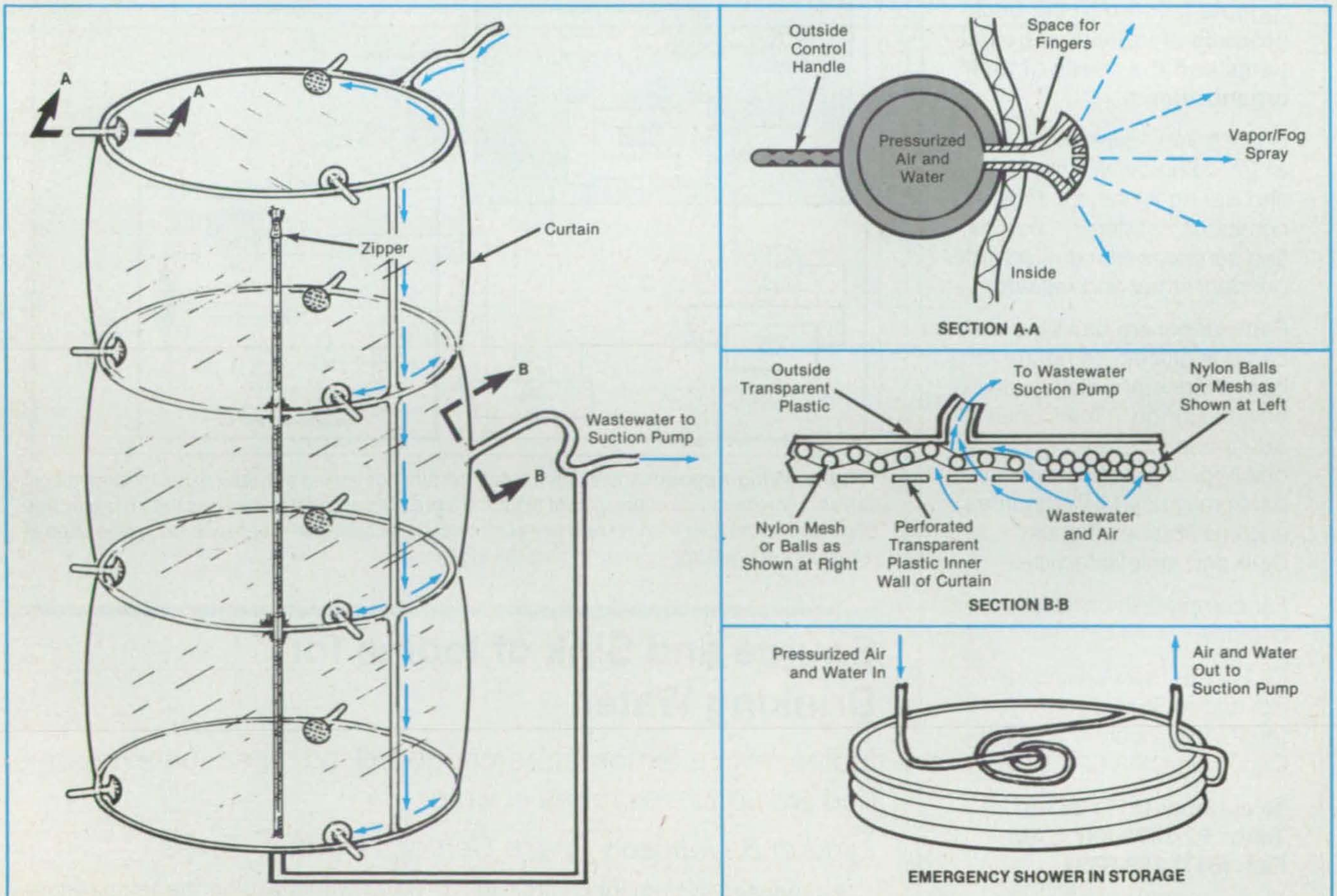
Other persons assisting the victim from outside the shower would direct flow to affected areas by selectively activating nozzles via handles that protrude through the curtain; thus, the consumption of water would be kept to a minimum.

A flexible hose would carry the mixture of pressurized air and water to a network of longitudinal and circumferential tubes in the curtain. The wastewater would leave through perforations in the inner wall of the curtain, flow into a collection tube, and be removed by suction. An inner layer of nylon mesh or nylon balls would keep the inner and outer walls separated despite the suction.

The shower would be collapsible to a disk for storage when the air-and-water supply is turned off. It would open to its full length quickly when the supply was turned on and pressurized the network of tubes.

This work was done by Francis E. Grenier of **Marshall Space Flight Center**. *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 16]. Refer to MFS-28459.



The **Emergency Fogger** would spray cleansing air/water mist from individually controllable nozzles.

Apparatus Circulates Sterilizing Gas

Only the parts to be sterilized are exposed to ethylene oxide.

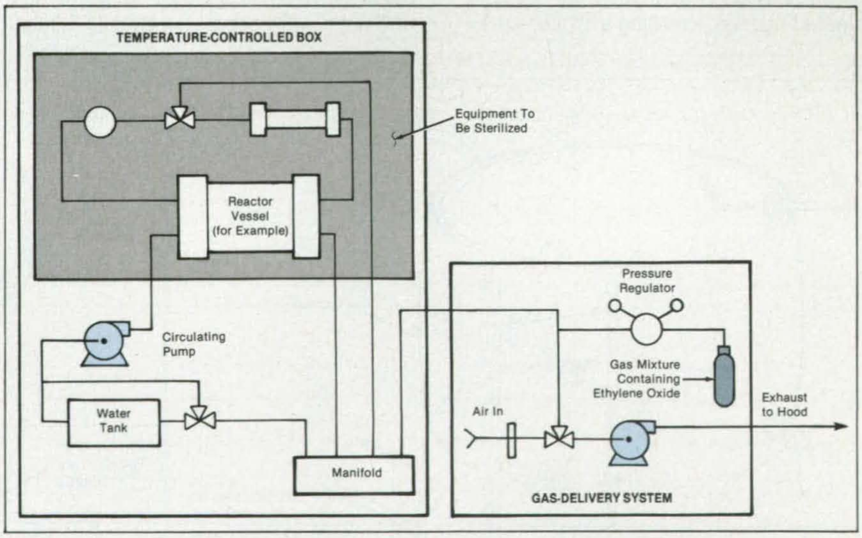
Lyndon B. Johnson Space Center, Houston, Texas

An apparatus circulates a sterilizing gas containing ethylene oxide and a chlorofluorocarbon through laboratory or medical equipment. It is particularly suitable for sterilization of the interiors of bioreactors, heart/lung machines, dialyzers, or other equipment that includes complicated tubing. The apparatus confines the sterilizing gas, circulating it only through the parts to be treated. This is an important advantage for three reasons: (1) it minimizes the exposure of personnel to ethylene oxide, which is toxic; (2) it maintains a sterilizing concentration of gas in restricted places, where the volume of the gas is small in relation to the areas of surfaces on which microbes reside; and (3) equipment not to be treated is not subjected to unwanted side effects of ethylene oxide or the products of its decomposition.

The apparatus consists of two units (see figure). One unit delivers the ethylene oxide/chlorofluorocarbon gas mixture and removes the gas after treatment. The other unit warms, humidifies, and circulates the gas through the equipment to be treated. The apparatus and the equipment to be treated are placed in a fume hood.

The sterilization process is partly cyclic. First, the gas, at a relative humidity of 30 to 50 percent, is circulated through the equipment to be sterilized. Any valves in the equipment are operated to assure thorough exposure of the interior surfaces to the gas. After the sterilization period, the system is evacuated to remove the sterilizing gas, and then sterile air is admitted. The cycle is then repeated at 4-minute intervals for 2 hours or more. If the equipment to be treated is a bioreactor, after the sterilization-gas treatment, it is washed with slightly acidic water overnight, then rinsed with neutral water. The process, taken as a whole, provides reliable sterilization with negligible residual toxicity from ethylene oxide.

This work was done by John H. Cross and Ray P. Schwarz of KRUG International for **Johnson Space Center**. *For further information, Circle 23 on the TSP Request Card.*
MSC-21552



The **Sterilizing Apparatus** circulates a gas mixture containing ethylene oxide through tubes, valves, and other parts of equipment to be sterilized. The apparatus contains the toxic ethylene oxide and is cheaper than an ordinary commercial gas sterilizer is because the gas is used at relatively low pressure—about 10 psig (69 kPa gauge).

Source and Sink of Iodine for Drinking Water

Iodine from a temperature-controlled iodinated ion-exchange bed would kill microbes in water.

Lyndon B. Johnson Space Center, Houston, Texas

A proposed system for controlling the concentration of iodine in potable water would exploit the temperature dependence of the equilibrium partition of iodine between solution in water and residence in an ion-exchange resin. The system would be used to maintain the concentration of iodine sufficient to kill harmful microbes, but not so great as to make the water unpalatable. The system would require little attention, yet would control the concentration of iodine more precisely than do iodination and deiodination by manual techniques. Conceived for use aboard a spacecraft, the system may have terrestrial applications in regions where water must be kept potable, resupply is difficult, and the system must operate largely unattended.

At present, manual injection is the only procedure for adding iodine at will to spacecraft water systems. Moreover, although iodine can be removed by use of activated-charcoal filters, this technique does not lend itself to lowering the concentration of iodine to a specified level.

The proposed system would include a temperature-controlled iodinated ion-exchange bed through which water from a potable-water storage tank would be circulated by a pump. By controlling the temperature of the influent water, one would control the temperature of the ion-exchange resin(R) of the bed. The temperature of the bed would, in turn, determine the concentration of iodine in the effluent water via the equilibrium chemical reaction

$$RI_3 \rightleftharpoons RI + I_2$$

This reaction would be independent of the iodine concentration in the influent water, depending only on the temperature. The higher the temperature, the more the equilibrium would lie to the right and the greater the concentration of iodine in the effluent water would be.

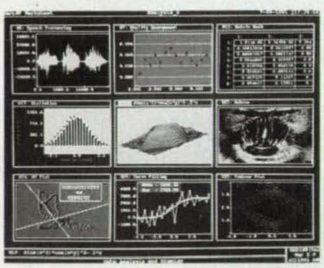
The temperature of the influent water and bed could be controlled by a heat exchanger immediately upstream of the iodinated ion-exchange bed. The heat exchanger could be of conventional design or based on the Peltier effect, in which heat is transported to or from a junction of two dissimilar metals by electric current. A conventional heat exchanger would be relatively energy-efficient and, if of the right size, could heat or cool the influent water quickly. A Peltier-effect heat exchanger of similar capacity would require more energy to operate but would have no fluid loops (other than that of the influent water) and no moving parts.

The proposed system could maintain the concentration of iodine at 2 to 5 parts per million, which is considered optimal, but could "shock" the system with a concentration of 15 parts per million or more to overcome high contamination. The system could also decrease the concentration below 2 parts per million to maintain some biocide while making the water more palatable. Even if not automated, the system would reduce the amount of attention required. Instead of manually calculating the required amount of iodine to be added and then manually injecting it, an operator would only have to set the concentration of iodine by setting a thermostat calibrated in the concentration equivalent of temperature according to the equilibrium chemical reaction. The system would require a minimum amount of expendable material because iodine could be removed and stored in the resin for later use.

This work was done by Richard L. Sauer of **Johnson Space Center**, *and David T. Flanagan and Randall E. Gibbons of Krug International. For further information, Circle 154 on the TSP Request Card.*
MSC-21739

New on the Market

The Vitrodyne V-200 tabletop **materials tester** from Liveco Biomechanical Instruments, Burlington, VT, is designed to handle samples too small for conventional apparatus. It can be used to determine the stiffness and elastic modulus of fibers, films, and catheters; the viscoelastic characteristics of foods and polymers; the tensile strength of adhesives, hydrogels, and tissue explants; the spring rate of polymer coils; and the flexural properties of sensor leads. Features include a custom software package that facilitates test setup and data handling, and a laser scan micrometer allowing measurement of lateral displacements such as Poisson's ratio.
Circle Reader Action Number 782.

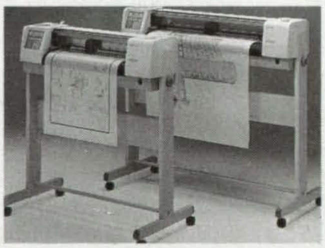


DADiSP **productivity software** from DSP Development Corp., Cambridge, MA, allows engineers and scientists to manipulate and analyze large amounts of data in both graphical and tabular formats. The latest release, version 3.0, includes hundreds of data reduction, mathematical, statistical, Fourier transform, peak analysis, and graphical tools. It also features an enhanced user interface, a set of matrix math and statistical functions, and powerful 3D and 4D plotting capabilities. DADiSP operates under X Windows on workstations from Sun, IBM, DEC, Hewlett-Packard, and Concurrent, as well as IBM PC/AT, PS/2, and compatible PCs.
Circle Reader Action Number 800.

Alias Research Inc., Toronto, Canada, has introduced Alias Sketch!™, a **freeform 3D illustration and design tool**. Its "3D pencil" allows users to sketch curves anywhere in 3D space. For more precise curves, Alias Sketch! features the Curve-o-Matic™, which provides the capability to automatically draw accurate 3D curves consisting of any combination of spline curves, arcs, or straight lines. Operable on any Macintosh II, the software permits organization and storage of frequently-used models, lighting conditions, materials, colors, textures, and points of view for future use.
Circle Reader Action Number 798.

A new low-cost **scan converter** from PE Photron, San Jose, CA, uses 24-bit internal processing to convert the RGB output from a computer display into standard video signals in real time. These signals can be connected to videotape and laser videodisc recorders, as well as standard television monitors and projection systems. No special software or hardware modifications are required to install and use the converter, which automatically locks to any computer display with a horizontal scan rate of 24 to 85 kHz, including PCs, high-resolution workstations, and supercomputers.
Circle Reader Action Number 786.

Mutoh America Inc., Elk Grove Village, IL, has introduced the XP series **pencil/pen plotters**, which use fuzzy logic for vector sorting to achieve more efficient plots, better line quality, and shorter plot times. The plotters look ahead 21 to 41 vectors, evaluate vector lengths and angles, then determine the most efficient number of vectors to be read, sorted, and plotted. Offering 0.005 mm/step resolution and 0.1 mm repeatability, the plotters use a 32-bit CPU and a fully-digital servo drive to attain a maximum plotting speed of 1131 mm/sec and 4.2 g maximum acceleration.
Circle Reader Action Number 776.



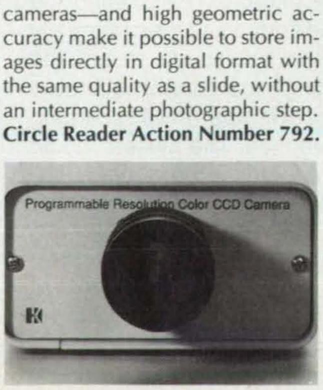
A **digital sound editor** developed by FORTE, Rochester, NY, allows users to create, edit, and display speech, music, and other sound files. The digitized sound is displayed in full graphics mode on a video monitor. Editing features include a zoom function that allows a full-screen view of any portion of a waveform.
Circle Reader Action Number 796.

A new lightweight **digital infrared thermometer** from Cole-Palmer Instrument Co., Chicago, IL, is easy to use: simply aim, pull the trigger, and read the digital display. In less than a second, the thermometer measures temperatures from -18° to 400° C with an accuracy of ±2 percent. It features a digital LCD display with mode indicators and 1° resolution.
Circle Reader Action Number 788.

A handheld **fiberscope video imaging system** developed by Moritex USA Inc., San Diego, CA, uses minute probes and a miniature CCD camera to provide full-color imaging for previously uninspectable places. A 75-watt xenon light source ensures illumination in dark areas, and a standard NTSC output on the rear panel permits coupling with a video printer or still video recorder. The system is suited for inspection of electronic components after assembly to printed circuit boards, quality inspection of catheter tubing, inspection of small-diameter membrane sensors, and internal inspection of bearing surfaces without disassembly.
Circle Reader Action Number 774.

IBM Corp., White Plains, NY, has introduced a notebook-size, **battery-operated computer** that allows users to access and input information from remote locations. The ruggedized 9075 PCradio™ connects to larger IBM computers via radio or cellular-based communications, or through conventional telephone lines using integrated modems. Designed for use by a broad range of industries, from transportation to utility companies, it uses an 80C186 microprocessor and operates at either 5 or 10 MHz.
Circle Reader Action Number 790.

A new **digital color camera** created by Roche Image Analysis Systems Inc., Elon College, NC, has programmable resolution from 499 x 580 to 2994 x 2320 pixels and 12 bits digitization per color channel. Designated the Prog Res 3012, it offers an on-line video signal for focusing and positioning, and a full-resolution input time of under 16 seconds. The camera's high light sensitivity—100 times higher than conventional line scanner cameras—and high geometric accuracy make it possible to store images directly in digital format with the same quality as a slide, without an intermediate photographic step.
Circle Reader Action Number 792.



An automatic, computer-controlled **welding system** developed by FUTEC Inc., Ft. Collins, CO, controls welding parameters in real time, producing precise weld sizes and penetration regardless of base metal temperature, welding speeds, or changes in base metal chemistries. Thru-the-arc sensing of weld size is made possible with EDAP® (Electro Dynamic Arc and Puddle Control) software. Originally developed for the nuclear industry, this system can be used wherever predictable zero-defect welding is required, such as in the aircraft, aerospace, and processing industries.
Circle Reader Action Number 784.

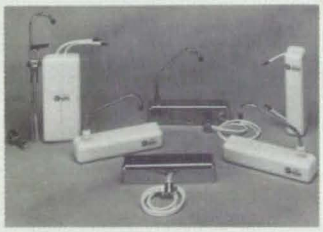
The Heat Spy® **infrared thermometer** from Wahl Instruments Inc., Culver City, CA, measures temperatures from 538° to 1760° C with ±0.5 percent accuracy full scale and ±3° repeatability. With a 60:1 field of view, the instrument can measure an 8" target from 40 feet away. Other features include a high-resolution, heat-resistant refractive silicon lens filtered to read in the 4.3 to 4.4 micron spectral range.
Circle Reader Action Number 778.

Evolution Computing, Tempe, AZ, has announced CadSpan, a **mapping program** that unites the graphical capabilities of CAD with the data analysis and storage capabilities of a spreadsheet or database. The program works in conjunction with EasyCAD 2 or FastCAD and Lotus 2.X or dBase III Plus compatible software. CadSpan combines spatial information about each geographical element, such as street network or census boundary, with data about each, such as road condition or population density, contained in a spreadsheet or database.
Circle Reader Action Number 794.

Analog Devices, Norwood, MA, has introduced the ADXL-50, a surface-micromachined **accelerometer** that features complete signal conditioning and self-test circuitry on-chip. It measures acceleration in a single plane of sensitivity over the ±50 g range with ±5 percent accuracy. Unlike other accelerometers, which monitor the resistance change of stressed piezoresistors to detect acceleration, the ADXL-50 measures changes in capacitance, and is therefore insensitive to temperature changes.
Circle Reader Action Number 780.

New on the Market

Metron Technology, Boulder, CO, has introduced a versatile tool for data acquisition, heat monitoring, and thermal analysis with a temperature range of -200° to 1700° C. The THERM 2280-8 has four independent channels configured for any of eight types of thermocouples, RTDs, and MTC thermistors for temperature as well as humidity, pressure, velocity, ma, mv, and low-volt sensors.
Circle Reader Action Number 762.



A new compact **bacteriostatic water treatment unit** is available from Ambassador Marketing, National City, CA. Called the Space-Saver 5000, the product utilizes water filtration technology originally developed for the space shuttle. It provides the filtering capacity of many larger units, and can be used wherever space is limited, such as in kitchens, bathrooms, and RVs.
Circle Reader Action Number 760.

An integrated system for **high-speed data acquisition and real-time processing** has been developed by Valley Enterprises, Tamaqua, PA. Standard configurations provide up to six input channels and 16 digital signal processors, and deliver the results to a VMEbus or other host. The system's input module digitizes up to 40 million samples per second on each channel with 10-bit resolution. Calculations such as spectral analysis can be done in real time on continuous input data streams up to 1 MHz or in burst mode for higher frequency signals.
Circle Reader Action Number 772.

Geltech Inc., Alachua, FL, has produced high-purity **silica porous glass** featuring uniform, interconnected pores. Called Gelsil®, the glass can be used as a stand-alone material or, by impregnating a dopant into the pores, as a substrate or matrix for making new composites. Pore diameter, specific pore volume, and specific surface area are variable and can be tailored to user specifications. Potential applications include gas diffusion and permeation, micro-optic arrays, laser-densified waveguides, and transpiration-cooled optics.
Circle Reader Action Number 766.

Structural Research and Analysis Corp., Santa Monica, CA, has introduced COSMOS/M DESIGNER, a seamless interface that links the company's **finite element analysis (FEA) tools** to AutoCAD Release 11. The software provides a fully-integrated H-Method and P-Method FEA system for 2D and 3D analyses using the AutoCAD Development System (ADS) environment. Employing familiar AutoCAD icons and submenus, COSMOS/M DESIGNER enables engineers to perform complete component analysis and design, and to address factors such as strength, shape, size, flexibility, volume, weight, and thermal considerations.
Circle Reader Action Number 764.

The 4090 series of **digital storage oscilloscopes** from Gould Inc., Valley View, OH, offers digitizing rates of up to 800 megasamples per second, allowing a true 200 MHz bandwidth for transient as well as continuous real-time signals. Four high-speed channels with sensitivity control maintain 8-bit resolution down to 2mv/division, an important feature for low-level signal measurement. The scopes combine dual timebases, dual triggering, and glitch capture for quick, precise troubleshooting capabilities. In digital test applications, they can pinpoint errors in switching signals that need to be accurately positioned, aberrations in rising edges, and a variety of infrequent events.
Circle Reader Action Number 770.

Ocean Optics Inc., Dunedin, FL, has introduced a low-cost, high-performance miniature **spectrometer** that interfaces to a computer for control and data acquisition. Light from a single optical fiber input is dispersed by a 6 x 5 x 2 cm spectroscope and detected with a highly-sensitive 1024-element photodiode array. Developed under a Small Business Innovation Research (SBIR) grant from the Department of Energy for use with fiber optic pH sensors, the new spectrometer can be configured for UV, VIS, NIR spectrophotometry fluorescence, reflectance, spectro-radiometry, or color analysis.
Circle Reader Action Number 768.

New Literature

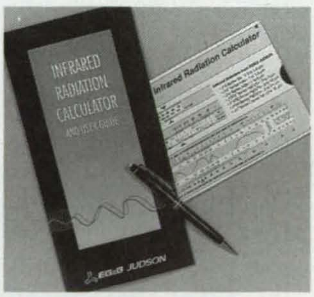
The new ULTRAlign **fiber positioning system** from Newport Corp., Fountain Valley, CA, is described in a 12-page brochure. System components include five positioners, both manual and electrostrictive drive systems, and a wide range of mounts and accessories, from a goniometer and fiber chuck holder to tilt mounts and a GRIN-Rod lens kit. A fold-out guide covers various application options, such as fiber-to-waveguide-to-fiber connections.
Circle Reader Action Number 724.

Instron Corp., Canton, MA, is offering free subscriptions to its **materials testing technology** newsletter. Entitled *Instron World*, the publication covers developments in material testing applications, equipment, and software, and includes sections on testing accessories and training.
Circle Reader Action Number 702.

High-speed linear products from Burr-Brown Corp., Tucson, AZ, are described in an eight-page brochure. Featured are high-resolution, high-speed A/D and D/A converters, sample/holds, operational amplifiers, and analog multipliers used in instrumentation, imaging, video, spectrum analysis, and direct digital synthesis. New products include a CMOS 12-bit, 333 kHz sampling A/D converter; a 12-bit, 5 MHz sampling A/D converter; a low-distortion 12-bit video D/A converter; and a wideband video amplifier.
Circle Reader Action Number 714.

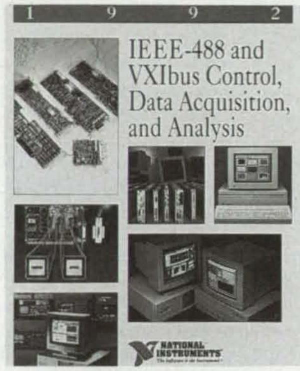
A **ball bearing system** that significantly reduces bearing wear in bidirectional pumps is discussed in a data sheet from MRC Bearing Services, Jamestown, NY. The new PumPac® Diamond system, consisting of two identical 15-degree angular contact ball bearings installed back to back, is suited for hydrodynamically-balanced pumps used in hydrocarbon processing, wastewater treatment, food processing, and other applications where lubricant breakdown due to ball sliding may be a problem. Available in bore diameters from 40 mm to 180 mm, the system features low bearing operating temperatures, low vibration, and increased radial shaft rigidity with reduced seal wear.
Circle Reader Action Number 704.

A free **infrared radiation calculator** from EG&G Judson, Montgomeryville, PA, can be used to determine the ideal operating wavelength and detector type for a particular application. The guide features instructions for calculating spectral characteristics of blackbody sources without complex mathematical analysis. Measurement options include total radiant and peak radiant exitance, blackbody radiation in a given spectral interval, number of photons per second per cm^2 emitted by the blackbody, and ratio of peak exitance to that of any wavelength.
Circle Reader Action Number 706.



National Technical Systems (NTS), Saugus, CA, has released a 16-page brochure reviewing its **testing and engineering** capabilities. NTS solves technical problems in such fields as engineering design, system safety analysis, electromagnetic interference, environmental testing, structural dynamics, and natural hazards evaluation. Some of its capabilities include acoustic testing to 171 dB, high-g shakers generating in excess of 45,000 force-lbs., pyrotechnic shock to more than 100,000 ft., and acceleration testing to 750g.
Circle Reader Action Number 716.

A new brochure from KMC Inc., Coventry, RI, describes its Deflection Pad **bearing**, which reduces friction up to 50 percent over conventional bearings. Its pad support structure permits each pad to deflect slightly at start-up to form a hydrodynamic wedge that carries heavy loads on a fluid film between the shaft runner and bearing. Full-color photos and line drawings illustrate the bearing's operation.
Circle Reader Action Number 718.



National Instruments Corp., Austin, TX, has announced its 1992 catalog of software and hardware products for **data acquisition, analysis, and presentation**. The 544-page publication describes products for developing instrumentation systems that use signal conditioning accessories with plug-in PC data acquisition boards and GPIB, VXI, or RS-232 instruments on a variety of computer platforms. The company's three application software systems are featured: LabVIEW® 2, a graphical programming system for Macintosh computers, LabWindows®, a code generator for C and QuickBASIC; and Measure, a transparent interface to Lotus 1-2-3, run on DOS-based computers.
Circle Reader Action Number 722.

Infrared imaging and measurement systems developed by Inframetrics Inc., North Billerica, MA, are reviewed in a free brochure. The full-color publication describes the systems' applications in predictive maintenance, nondestructive testing, electronics design, medicine, and night vision.
Circle Reader Action Number 726.

Solvay Polymers Inc., Houston, TX, has released a brochure describing its new IXEF™ line of glass-reinforced polyarylamide **resins**. The high-performance engineering thermoplastics provide good processability, high rigidity, low shrinkage in molding, and a slow rate of water absorption. They are suited for a range of injection molding applications, such as automotive components, household appliances, and electrical equipment.
Circle Reader Action Number 710.

A full-color brochure from Real World Interface Inc., Dublin, NH, highlights a **mobile robotic platform** for autonomous, semi-autonomous, and teleoperated robots. The self-contained B12 robot base, 12" in diameter and 6.75" high, includes motors, power amplifiers, a control computer, and software. It handles up to 40 pounds of payload and can travel up to six feet per second.
Circle Reader Action Number 712.

A free brochure from Canon USA, Lake Success, NY, highlights **laser rotary and linear encoders**, interface display units, and interpolators. The four-color publication also describes a wide range of industrial applications for Canon's encoders.
Circle Reader Action Number 708.

A 24-page **magnetic components** catalog from Prem Magnetics Inc., McHenry, IL, offers printed circuit power transformers, couplings and hybrid transformers for telecommunications, CRT products, and inductors for use in switched-mode power supply applications. Prem's power transformer line carries both UL and CSA listings.
Circle Reader Action Number 720.

A free brochure from Eason Technology Inc., Healdsburg, CA, spotlights the SOI-1100, a **smart operator interface** for a variety of industrial control applications. The unit has sufficient intelligence and I/O to handle both the man-machine interface and machine or process control in many applications. Features include a backlit display and a 30-key waterproof keypad with nine soft keys and a programmable, context-sensitive help key. The brochure contains photos, product specifications, and connector data.
Circle Reader Action Number 728.

Subject Index

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Simulate system response using built-in expression interpreter or apply fuzzy rules to file data
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Circle Reader Action No. 664

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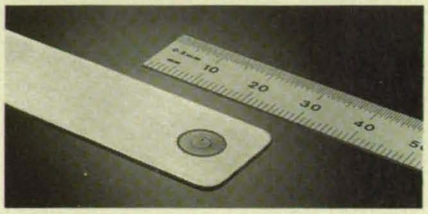

Capacitec HPS Series of thin (back to back) sensors can measure gaps as small as **0.010"(.254mm)** inboard 84" (2133.6mm) with accuracies of 0.0003" (7.6μm), without scratching delicate surfaces.

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Emcor Product's line of TEMPEST-style/Mil-Spec enclosures provide a higher level of shielding attenuation. These nickel-plated enclosures have been tested to MIL-STD-285. Special features include a rigid 12-gauge frame, a unique patented door and latching system, and modular options. Free catalog available.

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RESOLUTION REVOLUTION!

Introducing a breakthrough that replaces microsteppers, this uniquely designed step motor resolves 800 full steps per revolution (.45° per step). The motor is optimized for resonance free performance and is particually suited for use on constant current (chopper) drives. Size 23 by 2.0" with 1/4" shaft, the motor is single or double ended. Nominal current for 35 oz.-in is 2 amps per coil.

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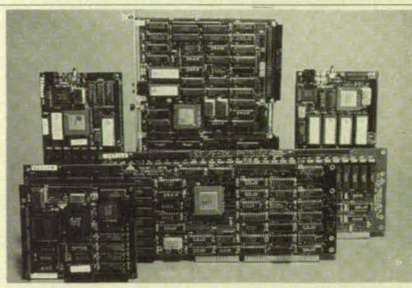

SC/FOX™ Embedded-System Computers

SC/FOX VME SBC (Single Board Computer) 18 MIPS, 60 MIPS burst, general-purpose, slot-1 Master/Slave System Controller. Up to 640K bytes 0-ws memory, 1 SCSI, 1 ptr, 2 serial ports. Uses 16-bit Harris RTX 2000.

SC/FOX PCS (Parallel Coprocessor System) 15 MIPS, 50 MIPS burst, general purpose PC/AT/386 plug-in board, 32K to 1M byte 0-ws static memory, multiple PCS operation, SCSI option. Uses Harris RTX 2000.

SC/FOX SBC (Single Board Computer) 18 MIPS, 60 MIPS burst, Stand-alone operation, Eurocard size, 1 ptr, 1 serial port, up to 512K bytes 0-ws memory, 2 50-pin user connectors, SCSI option. Uses Harris RTX 2000.

SC/FOX PCS32 (Parallel Coprocessor System 32) 15 MIPS to 70 MIPS, general-purpose PC/AT/386 32-bit plug-in board with 64K to 1M byte 0-ws static memory. Uses 32-bit SC32 Forth microprocessor.

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Circle Reader Action No. 679

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PC AT compat. w/hd dr, 1 MB

MAC - StereoMac - World's 1st 3D for the Mac! Glasses, interface, disk, $195. Mac+/SE/II

AMIGA - X-Specs 3D - $125 Game disk, $50. 3D Dev. kit - disk, manual, $100. Flight Simulator coming soon!

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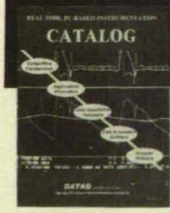

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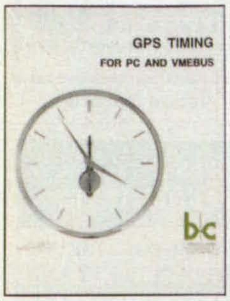
(continued on page 128)

NASA Tech Briefs

LITERATURE SPOTLIGHT

Free catalogs and literature for NASA Tech Briefs' readers. To order, circle the corresponding number on the Reader Action Request Form (page 113).

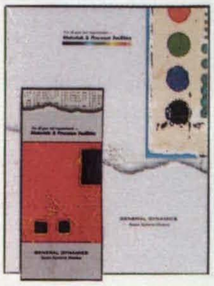


GPS TIMING FOR PC AND VMEBUS

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

Bancomm

Circle Reader Action No. 301



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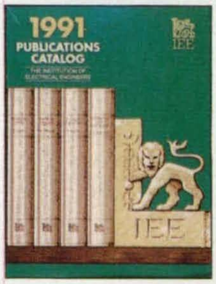


1991 IEE PUBLICATIONS CATALOG

This catalog lists books, conference proceedings, and journals available from this prestigious publisher, The Institution of Electrical Engineers. Subject categories include: telecommunications, control engineering, electronic devices, electromagnetic waves, electrical power systems, computing and signal processing, and much more.

Circle Reader Action No. 303

NOISE CONTROL PRODUCTS

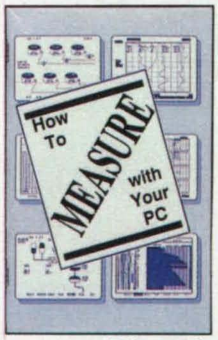
New color brochure describes SONEX and SONEX 1 sound-absorbing materials with patented shapes that control noise better than standard acoustical treatments. Brochure explains basic noise control techniques and presents the many forms, sizes, and colors of SONEX products available for effective industrial, office, and OEM noise control. Brochure also shows typical applications and includes information on acoustical performance.

Circle Reader Action No. 304

INSTRUMENT CONTROL AND DATA ACQUISITION

Free 1992 catalog of instrumentation products for PCs, workstations, and more. Features IEEE-488.2 interfaces and software, plug-in data acquisition boards, VXIbus controllers, DSP hardware and software, and signal conditioning accessories. Application software for complete acquisition, analysis, and presentation of data, including graphical interfaces. Application tutorials and training classes also detailed.

Circle Reader Action No. 305



HIGH-RESOLUTION DATA ACQUISITION

FREE booklet shows many ways to automate data collection using your personal computer. It comes with a FREE Instatrend Real-Time Graphics Demo Disk.

Dianachart, Inc.

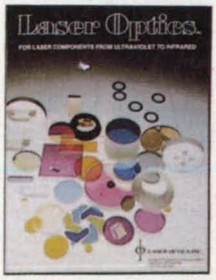
Circle Reader Action No. 306

COST ESTIMATING

World's best-selling system has been updated with nine databases and full process planning capability. Provides consistent, fast estimates for job shops and Fortune 500.

Manufacturers Technologies

Circle Reader Action No. 307

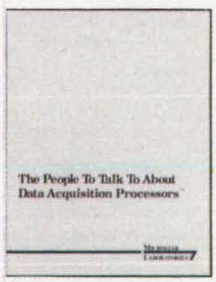


LASER COMPONENTS —UV TO IR

A 32-page catalog of optical components and coatings for ultraviolet, visible and infrared applications, including lenses, windows, prisms, beamsplitters, mirrors, and filters. Broad range of zinc selenide, germanium and silicon optics for CO_2 lasers. Specialists in optical coatings for high-power applications.

Laser Optics, Inc.

Circle Reader Action No. 308



INTELLIGENT DATA ACQUISITION SOLUTIONS

Use on-board intelligence, memory, and the DAPL™ operating system for PC-based data acquisition. This 16-page full-color brochure shows you how. It outlines hardware and software solutions from Microstar Laboratories — including an easy-to-use approach to DSP.

Microstar Laboratories, Inc.

Circle Reader Action No. 309

EXTRUDED OPEN CELL ELASTOMERS

Microfoam, Inc., uses its unique extruding process to cover various users of open cell elastomers for both dry and liquid dispensing application. Pore size, foam density, fluid composition and viscosity, transfer pressure, and other factors are adjusted to meet each customer's specific application. Microfoam is ready to discuss your concepts and challenges with imagination and efficiency.

Circle Reader Action No. 310

SPECIALTY GAS, EQUIPMENT CATALOG

Spectra Gases' 1992 specialty gases and equipment catalog is now available. This catalog contains specifications on pure gases, gas mixtures, gas handling systems and related equipment, halogen scrubber systems, ion-laser tube repair, and isotopic gases and related equipment.

Spectra Gases, Inc.

Circle Reader Action No. 311

1991-1992 COLE-PARMER INDUSTRIAL INSTRUMENTS CATALOG

The 1991-92 edition of Cole-Parmer's general catalog is now available. The new book features over 1,200 pages in full color and over 21,000 products, and includes a detailed product index and a color-coded table of contents making the book easy and convenient to use.

Cole-Parmer Ind. Instruments Co.

Circle Reader Action No. 312

FLUID CONTROL SOLUTIONS

This brochure explains the specialized liquid or gas control components and systems Marotta designs and manufactures. Also, Marotta provides engineering or manufacturing of customer-developed products, plus pooling their capabilities through teaming, consortium, or licensing agreements.

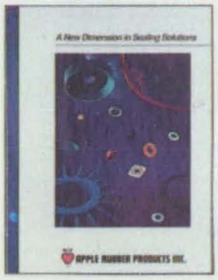
Marotta Scientific Controls, Inc.

Circle Reader Action No. 313

BATTERY POWERED 8-CHANNEL FIELD RECORDER

Astro-Med's portable 8-channel field recorder operable from its internal battery is described in an illustrated 10-page brochure. The lightweight unit, called the Dash 8, features extraordinary capabilities. It offers frequency response to 25 kHz; "on the fly" grid formats; AC and 11-18 VDC operation; on-demand self-calibration; and data capture and playback.

Circle Reader Action No. 314

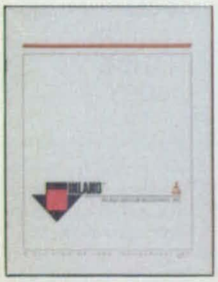


SEALING SOLUTIONS

Publication provides a complete overview of Apple Rubber's products and services. Included in wide variety of seal products are: O-rings standard, metric, microminiature, and oversized; custom molded seals and shapes; composite seals of rubber-bonded-to-metal or plastic. Services include design engineering assistance and quality assurance programs.

Apple Rubber Products, Inc.

Circle Reader Action No. 315

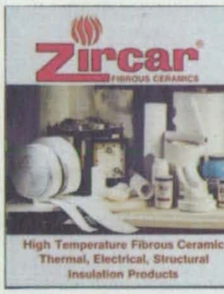


VACUUM PUMP FLUIDS

Inland Vacuum's '91 catalog features their complete line of vacuum pump fluids, greases, and preventative maintenance products. A complete vacuum fluids chart is enclosed for easy reference. Reclamation service for expensive fluids and oils is described for environmental and cost savings measures.

Inland Vacuum Industries, Inc.

Circle Reader Action No. 316



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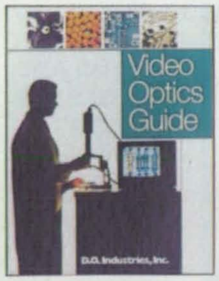
Manufacturers & fabricators of high-performance, high-temperature fibrous ceramic thermal, electrical, and structural insulation products. Fiber types offered include: zirconia, alumina silica, and other refractory oxide compositions. Product forms include: bulk fiber, powders, cements, hardeners, felts, cloths, papers, boards, cylinders, ceramic composite shapes, and engineered insulation assemblies in standard and custom shapes. Heating elements and accessories are also available.

Circle Reader Action No. 317

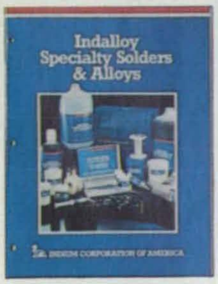


VIDEO OPTICS GUIDE

A new 70-page full-color catalog featuring the Zoom 6000 video microscope system for quality control and inspection applications is available from D.O. Industries Vision Systems Div. The catalog also includes Zoom 7000 macro lenses, Dyotar high-depth-of-field lenses and a full line of video lenses, and accessories.

D.O. Industries

Circle Reader Action No. 318



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Call (800 4 INDIUM) for Free Guide to Indium Solders which: 1) Offer low scavenging of precious metals. 2) Wet glass, quartz, and glazed ceramics. 3) Remain ductile in cryogenic applications. 4) Accommodate TCE mismatches. 5) Are available in alloys for step soldering and rework 6) Can be fabricated into preforms, wire, foil, ribbon, powder, paste, and more! 7) Have just been added to Mil Spec QQ-S-571.

Indium Corp. of America

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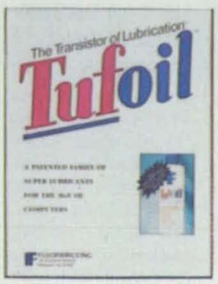

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Fluoramics, Inc.

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MOTION CONTROL PRODUCT GUIDE

Aerotech's 216-page Motion Control Product Guide describes their extensive lines of motor-driven linear and rotary positioning stages; DYNACRON micro-stepping translators; stepping motors and drives; servo motors, amplifiers and drives; and brushless drives. Also described is Aerotech's UNIDEX™ motion controller line. A special four-page insert describing the capabilities of Aerotech's Systems Engineering Division is included.

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THE SUMMAGRAPHICS SUPPLIES AND ACCESSORIES CATALOG

Summagraphics Corporation offers a full selection of accessories for its graphics tablets and Houston Instrument plotters and scanners through the Supplies and Accessories Catalog. Pen plotter users may choose from a variety of pen types, colors, and pen-tip sizes. Graphics tablet users may choose from cursors, styli, and productivity-enhancing Master Templates and subtemplates.

Circle Reader Action No. 323

WASHERS AND SPACERS

Boker's 28-page Catalog '91 offers 10,000 nonstandard sizes with no tooling charges. Outside diameters are 0.080 to 2.631, with numerous inside diameters and thicknesses. 2,000 material variations, including plastics, create millions of possibilities.

Boker's, Inc.

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DIGITIZING WITH ANALYSIS

Hi-Techniques offers digitizing rates from 100 Ksps to 200 Msps in mainframes containing up to 32 channels. High-performance circuits combine the complex triggering and instant display found in digital oscilloscopes with the analysis capabilities of computers.

Hi-Techniques, Inc.

Circle Reader Action No. 325

ELECTRIC LINEAR ACTUATORS

Three series of electric rodless and standard cylinders and controls are covered in this 136-page catalog. It provides performance data, comparisons, dimensions, and accessories. Additional sections provide sizing and selection design considerations and applications.

Industrial Devices Corp.

Circle Reader Action No. 326

INDUSTRIAL COMPUTERS SELECTION GUIDE

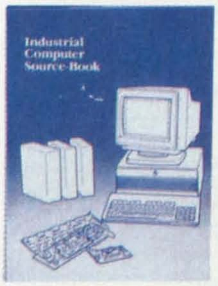
Pro-Log's Industrial Computers with modular, standard I/O schemes are ideal for environments where temperature, shock, vibration, and reliability are a concern. The 224-page Selection Guide features specifications for over 60 products. An applications section guides the user through system design. Systems are available as an integrated PLC, a 286/386 PC/AT compatible, a high-speed 32-bit workstation, and in real-time configurations.

Circle Reader Action No. 327

NEW! POSITIONING SYSTEMS AND COMPONENTS CATALOG

Daedal's 200-page catalog provides specifications for cross roller and ball slides; center and side drive cross roller tables; closed and open frame motorized tables; rail tables; manual and motorized rotary tables; digital micrometer stages; single- and multi-axis motion controllers; half-step, microstepping, and servo motor drives; and optical positioners and hardware.

Circle Reader Action No. 328



INDUSTRIAL COMPUTERS AND DATA ACQUISITION SOLUTIONS

The 1991 Industrial Computer Source-Book™ **Computer Systems Edition III** is 96 pages, covering over 500 IBM PC products. Products include: 20/15/10 slot rack and tabletop chassis, Industrial Portables, and a Heavy-Duty Industrial NODE Chassis. We have also added our NEW Line of POWERUSAR™ 386/486 Modular Upgradeable CPU Cards, and QNX Real-Time Operating System Software.

Circle Reader Action No. 329

HIGH-PERFORMANCE ALLOY

Elgiloy® is a high-performance nickel-cobalt alloy. This brochure describes its characteristics and properties as well as processing information. Elgiloy® is offered in strip and wire and is used in a variety of specialized applications.

Elgiloy® Limited Partnership

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PROGRAMMABLE POSITION CONTROL

A complete 416-page engineer's guide with specifications, dimensions, and performance data presents brushless servos, microstepping motor systems, indexers, linear motors, and absolute encoders.

Parker Hannifin Corp.

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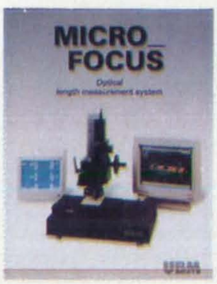

UBC-14 LASER MEASURING SYSTEM

Noncontact sensor unit with movable stage (x,y,z), computer-based controller and video monitor to show exact measuring point. Measure surface profile, roughness, flatness, etc. (practically any material) with range of 0.4" and accuracy of 0.01 μm.

UMB Corp.

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WORK STATIONS, LAB FURNITURE

Twenty-page illustrated guide covers the Teclab line of technical work stations and laboratory systems furniture. Included are versatile work stations of different lengths, combined with a choice of cabinets, shelves, parts drawers, partitions, and other accessories. Catalog has dimensions and shows typical arrangements. It also describes available work surfaces, and has a convenient color selection guide.

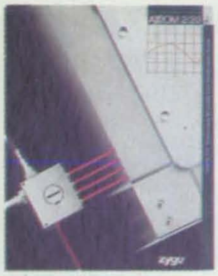
Circle Reader Action No. 333

PROGRAMMABLE VIDEO GENERATORS

TEAM SYSTEMS' new six-page brochure emphasizes the advantages of Video Generators in general and the ASTRO 800 Series in particular for engineering, qualification, incoming inspection, production and marketing of Monitors, Projection Systems, Scan Converters, and many other types of equipment.

Team Systems

Circle Reader Action No. 336



DISTANCE/ ANGLE MEASURING INTERFEROMETER

AXIOM 2/20 brochure illustrates displacement measuring metrology systems. It suits applications like single- and multiple-axis stage calibration, servo track writers, micropositioning machines, structural motion and vibration measurement, machine calibration, and laboratory metrology.

Zygo Corp.

Circle Reader Action No. 358

DIGITAL SIGNAL PROCESSING

Ariel Corporation's 52-page catalog features DSP products for VMEbus, Sun SPARCstation and Macintosh. Product line includes 30 unique hardware products, plus advantaged DSP development software, flexible expansion options, and extensive third-party software support.

Ariel Corp.

Circle Reader Action No. 338

LASER TRIANGULATION PROBES

Probes perform noncontact measurement of metals, rubber, plastics, liquids, and wood. Measure displacement, differential thickness, height, level detection, vibration, and profile plotting of stationary and moving parts. Repeatable to ±0.006 mm, 2 KHz sampling rate.

Zygo Corp.

Circle Reader Action No. 357

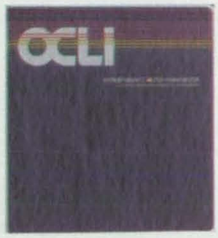
CCTV CAMERAS & SYSTEMS

A New Short-Form Catalog features color and monochrome CCD cameras, including high-performance, low-light-level and digital output models. Cohu cameras are designed and manufactured in the USA for security/surveillance and electronic imaging applications.

Cohu, Inc., Electronics Division

Security/surveillance applications: Circle No. 340

Electronic imaging applications: Circle No. 341



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OCLI

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ADAMS OVERVIEW DISKETTE

ADAMS simulation examples and an overview of multibody systems analysis are presented via color animation and branching menus. The free diskette runs on IBM-like PCs with VGA graphics; 3 megs of disk space; and 520k available RAM.

Mechanical Dynamics, Inc.

Circle Reader Action No. 345

LOW-COST VIBRATION SYSTEMS

Vibration systems from 25 to 600 pounds force for: Research and Development; Products Qualification; Vibration Stress Screening; Modal Excitation; Vibration Demonstrations. Also available: Multiple Shaker Systems; Table Expanders; Cube Fixtures; Custom Fixtures; Slip Tables.

Vibration Test Co.

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LABORATORY OIL-LESS AIR SYSTEM

The 2000, a unique Laboratory Air System, provides a continuous supply of dry, clean air. This *Quiet* system can be situated under a lab bench. Maintenance is limited to once every 2000 hours; system is supplied with a full two-year warranty.

Jun-Air

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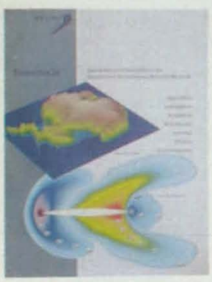

SPYGLASS™ TRANSFORM 2.0

Spyglass™ Transform converts 2D arrays into color raster images, and lets you create contour, surface, and vector plots. A four-page brochure describes visualization, data import, manipulation, and output features of this affordable, easy-to-use Macintosh application.

Spyglass, Inc.

Circle Reader Action No. 346

SPYGLASS DICER™

Spyglass Dicer™ lets you display 3D volumetric data and interactively create slices, cubes, and cutouts. Dicer also generates animation sequences. A four-page color brochure describes these and all the other features offered by this affordable Macintosh application.

Spyglass, Inc.

Circle Reader Action No. 347

FREE DATABOOK FOR DATA ACQUISITION BOARDS

DATEL, Inc., announces an all new 180-page catalog covering over 70 high-resolution, high-speed data acquisition and control boards for PC/XT/AT, VMEbus, and Multibus applications. Also included are the very latest high-resolution, high-speed (up to 4 MHz), Analog I/O and DSP (PC-414 & PC-430) boards available anywhere.

Circle Reader Action No. 348

FREE 756-PAGE INSTRUMENT CATALOG

Our 1991-92 catalog features over 15,000 of the latest Test, Measurement, and Control instruments available. Included are Air Velocity Meters, Flow Meters, Pressure Gauges, Sound Level Meters, Light Meters, pH Meters, Thermometers, Force Gauges, Tachometers, Stroboscopes, Gas Detectors, Multimeters, Recorders, and many other types of instruments. Representing over 150 manufacturers such as Fluke, Honeywell, and Dwyer.

Circle Reader Action No. 349

NEW DATA CONVERSION COMPONENTS DATABOOK

DATEL's new 294-page, comprehensive, Data Conversion Components Databook is presented in a complete data sheet format and details 232 product models covering the latest in data conversion component technology. More than 42 NEW product models are showcased. The Databook also details new MIL-STD-883B and BS9000 products. This comprehensive Databook is available at no charge.

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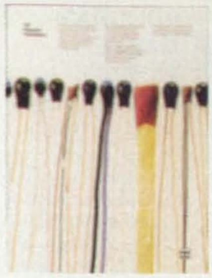


YSI PRECISION INTERCHANGEABLE THERMISTORS & PROBES

YSI thermistors provide stable temperature measurement, control, indication, and compensation with tolerance of ±0.2°C, ±0.1°C. Space-Qualified Thermistors are approved for NASA and DOD; Machine Insertable Thermistors reduce manufacturing costs.

YSI, Inc.

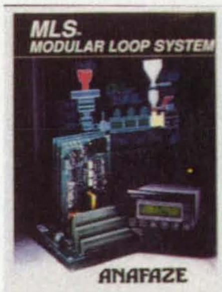
Circle Reader Action No. 351

TOSHIBA VIDEO SYSTEMS MICRO-MINIATURE CAMERAS

Toshiba Video Systems proudly offers this informative full-line Product Guide. Featuring the Toshiba technologically advanced Microminiature cameras. High-resolution of up to 460 lines and a powerful 420,000 pixel CCD — makes them perfect for industrial or scientific applications.

Toshiba America

Circle Reader Action No. 354



MEASUREMENT & CONTROL SYSTEM HANDLES DOZENS TO HUNDREDS OF SENSORS

New brochure describes family of products called MLS™ (for Modular Loop System) that provides from 8 up to 512 measurement and PID control loops, even for mixed sensor types: thermocouple, RTD, Infrared, mA, and mV.

Circle Reader Action No. 353

SMART MASS FLOW SYSTEMS

Color brochure is a 5-minute introduction to K-Flow Mass Flow Meter Systems, their advantages and smart transmitter capabilities. Software-rich transmitter can replace PLC's & PID controllers in batching, mixing, blending, metering, injection, and many other local control applications. Anywhere variables such as mass flow, density, temperature, multi-phase constituency (%solids/liquids/mass), and viscosity.

Circle Reader Action No. 352

RF SHIELDING SELECTION

This 28-page catalog provides information on beryllium copper shielding gaskets, electro-static grounding products, and grounding and shielding contacts. EMC testing services, engineering kits, plating finishes, engineered stampings and assemblies, and ordering information are detailed. A metals compatibility chart and schematic drawings are also included

Instrument Specialties Co., Inc.

Circle Reader Action No. 356

NOISE CONTROL CATALOG

12-page catalog features Noise Control Products & services. It includes application ideas, step-by-step guide for ordering the product & information on "guaranteed" acoustical modeling service. AZ-USA acoustical foam has a patented pyramid surface pattern that scatters, dissipates, & deflects noise. AZ-USA offers a flame-resistant version of its products, & a variety of noise control products.

AZ-USA, Inc.

Circle Reader Action No. 355

ATE POWER PRODUCTS

Elgar's free catalog includes programmable AC power sources, DC power systems and loads, VXP power systems, plug-in oscillators, and global and on-line UPS's. Application needs are cross-referenced with Elgar products in several easy-to-use tables throughout the catalog.

Elgar

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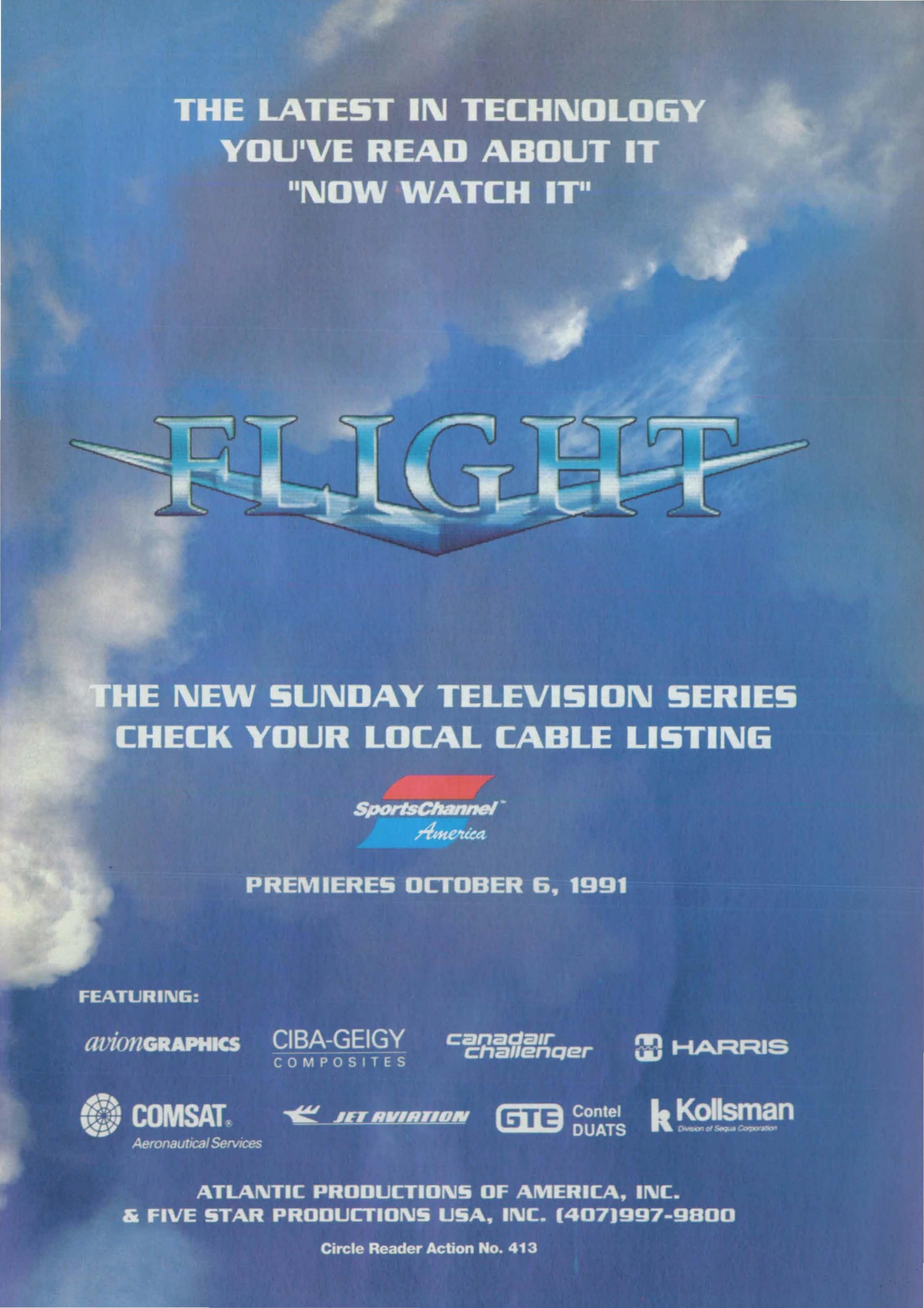
Subject Index

(continued from page 123)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