# NASA Tech Briefs

Official Publication of
National Aeronautics and
Space Administration
Volume 15 Number 12

Transferring Technology
to Industry and
Government
December 1991

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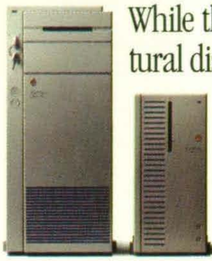

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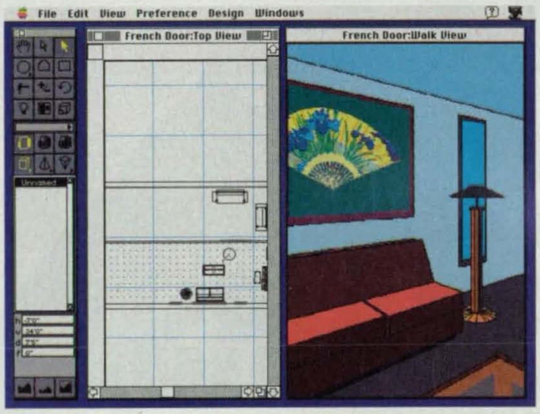


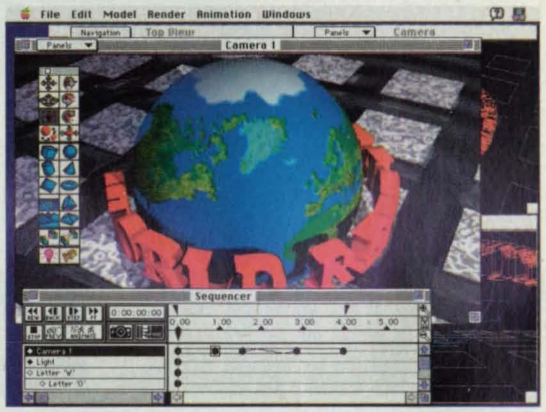


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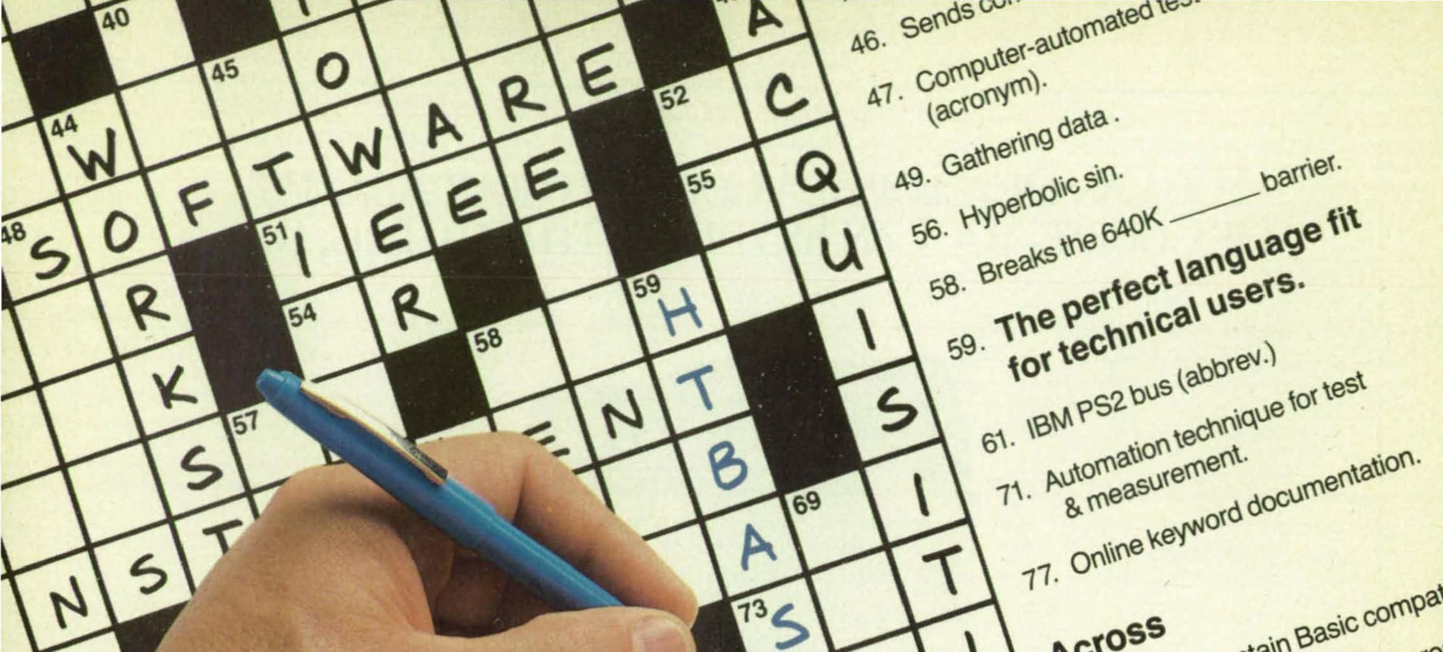


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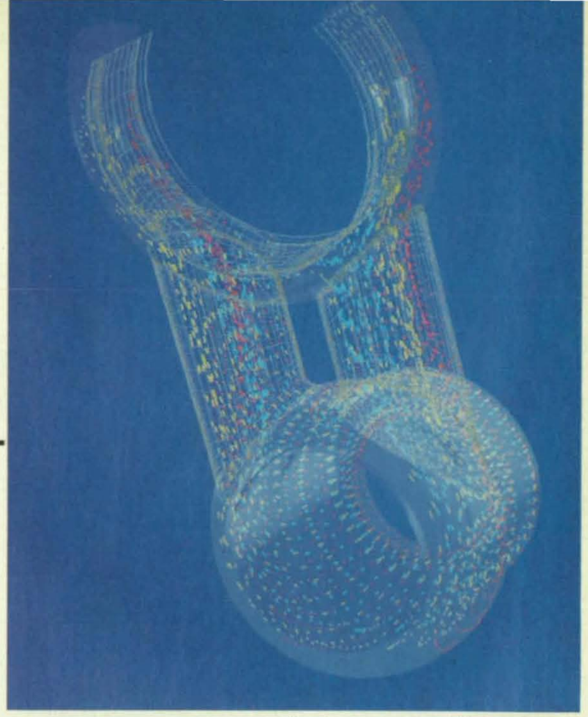
## SPECIAL FEATURES



## TECHNICAL SECTION





Graphic courtesy Ames Research Center

***A research team at NASA's Ames Center is developing methods to simulate viscous, incompressible flows. In the computer recreation above, a finite-difference scheme was used to trace flow through the hot-gas manifold of the space shuttle main engine. Turn to the tech brief on page 74.***

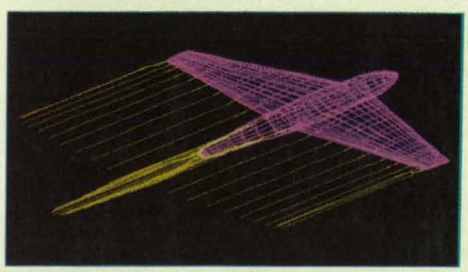
## DEPARTMENTS

***On The Cover: NASA's leading scientists and engineers will present an array of inventions available for license at the Technology 2001 conference (see NASA's Innovators, page 10). They will be joined by technologists from ten other government agencies, their contractors, and other high-tech firms showcasing new technologies in such areas as computing and manufacturing. The cover graphic, produced by Technology 2001 exhibitor Stardent Computer Inc., shows slice planes and particle representations of a curvilinear data set used in complex fluid dynamics problems.***



***Langley Research Center has created a general-purpose numerical-optimization software program for design engineers (page 57).***

Graphic courtesy Langley Research Center





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# NASA Tech Briefs

Official Publication of National Aeronautics and Space Administration

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Published by .......... **Associated Business Publications**
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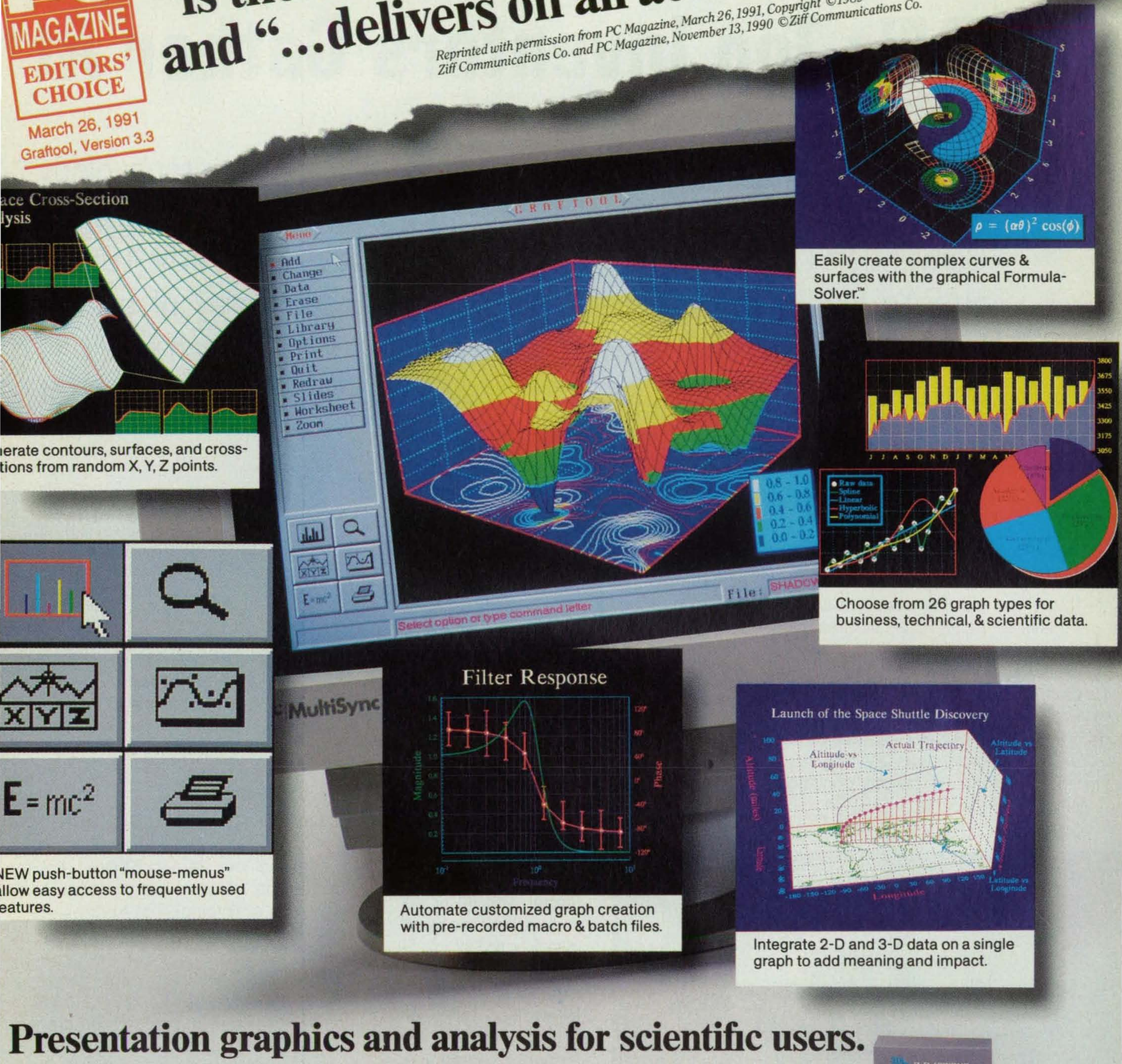


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# NASA's Top Inventors Gather At

Technology 2001, the second national technology transfer conference and exposition (December 3-5, San Jose Convention Center), will feature presentations by nearly 100 of NASA's leading researchers, detailing a broad array of space-based inventions with down-to-Earth applications in such fields as agriculture, manufacturing, and medicine. Here's a look at some of these innovators and their cutting-edge work.

## Spotting A Plant's SOS Signal

A dying plant signals its distress, but by the time anyone notices it is too late.

This scenario occurs in forests and on farms around the world because the human eye cannot detect an unhealthy plant's warning signs. A new optical filter developed by **Leonard Haslim**, a scientist at the Ames Research Center, enhances these signs, alerting scientists and farmers before conditions become irreversible.

The device, called the Passive Chlorophyll Detector (PCD), uses a dyed optical filter plastic sheet to discriminate the reflectance spectra of chlorophyll-bearing vegetation and trees. The filter conveys the effects of plant stress, caused by such factors as insufficient water or minerals, by exaggerating the visual effects of incipient chlorosis. Observing vegetation through PCD goggles makes yellowed plants appear more yellow and healthy, green plants seem more green for a striking contrast.

"Now untrained observers can easily see what formerly only a farmer with 30 or 40 years experience could detect," said Haslim.

The low-cost PCD filters can be tailored for various types of foliage and used by farmers to determine when to nurse or replant unhealthy fields, thereby increasing crop yields. The PCD would allow environmental scientists to monitor the health of forests and wetlands exposed to acid rain or contaminated groundwater. Large areas could be evaluated rapidly by flying over and filming them using a camera with a PCD film over the lens. Such cameras could even be used on routine inspection flights in remote-piloted aircraft to provide real-time imaging.

***Viewing foliage through the unassisted human eye (top) fails to reveal areas of plant stress that are highlighted (in red) looking through the Passive Chlorophyll Detector.***

Photo courtesy of Ames Research Center

## The Climbing Robot

"I'm only 70, and I think I'm just coming into my own with this one," said design engineer **James Kerley**, discussing the latest of his roughly 50 inventions, a climbing robot. Kerley and two other Goddard Space Flight Center engineers have developed a robot that crawls like a segmented worm, traveling up and down, back and forth, and upside down, bending around corners, and even climbing stairs. The key to its agility and what sets it apart from other robots, according to Kerley, is its low center of gravity.

The robot's pneumatic, hydraulic, or electric actuators are strung together by cable to form a train, allowing it maximum flexibility. Its feet can be grippers, magnets, wheels, or suction cups. The modules can wield various paint brushes and rollers, sand blasters, air blast cleaners, radio communicators, brush cleaners, and a range of sensors and cameras.

The dexterous machine can be used to inspect antennas, cranes, towers,

# Technology 2001

launch sites, buildings, drill rigs, ship tanks, bridge girders, hazardous waste containers, and boilers. While inspecting the structures, it could sandblast or scrape and paint them. In high-radiation environments, the robot could read gauges, make repairs, and adjust levers and switches; under water, it could scrape barnacles off and open up frozen sea cocks.

The "caterpillar robot" incorporates off-the-shelf electronics and inexpensive cable. Its parts require no machining and can be stamped for mass production. "I think this will really catch on," said Kerley. "It's the right machine at the right time."

## Microfarming at JPL

In a process much like farming, but on a remarkably smaller scale, researchers at Jet Propulsion Laboratory have succeeded in harnessing bacteria to produce various polysaccharides, complex carbohydrates that are used in materials coatings, chemical/pharmaceutical delivery systems, and as additives in food, paper, paint, and plastic products. "We hope to focus attention on the ability of living systems to make high-fidelity complex molecules," said **Roger Kern**, of JPL's Space Biological Sciences Group.

Kern has developed a unique genetic technique, based on bacteria-bacteriophage interactions, for the selection of bacterial mutants of the genus *Klebsiella*, which produce high yields of structurally-altered polysaccharides. The mutants produce by fermentation polysaccharides with useful rheological properties that can be used to thicken liquids, for example, or reduce drag.

Continued research seeks to further enhance the rheological properties, and thereby utility, of the bacterially "farmed" polysaccharides. Long-term goals include genetic and chemical manipulation of polysaccharides based on their piezoelectric and pyroelectric properties for application in electronic and optical devices.

## Pilot's Pathfinder

The Global Positioning System (GPS), expected to be fully deployed by 1995, will gradually replace all other navigation systems. **Marshall Scott**, a systems engineer at Kennedy Space Center, has created a pilot's display

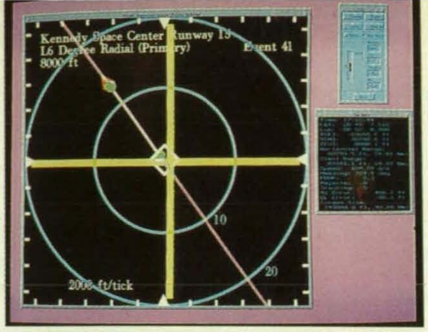
***High above the trees, where a human would find no safe footing, the cable robot steadily bends and climbs as it inspects a structure.***
Photo courtesy of Goddard Space Flight Center

that uses GPS satellite data to calculate aircraft position, providing direct feedback in real time. "Eventually, something like this display will be in every commercial aircraft," he said.

The display was developed for flight inspection tests used to certify the Microwave Scanning Beam Landing System at space shuttle landing facilities and has improved the tests' efficiency. Using data from four GPS satellites, pilots can precisely follow the flight paths prescribed by test engineers, even through haze and cloud cover.

The display features a pair of "fly-to" alignment needles. The distance of each needle from the center of the display represents the plane's deviation from the desired flight path. The pilot can correct the aircraft's course by flying so that the needles move toward the display's center. Position updates are received once per second and the information is logged to a file for later analysis. The system also compensates for sources of error in GPS data such as ionospheric and tropospheric delays.

It runs in the X Windows environment and uses the Motif graphical user interface. Potential applications include land surveys, particularly those that require a specific path be flown repeatedly. The system recently was adapted to aid inspection flights for Tactical Air Navigation ground stations.



***A new GPS-supported pilot's display features two perpendicular "fly-to" needles that provide direct feedback on aircraft position. By flying so that the needles intersect at the center of the display, the pilot keeps the plane precisely on course.***

Photo courtesy of Kennedy Space Center

## New Life For A Time-Tested Metal

TAZ-8A, a high-performance metal developed for aerospace applications in the 1960s, recently has attracted a resurgence of interest. Created at the Lewis Research Center, this nickel-based "superalloy" boasts a unique combination of properties that makes it ideal for high-temperature industrial processes, according to **William Waters**, a Lewis engineer and one of the material's original developers. Containing tantalum and columbium, it offers high-temperature strength, oxidation and abrasion resistance, and exceptional thermal shock resistance.

The alloy could improve the performance and dramatically extend the service life of industrial elements exposed to extreme heat, harsh abrasion, and thermal cycling. It is, however, expensive and so tough it is resistant to many machining techniques. These drawbacks do not diminish its potential for wide application, said Waters, but do suggest a need for careful evaluation. Lewis researchers will produce prototypes so that businesses can test TAZ-8A for specific tasks.

Cost and fabrication difficulties may

***TAZ-8A, an alloy developed in the 1960s and used for the heat-resistant nose cone of the X-15 rocket-powered research plane (shown here mounted under a B-52 wing), is finding new industrial applications.***

Photo courtesy of Lewis Research Center

be reduced by employing TAZ-8A as a coating on a low-cost substrate. NASA has developed various plasma spray and modified plasma vapor deposition (PVD) techniques suited for applying the TAZ-8A coating. The PVD process provides a coating with high reflectivity, extreme hardness, and abrasion resistance. Tests have shown that coating steel rolls increases thermal shock resistance in temperature-cyclic applications by 300-400 percent.

## From Egypt to Orbit, Dynamic Imager Aids Research

"Anything that can be expressed in an image is grist for the mill," said **Douglas Rickman**, a geologist at the Stennis Space Center, referring to the myriad applications of ELAS, a powerful image processing software package. Originally created at Stennis to process images from the Landsat Multispectral Scanner, ELAS has found broad use in the fields of forestry, agriculture, geology, archaeology, oceanography, medicine, ecology, sonar imagery, and microclimatology. It has processed data from satellite and aircraft; images of Egyptian tomb paintings; fish scales and turtle flippers; MRI images of the human heart; soil maps; gravity potential fields; and submarine sonar images.

ELAS offers a modular approach to raster processing, assigning tasks to roughly 250 application modules that can be ordered and applied in a variety of ways. The modules are loaded independently and swapped in and out of memory to minimize the system's memory requirements. The software is command-line driven rather than menu-oriented, and each module allows the user to set values on processing parameters. This high degree of user control is ideal for applications requiring flexibility, according to **David Walters**, an electronics engineer at Stennis and ELAS programmer.

The modules fall into many general categories of functions, including reformatting for data import and export, interactive data display, statistical analysis, pixel classification using definitions from statistical analyses, geometric operations, modeling, polygon manipulations, and filtering for noise removal. Recent enhancements to the package include a multi-byte capability, enabling it to store and process up to 32-bit or 64-bit floating point digital data.

***The image processor ELAS operates on four images concurrently: three scanned images–a gray scale, a color look-up, and an RGB color composite–are manipulated using the color table and scaling functions on their respective look-up table windows, while below, a color composite of CAMS data is processed.***
Photo courtesy of Stennis Space Center

## Clear Advantages to Fuzzy Logic

Already hot technology in Japan, fuzzy logic is just beginning to find widespread domestic use. Fuzzy logic is a mathematical means of handling concepts that are "fuzzy" by nature. These include conditions such as "slow" and "fast" that don't have precise definitions. It enables mathematicians and engineers to apply human-like thinking in decision-making processes that re-

quire manipulation of imprecise information. Incorporating fuzzy logic into control systems gives them a sort of "common sense," reducing human involvement in industrial processes and resolving complex control problems where precise modeling is impossible.

American industries have been slow to apply this logic because they fear that anything "fuzzy" must be unreliable, according to **Dr. Robert Lea**, an engineer with the Johnson Space Center, where fuzzy logic is used in expert control systems. "The Japanese had the same problem with their native word, so they started using the American term instead," he explained. Japan has successfully applied it to subway and automatic transmission control, camera autofocusing, air conditioning, and numerous other systems.

Johnson researchers have employed fuzzy logic in guidance control systems for spacecraft, learning systems using neural networks, control of data processing during rendezvous navigation, collision avoidance, and camera tracking. Current research focuses on its use in diagnostic systems, control of robotic arms, and image processing.

Fuzzy logic, Lea said, is an especially good candidate for control whenever decisions are made based on sensor feedback, which is inherently inaccurate. Fuzzy control systems are usually robust and stable, and are often much faster and cheaper to develop than conventional systems.

"Fuzzy control has already proven itself a useful technology," said Lea. "If only more Americans would understand that fuzzy logic has nothing to do with sloppy thinking."

## Computer-Aided Surgery

The surgeon lifts a scalpel, preparing to make an incision. How hard must the blade be pressed, how much will the human tissue resist? The skill required to know how to cut deeply enough but not too deeply, to avoid nerve and organ damage, must be learned. A new device developed by engineers at the Langley Research Center may expedite surgical training by providing the first direct measure and record of the forces applied during surgery.

A prototype surgical force detection probe has been produced by **Ping Tcheng**, **Paul Robert**, and **Charles Scott** of NASA Langley, and **Richard Press** from Eastern Virginia Medical School. The probe is an adaptation of another instrument developed at Langley, a multi-component, strain-gaged aerodynamic balance that precisely measures the forces and moments imposed on aircraft during wind tunnel tests.

The designers fit the balance into a pen-shaped instrument one-half inch in diameter and seven inches long that can accurately measure surgical force without impeding the surgeon's work. Able to withstand sterilization, the probe accepts various interchangeable tips. It will be connected to a PC-based data system providing signal conditioning, data acquisition and graphics display. Detailed records will enable surgeons to monitor training sessions and actual operations as well as to perform post-test analyses, benefiting both experienced and inexperienced surgeons and, most importantly, patients.

The probe's utility extends beyond the operating room. A razor manufacturer recently contacted Langley regarding application of the probe in surgical blade testing, said Tcheng. Further, the tip could be replaced by a pen to convert the probe into a writing tool that would assess soberness by monitoring the steadiness of handwriting.

## Space Spinoff: An X-Ray Inspection Tool For Industry

Just as x-rays can scan the human body to aid doctors in the diagnosis of disease, they can penetrate a wide range of inanimate objects to help scientists and engineers pinpoint structural defects. This technology, called computed tomography (CT), is gaining acceptance by industry as a tool for nondestructive inspection.

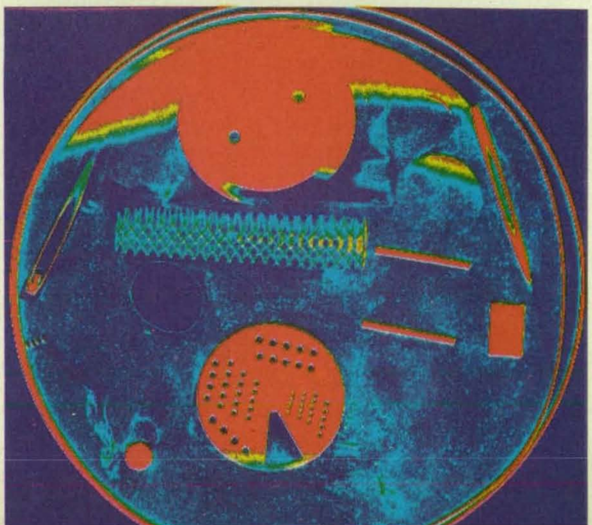
The Advanced Computed Tomography Inspection System (ACTIS), a highly flexible CT device developed at the Marshall Space Flight Center to support solid propulsion tests, demonstrates the value of CT for industrial inspection applications. It can evaluate components ranging in diameter from four inches to four feet and materials ranging from steel to rubber. ACTIS has provided results superior to conventional techniques in contrast sensitivity, spatial resolution, and visualization, according to **Lisa Hediger**, a materials engineer at NASA Marshall.

"This system is an excellent choice any time the major concern is the homogeneity of the materials, especially nonmetallics," said Hediger. Generated in digital format, the ACTIS data can be stored, recalled, and digitally enhanced for analysis. ACTIS provides image-processing tools such as multi-planar reconstruction to aid researchers in locating structural defects. It offers contrast adjustment, statistical image analysis, zoom magnification, and is capable of full 3D reconstructions. Further, it generates relative density plots along a line through the image and can assess wall thicknesses in a casting's internal geometries.

ACTIS can help diagnose design problems early in the product development cycle, saving time and expense, according to Hediger. The system identified anomalies in the space shuttle main engine turbopumps at an early development phase, prompting changes in the casting process. It has been used by the US Department of Energy to inspect sealed barrels of nuclear waste and by automotive manufacturers to inspect prototype steering wheels, engine blocks, and gear boxes. Studies indicate that it could grade lumber and assist in optimizing cutting plans for the lumber industry.

More small businesses should consider taking advantage of ACTIS and other CT systems, Hediger said. The expense of CT, she explained, can be reduced by purchasing smaller, customized systems, leasing an industrial system, or buying time at a medical radiology laboratory. ❑

*For more information about the technologies described in this article, contact the Technology Utilization Officer at the center sponsoring the research* *(see page 20).*



***An image taken by ACTIS, a versatile CT inspection device, shows a detailed cross-section of a nuclear waste drum. Clearly visible in the interior are an air respiration filter, a resolution standard, and a pair of tweezers.***

Photo courtesy of Marshall Space Flight Center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# New Product Ideas

**New Product Ideas are just a few of the many innovations described in this issue of *NASA Tech Briefs* and having promising commercial applications. Each is discussed further on the referenced page in the appropriate section in this issue. If you are interested in developing a product from these or other NASA innovations, you can receive further technical information by requesting the TSP referenced at the end of the full-length article or by writing the Technology Utilization Office of the sponsoring NASA center (see page 20). NASA's patent-licensing program to encourage commercial development is described on page 20.**

## Direct-Link Prehensor

A mechanical prehensor replicates the movements of an operator's hand and fingers just a few centimeters from the hand. Equipped with a protective shroud, the prehensor permits the operator to manipulate nearby hazardous materials or objects in hostile environment.
(See page 78)







## Instrument Measures Ocular Counterrolling

A compact, battery-powered, noninvasive instrument measures ocular counterrotation. Developed for studies of space motion sickness, the instrument can be adapted to use on Earth to evaluate patients who may have impaired otolith functions.
(See page 91)

## Smaller Coaxial-View Welding Torch

A new torch for gas/tungsten arc welding has only two-thirds the length and width of its predecessor. Because of its size, the new torch can be used in small, previously inaccessible spaces.
(See page 82)

## Lock for Valve Stem

A simple, inexpensive device locks a valve stem so that a valve cannot be turned by unauthorized people. The device is intended for use on double-union polyvinyl chloride ball valves.
(See page 63)

## Ionizable-Substance Detector

This detector can monitor continuously ionizable substance in a stream of fluid without disrupting the flow or the chemical composition. Hydrogen, sodium, fluorine, chlorine, oxygen, and bromine are among the substances that can be monitored.
(See page 38)

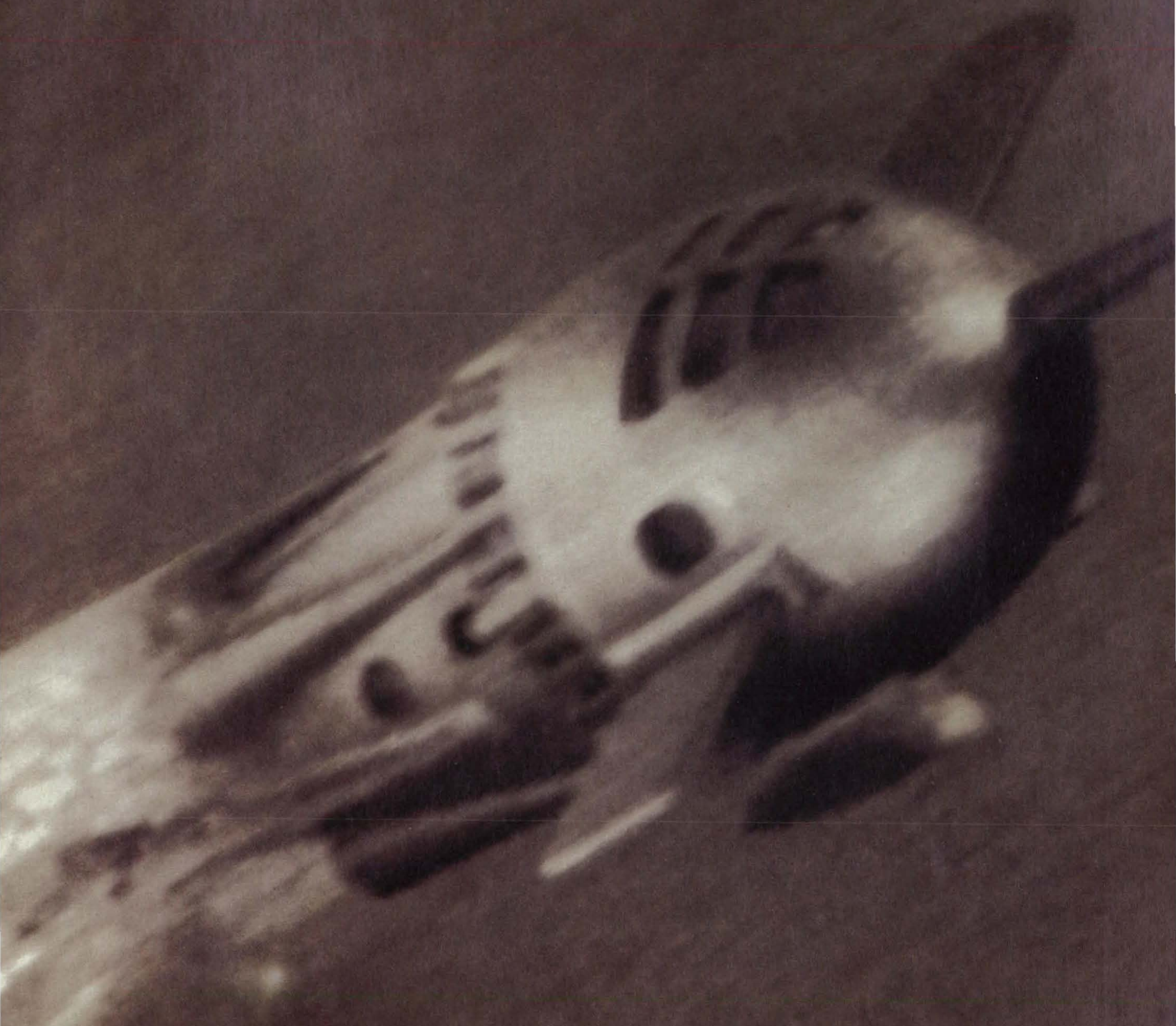
## Multiaperture Spectrometer

A proposed spectrometer containing a single grating would provide high spectral resolution over a broad spectrum. The instrument would use the available light more efficiently and display various orders of the spectrum parallel to each other.
(See page 38)

## Lightweight Valve Closes Duct Quickly

An expanding balloon serves as a lightweight emergency valve to close a wide duct. This type of valve is much lighter than conventional butterfly, hot-gas, or poppet valve.
(See page 64)

# One space vehicle that got there without us.



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

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# Electronic Components and Circuits



## $Si/IrSi_3$ Schottky-Barrier Infrared Detectors

Ir and Si are codeposited in stoichiometric ratio to suppress mixed Ir/Si phases.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

Silicon/iridium silicide Schottky-barrier detectors that have cutoff wavelengths from about 9 to about 14 μm have been fabricated with the help of an improved Ir/Si-codeposition process. This is part of a continuing effort to develop imaging arrays of Schottky-barrier detectors that operate at far-infrared wavelengths. Imaging arrays of 512×512 silicon/iridium silicide Schottky-barrier detectors with a cutoff wavelength of 7.3 μm had been fabricated previously, but these and other devices made of silicon/iridium silicide had exhibited poor and unreproducible diode characteristics, and their quantum efficiencies have been lower than those of silicon/platinum silicide Schottky-barrier detectors. (Silicon/platinum silicide detectors exhibit a cutoff wavelength of 5.6 μm, and the technology of these devices is relatively mature.)

Previously, silicon/metal silicide Schottky-barrier devices were fabricated by depositing metals on silicon substrates, then annealing to form the silicides by chemical reactions between the metals and the silicon. In the case of silicon/iridium silicide, the poor quality of the resulting devices has been attributed partly to contamination — primarily oxygen — at the silicon/silicide interfaces. In addition, iridium tends to react with the oxygen at the interfaces to form iridium oxide, which impedes diffusion across the interfaces, thereby impeding the formation of iridium silicide. The products of the reactions are mixtures of the IrSi, $IrSi_{1.75}$, and $IrSi_3$ phases. Either IrSi or $IrSi_3$ (not both) is preferred. Undesirably, the presence of the three phases in varying amounts causes variations in the heights of the Schottky barriers (with corresponding variations in cutoff wavelengths), and $IrSi_{1.75}$ contributes to high series resistances.

Both Si/IrSi and $Si/IrSi_3$ detectors (see Figure 1) have been fabricated by the improved process. In this process, the silicon substrate is oriented for deposition on the (100) surface, and prior to deposition, the surface is cleaned. In a vacuum chamber, Ir and Si are codeposited by molecular-beam epitaxy in the stoichiometric ratio of 1:1 or 1:3 from two electron-gun

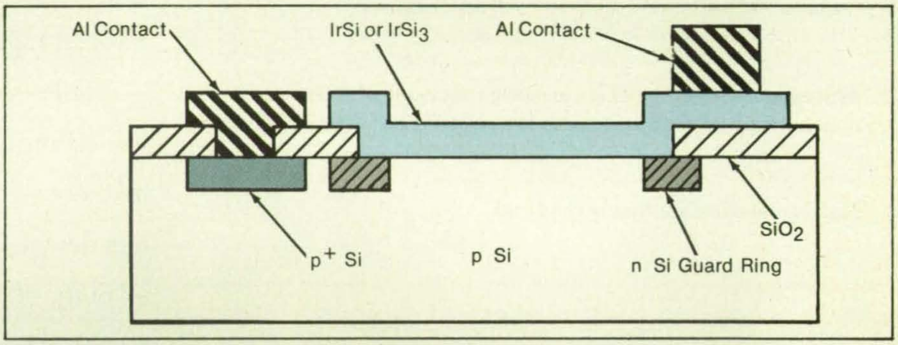


Figure 1. The **Si/IrSi or $Si/IrSi_3$ Schottky-Barrier Detector** is fabricated by the stoichiometric codeposition of Ir and Si on the p Si substrate. It includes a $p^+$ substrate contact, the silicide electrode, and an n Si guard ring, which suppresses leakage around the periphery of the silicide electrode.

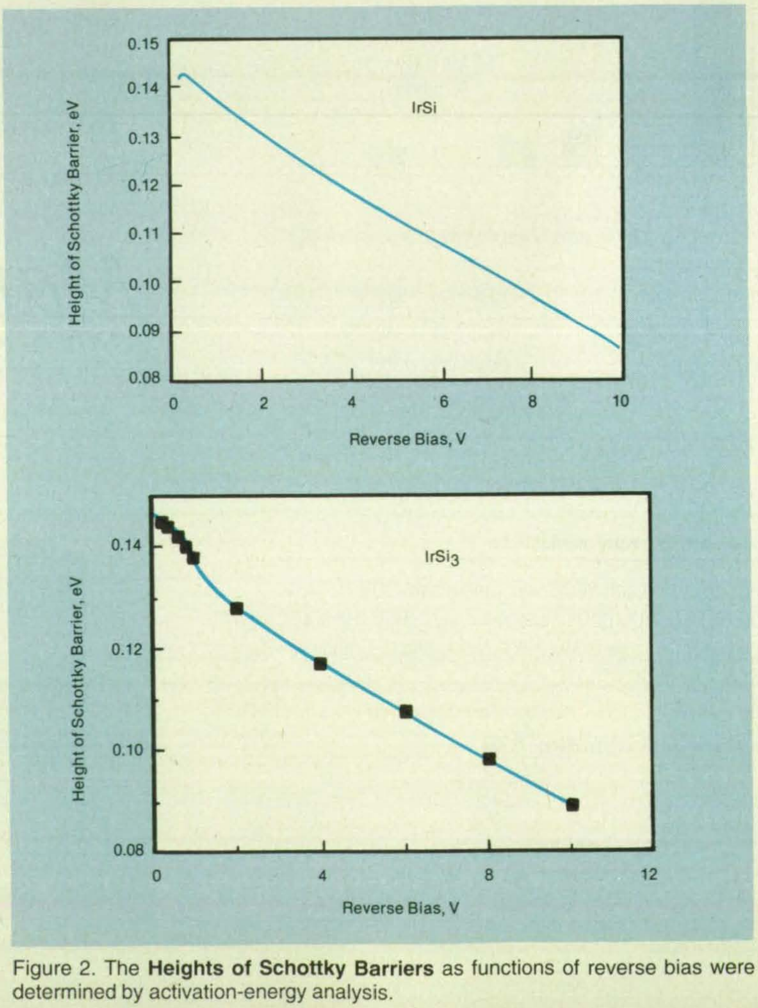


Figure 2. The **Heights of Schottky Barriers** as functions of reverse bias were determined by activation-energy analysis.

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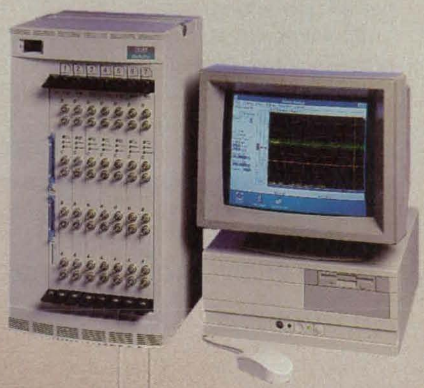

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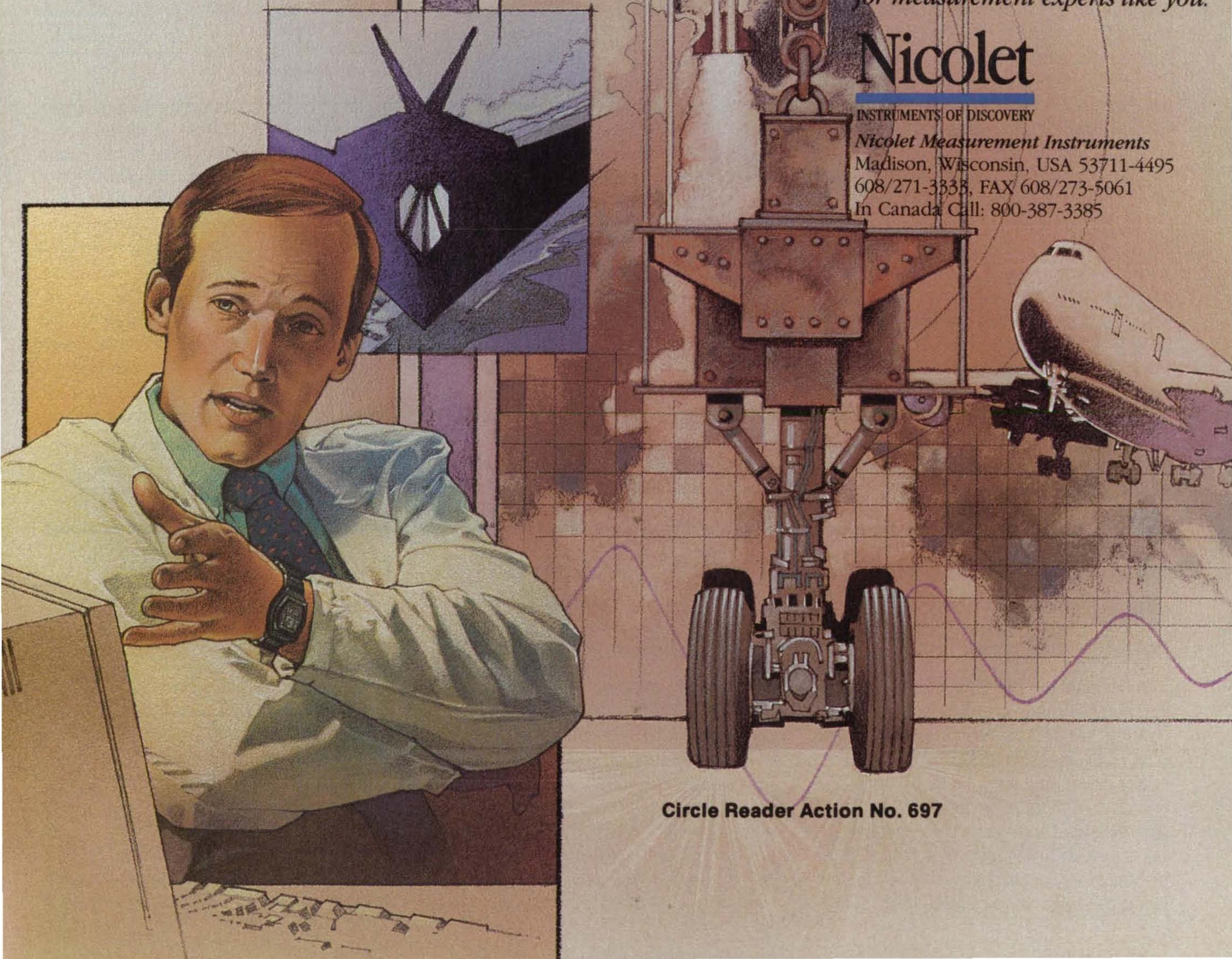

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sources. The thickness of the deposit is about 50 Å. The substrate is heated to a temperature between 200 and 500 °C or between 680 and 800 °C for the deposition of IrSi or $IrSi_3$, respectively. The IrSi or $IrSi_3$ is then patterned by ion milling. Aluminum contacts are then deposited on the silicide and substrate.

Experimental devices fabricated by this process have been characterized by current-vs.-voltage measurements and activation-energy analysis. In addition, the cutoff wavelength of an Si/$IrSi_3$ detector was determined independently by measuring its photoresponse. For Si/$IrSi_3$, the measured heights of the Schottky barriers ranged from 0.138 eV to 0.089 eV as the reverse bias voltage ranged from −1 to −10 V; this represents a range of cutoff wavelengths from 9 to 14 m. Similar results were obtained for Si/IrSi (see Figure 2).

*This work was done by True-Lon Lin of Caltech for* **NASA's Jet Propulsion Laboratory**. *For further information, Circle 122 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-18027 and NPO-17946, volume and number of this* NASA Tech Briefs *issue, and the page number.*

# Characterization of Electrical Response of Photodetector

Fourier analysis of input and output yields electrical frequency response.

*Goddard Space Flight Center, Greenbelt, Maryland*

Fourier analysis is the basis of a method of characterizing the electrical frequency or time response of a photodetector. In this method, the detector is stimulated by an optical input signal, the intensity of which is modulated with a square wave or other repetitive waveform of known frequency spectrum, and the output of the detector is recorded. The electro-optical transfer function, which characterizes the frequency response of the detector, is then computed as the ratio between the discrete Fourier transforms of the output and input waveforms (see figure).

The real and imaginary components of the discrete Fourier transform $S(k)$ at the $k$th point in frequency space are given by

$$S(k)_{real} = \frac{1}{N}\sum_{i=0}^{N-1} X(i)\cos\left(\frac{2\pi ik}{N}\right)$$

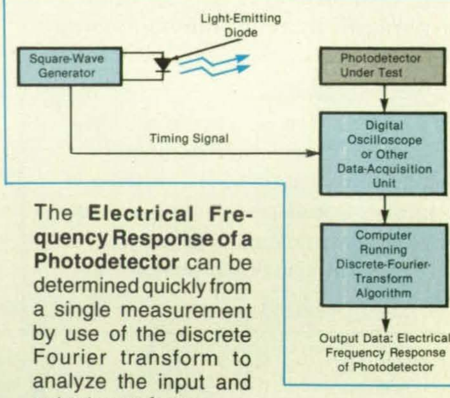
$$S(k)_{imaginary} = \frac{1}{N}\sum_{i=0}^{N-1} X(i)\sin\left(\frac{2\pi ik}{N}\right)$$

where $N$ is the number of samples, $k$ can be any integer from 0 through $N-1$, and $X(i)$ is the instantaneous amplitude of the signal in question at the time of the $i$th sample. The sampling period, $T_s$, must be an integral submultiple of the period of the waveform, and the reciprocal of the sampling period must be at least twice the highest frequency present in the waveform. The frequency resolution, $\Delta f$, becomes finer as the number of samples increases:

$$\Delta f = 1/NT_s$$

The method has been applied successfully to Golay-cell and bolometer detectors and is applicable to any detector system, the ac component of the electrical response of which is linear. The principal advantage of this method is speed; because the input waveform contains many frequencies spanning the entire spectral range of interest, one set of measurements serves to characterize the response of the detector at all of these frequencies. On the other hand, in the traditional method, the frequency response of a detector is measured by exciting it with a sinusoidally modulated signal, one frequency at a time, and measuring the output with a lock-in amplifier or spectrum analyzer. This is a time-consuming and tedious process in which accuracy depends on stability in both the output of the modulated source and the sensitivity of the detector. Changes in either the source or the detector (e.g., temperature dependence of the sensitivity of a bolometer) during a series of measurements can render the calibration invalid.

In one instance of the method, a Golay cell was illuminated by an infrared light-emitting diode powered by square wave with a period of 2.048 s. A digital oscilloscope sampled the input and output waveforms at 4,096 equal intervals (1/2 ms) during one cycle. The waveform data were transferred to a computer, where they were processed via an algorithm that first computed a modified binary Fourier transform, then computed the electro-optical transfer function by taking the ratio between the nonzero terms of the discrete Fourier transforms of the output and input waveforms.




**The Electrical Frequency Response of a Photodetector** can be determined quickly from a single measurement by use of the discrete Fourier transform to analyze the input and output waveforms.

*This work was done by John G. Hagopian and William Eichorn of* **Goddard Space Flight Center**. *For further information, Circle 156 on the TSP Request Card.*
*GSC-13349*

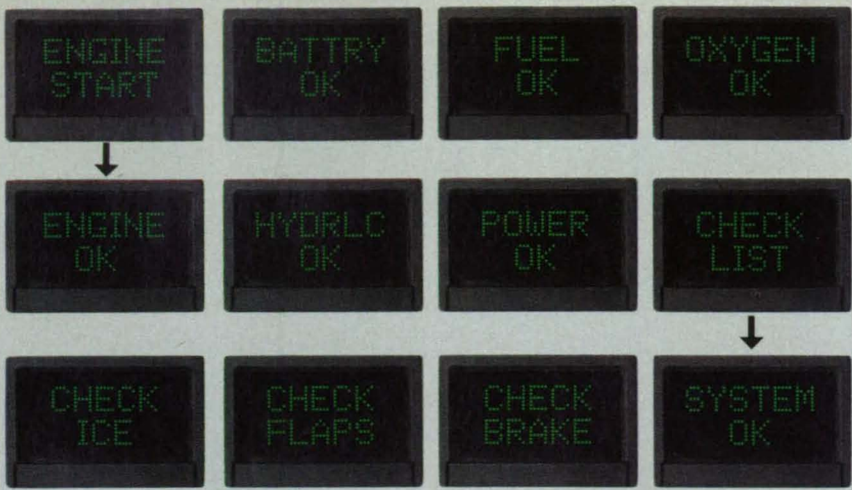
# Automatic Rejection of Multimode Laser Pulses

Characteristic modulation is detected, enabling the rejection of multimode signals.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

A monitoring circuit senses multiple longitudinal mode oscillation of a transversely excited, atmospheric-pressure (TEA) $CO_2$ laser. This facility was specifically developed for inclusion into a coherent detection laser radar (LIDAR) system. However, the circuit described would be of use in any experiment where it is desirable to record data only when the laser operates in a single longitudinal mode. In the case of the LIDAR application for which this device was originally conceived, received signals, derived from multimode transmitted pulses, exhibit a much broader frequency bandwidth than that of the receiver electronics in a typical heterodyne (coherent) detection configuration. They, therefore, contribute little or nothing to the detected signal. Although control circuitry usually enforces single-mode operation, the subject laser can occasionally revert to multimode operation. When this occurs, the monitoring circuit causes the data-acquisition system to ignore the incoming signal, thereby optimizing the signal-to-noise ratio in a signal averaging situation.

Multimode oscillation causes the laser pulse to be strongly amplitude-modulated at the frequency of separation between the

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2
3

**AN APPLICATIONS EXAMPLE.** While the following example is for aircraft, it could apply to any air, land, sea or space system.

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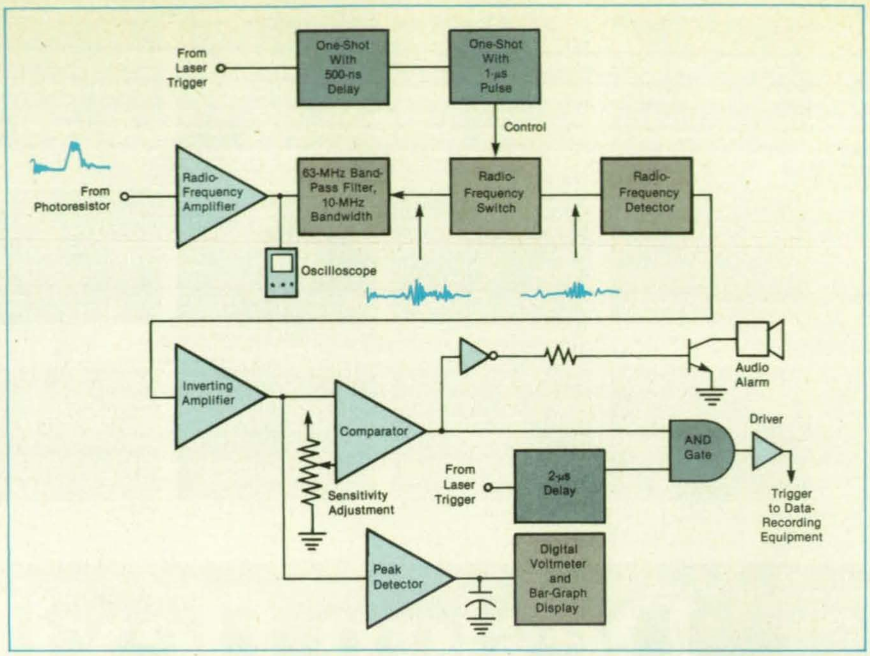
longitudinal modes. This intermode-separation frequency is the reciprocal of the period required by light to make one round trip within the laser cavity, so that the modulation is easily detectable as long as the laser pulse duration exceeds this round-trip period. The monitoring circuit (see figure) senses this modulation and processes it to determine whether the detected data should be rejected.

A low-reflectivity beam splitter samples a portion of the subject laser beam and directs it onto an HgCdTe photoresistor. The output of this photoresistor is band-pass-filtered at the intermode-separation frequency (63 MHz in the original application). The resultant filtered signal is then amplified and sent to a radio-frequency switch controlled by the laser trigger via a delay circuit. The switch blocks the burst of broadband excitation noise that occurs before the laser pulse and that can trigger a false multimode-operation alarm. The switch passes the signal during the time window containing the main part of the laser pulse, then shuts off to block the "tail" of the pulse, which occasionally contains modulation that could also trigger a false multimode alarm.

After passing through the switch, the signal is envelope-detected, amplified, and fed to a comparator. If the signal exceeds a preset value, the comparator sends a pulse to an AND gate. The other input to the AND gate is derived from the laser trigger, but delayed so as to render it synchronous with the output of the comparator. The AND gate is configured so that if a multimode laser pulse has been detected, then the data system trigger (the output from the AND gate) is inhibited and the multimode data thus rejected.




**Amplitude Modulation at the Intermode-Separation Frequency** during the laser pulse causes this circuit to suppress the data system trigger.

*This work was done by David M. Tratt and Robert T. Menzies of Caltech and Carlos Esproles of Ball Systems for* **NASA's Jet Propulsion Laboratory**. *For further information, Circle 109 on the TSP Request Card.*

*NPO-17777*

# Two-Period Gratings for Surface-Emitting Lasers

More light is reflected back into the lasers.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

Solid-state lasers of the type that emit light perpendicularly to their broad surfaces can be made more efficient by use of two-period surface diffraction gratings. Heretofore, a typical device of this type has been made with two gratings, both of which have a single spatial period equal to the wavelength of the light.

In such a device with a single-period grating, the same gratings serve both to couple light out from the surface and to reflect light back into the laser resonator (see Figure 1). To obtain high efficiency and low threshold current, it is necessary to reflect most of the light back inside and couple out only a small fraction. It is difficult to fabricate a single-period grating in such a way as to attain the desired ratio of output coupling to reflection; as a result, the proportion coupled out is too large, the proportion reflected back in is too small, and consequently the single-period devices tend to exhibit low efficiencies and

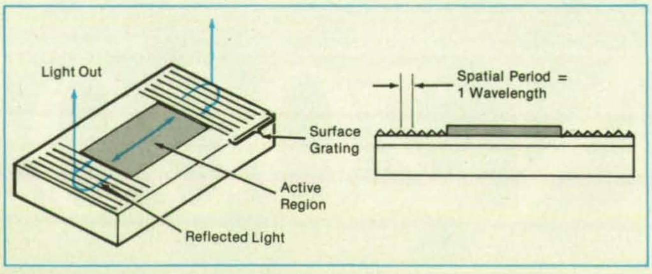



Figure 1. In a **Surface-Emitting Laser With Single-Period Gratings**, the same gratings both couple light out and reflect light back inside.

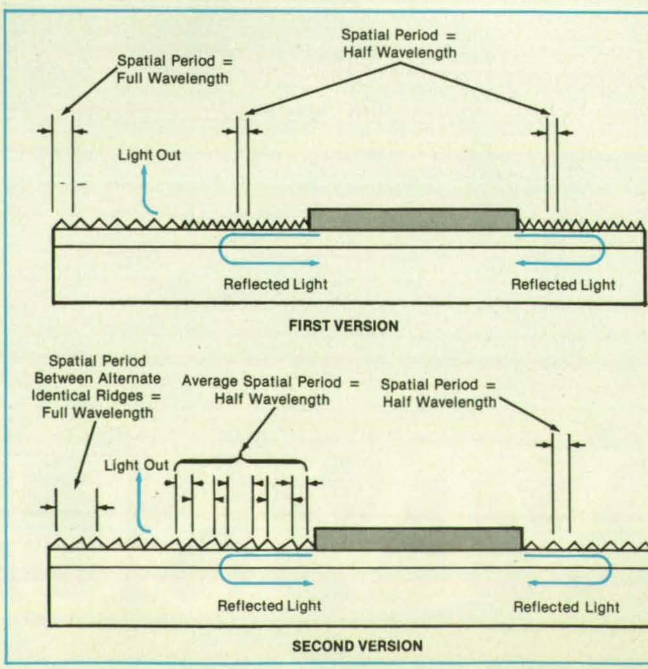



Figure 2. **Grating Surfaces That Have Two Spatial Periods** can be tailored to obtain the desired proportions of output coupling and inward reflection.

high threshold currents.

Figure 2 illustrates two versions of a rectangular two-period-grating surface-emitting laser. In the first version, one of the gratings is divided into two adjacent parts: an output part in which the spatial period is equal to or slightly less than the wavelength and a reflecting part in which the spatial period is half the wavelength. By separating the output-coupling portion from the reflecting portion, one can tailor each independently of the other to optimize the structure of the device to obtain low threshold current. This device has been demonstrated to give a 40 percent reduction in threshold current compared to conventional devices.

In the second version, the grating on the reflecting (only) surface has a spatial period of half the wavelength, while the grating on the output surface has a single pattern characterized by two spatial periods. The average distance between adjacent ridges is half the wavelength. The even- and odd-numbered ridges have slightly different shapes and/or are displaced toward or away from each other by a small fraction of the wavelength; this amounts to a slight perturbation in the half-wavelength pattern, with a spatial period equal to the full wavelength. The strength of the output coupling from this grating increases with the amount of full-wavelength perturbation from the half-wavelength pattern.

The same principle should also be applicable to an annular-Bragg-reflector-grating surface-emitting laser described in *NASA Tech Briefs* Vol. 14, No. 10 (1990), page 20 (NPO-17912). In this case, the annular grating would be divided into two parts: an inner first-order grating (with radial period ≈ half the wavelength) for reflection and an outer second-order grating (with radial period ≈ the wavelength) for output coupling.

*This work was done by Robert J. Lang of Caltech for* **NASA's Jet Propulsion Laboratory**. *For further information, Circle 131 on the TSP Request Card.*

*This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 20]. Refer to NPO-18054.*

# Rugged Direct-Current Transducer

## The solid core withstands mechanical and thermal shocks.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

A direct-current transducer withstands thermal and mechanical shocks. It operates from a single, nominally 15-V power supply and is nearly insensitive to both large variations in temperature and variations of as much as ±5 V in the supply voltage. Its output voltage is a highly linear function of the sensed current, with a full-scale value of about 3 Vdc and an offset of about 0.1 Vdc at 0 sensed current.

The ruggedness of the transducer is due in large part to the novel magnetic core, which is machined from a solid block of a nickel/iron high-permeability, low-hysteresis alloy. This kind of core can withstand more mechanical and thermal abuse than can the tape-wound and sintered cores used in older transducers. The core includes mounting tabs and a gap that accommodates a Hall-effect sensor (see Figure 1). The wire carrying the current to be sensed is wrapped around part of the core.

The Hall-effect sensor is connected to an instrumentation amplifier (see Figure 2). This sensor puts out a voltage proportional to the current to be sensed and to the constant current $I_c$ that is supplied to it. $I_c$ is generated by part of the instrumentation amplifier; namely, the combination of Zener diode $CR_2$, constant-current diode $CR_1$, and operational amplifier $U_A$, which is part of a quad operational amplifier that also includes operational amplifiers $U_B$, $U_C$, and $U_D$.

The output voltage $V_H$ from the Hall-effect sensor is fed to $U_B$ and $U_C$. The outputs of $U_B$ and $U_C$ are fed to $U_D$, which serves as the output amplifier. Resistor $R_{13}$ is selected to provide the desired output-voltage offset, and $R_{14}$ is selected in conjunction with the number of turns in the coil on the core to provide the desired gain. Three units were built, 1 turn for 20 A, 2 turns for 10 A, and 20 turns for 1 A.

*This work was done by Colonel W. T. McLyman of Caltech for* **NASA's Jet Propulsion Laboratory**. *For further information, Circle 92 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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*Pasadena, CA 91125*

*Refer to NPO-17957, volume and number of this* NASA Tech Briefs *issue, and the page number.*

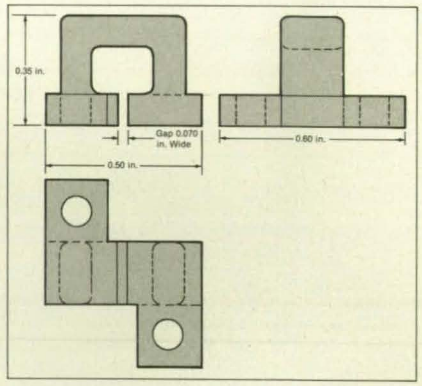


Figure 1. The **Magnetic Core** is machined from a solid block of high-permeability nickel/iron alloy.

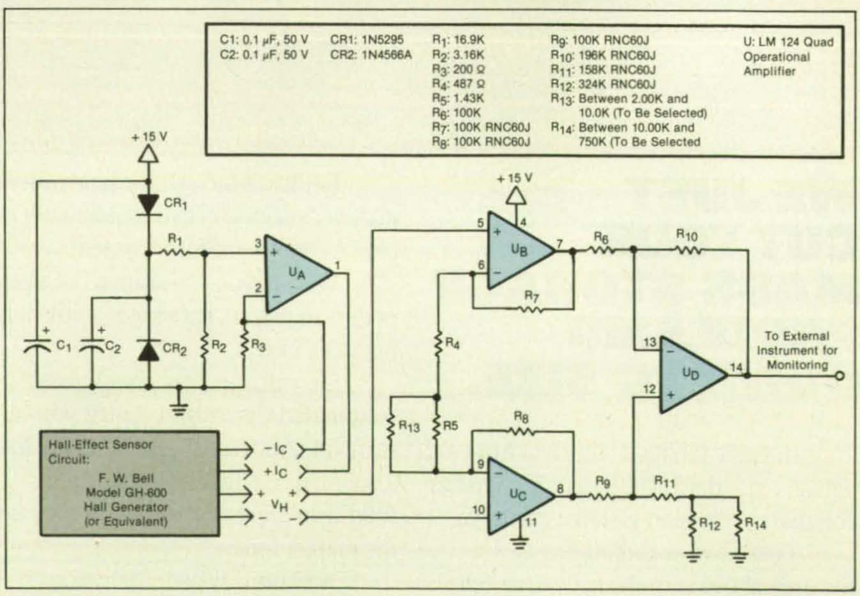


Figure 2. The **Transducer Circuit** excites a Hall-effect sensor and puts out a voltage that varies linearly with the sensed current.

# Electronic Systems



## Altering Interline Transfer in a CCD To Reduce Saturation

Charges accumulated during part of a frame period would be dumped.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

In a proposed interline-transfer timing scheme for a charge-coupled-device (CCD) video imaging array, the charges accumulated during some fraction of a frame period would be read out in the usual way, while the charges accumulated during the remaining fraction of a frame period would be swept out and dumped to prevent overloading and saturation in intensely illuminated photosites. The excess charges would be swept out at the highest possible rate, while the charges used for imaging would be read out at a rate that was lower but that was nevertheless the highest rate that would provide complete transfer of charge on the array and that could be handled by subsequent signal-processing equipment.

In the typical operation of an interline CCD, the charges accumulated in the photosites (picture elements) are periodically transferred from rows of photosites into columns of optically masked CCD transfer gates. These charges are sequentially stepped along the columns into a row shift register so that information on the image can be extracted as a series of charges in rows of picture elements. In interlaced scanning (to which the proposed scheme applies), the complete scene is read out in frames, each of which consists of two fields. The first field consists of the odd-numbered lines; the second, of the even-numbered lines.

Figure 1 illustrates two of several versions of the proposed timing scheme. Let $F$ denote the frame period, and let the zero of time be denoted as the leading edge of a pulse that would mark the beginning of readout of the odd field. A similar pulse would mark the beginning of readout of the even field at $F/2$. An interval of $F/4$ would be devoted to the readout of each field. In the first version of the timing scheme, the charges would be swept out of the odd (or even) field at some time during the interval of $F/4$ between the end of readout of that field and the beginning of readout of the subsequent even (or odd) field. In the second version, the charges would be swept out of each field at some time during the interval of $F/4$ that would immediately precede the readout of that field.

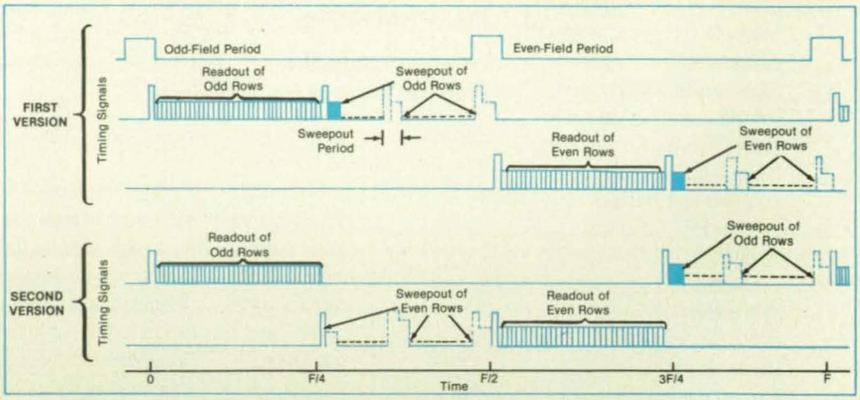


Figure 1. These **Timing Signals for Interline Transfer** of charges in a CCD would be used in two versions of the proposed scheme. In still other versions, the frame period, $F$, could be broken into intervals of $F/8$ or less.

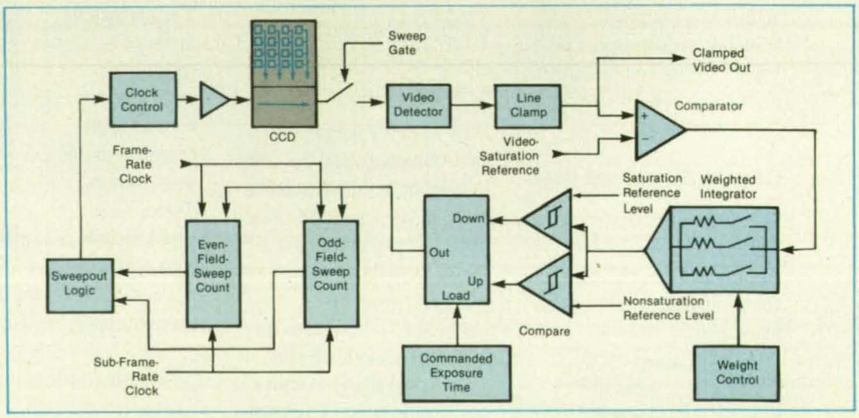


Figure 2. This **Control System** would vary the time of beginning of the last sweepout period for each field in such a way as to prevent or reduce the incidence of both overexposure and underexposure.

In both versions, the last sweepout of a field during each frame period would have to commence no later than one sweepout period before the beginning of the readout to follow. Provided that each such last sweepout occurred as late as possible and that the sweepout period was much shorter than $F/4$, the first version could dispose of as much as 1/4 the charges integrated during the frame period, $F$, allowing an overexposure of 4/3 the saturation intensity. The second version could allow a much greater overexposure because it would limit the charge-integration time to the time required to gain access to the photodetectors and sweep out the excess charges.

Figure 2 illustrates a scheme to control the time of the beginning of the last sweepout in response to the amount and location of overload in a scene. The readout charges would be passed from the CCD to a video detector and line clamp. The detector would filter the noise component out of the signal, while the clamp would fix the signal at a minimum dc reference level. A voltage comparator would indicate any picture elements in which the charge exceeded a reference level just below the saturation level of the CCD.

The output of the comparator would be integrated over a frame period to produce a signal indicative of the fraction of the CCD array that was saturated, if any. The integration could be weighted to emphasize the center or any other portion of the array. The output of the integrator would be applied to a pair of hysteretic voltage comparators, which would define a range of acceptable exposure. The comparators would drive the "up" and "down" control lines of a bidirectional counter, the output of which would determine the beginning of the last sweepout period. If overexposure were signaled, the counter would decrement by one count per frame until the exposure was sufficiently short or until the minimum integration time was reached. If underexposure were signaled, the counter would increment one count per frame to boost the signal. When correct exposure was signaled, no counting would occur.

*This work was done by Edward M. Rentsch of General Electric Co. for* **NASA's Jet Propulsion Laboratory**. *For further information, Circle 163 on the TSP Request Card.*
*NPO-17935*



## Knowledge-Based Flight-Status Monitor

Telemetered data from advanced aircraft would be processed automatically to detect failures.

*Ames Research Center, Moffett Field, California*

A conceptual digital computing system is intended to monitor and interpret telemetered data on the health and status of a complicated avionic system in an advanced experimental aircraft. When fully developed, the monitor would be programmed with expert-system software to interpret the data in real time. The software would include a rule-based model of the failure-management system of the aircraft that would process fault-indicating signals from the avionic system to give timely advice to human operators in the mission-control room on the ground. A prototype of the expert-system software was developed via the MUSE system, which is a software toolkit for the development of real-time applications of artificial intelligence.

In the flight-status monitor (see Figure 1), the telemetered data would be translated into digital words, then fed into the expert system, which would determine whether any changes in the data had occurred since the previous sample. The expert system would evaluate the effects of any such changes. A data-driven foreground loop would determine the state of the system and inform the user — in this case the systems engineer — of the changes and consequences. If a failure were detected, a warning or caution would be issued along with corrective or emergency procedures, when required. As a part of this evaluation, the expert system might ask the user questions on the state of the aircraft. A background task would allow the user to query the monitor for information on the state of the flight-control system or the rationale used to reach its conclusions. The expert system would interrupt the background task, when necessary, to evaluate new data, but if the state of the flight-control system had not changed between inputs, the expert system would not reevaluate that state.

The knowledge base would contain both rules specific to the aircraft and metarules, which are the rules that the systems engineer uses to determine the correct response to a failure. The flight-status monitor would use these rules to model the failure-detection subsystem of the flight-control system and compare the modeled state with that of the aircraft. If the conclusions of the monitor disagreed with the state of the aircraft, a warning would be issued, and the user could ask the system to resolve the conflict. The conflict would be resolved as part of the background task so as not to interfere with the higher-priority task of evaluating the aircraft data as they were received.

The prototype software consists of several separate expert systems, each with its own inference mechanism. The internal structure of the flight-status monitor, as represented in the software, is shown in Figure 2. The inference mechanisms involve predominantly forward-chaining, data-driven processes. The aircraft sensor-and-failure-management (ASFM) expert system uses a forward-chaining logic mechanism to model the failure-management system of the aircraft and to deduce conditions of concern or danger based on the failure-indicator information. A metamonitor expert system deduces situations of concern based on knowledge of deductions from the ASFM expert system and the failure-management system. The situations of concern deduced by the metamonitor are analyzed by a fault-isolation expert system that deduces probable causes of conflicts, recommends corrective actions, and issues warnings.

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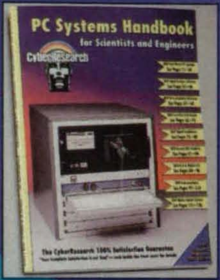


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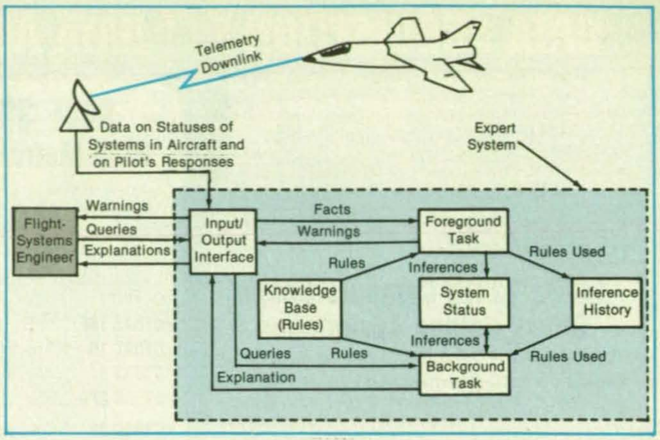


Figure 1. The **Flight-Status Monitor** would alert the flight-systems engineer to the need for corrective action in the event of a failure during flight.

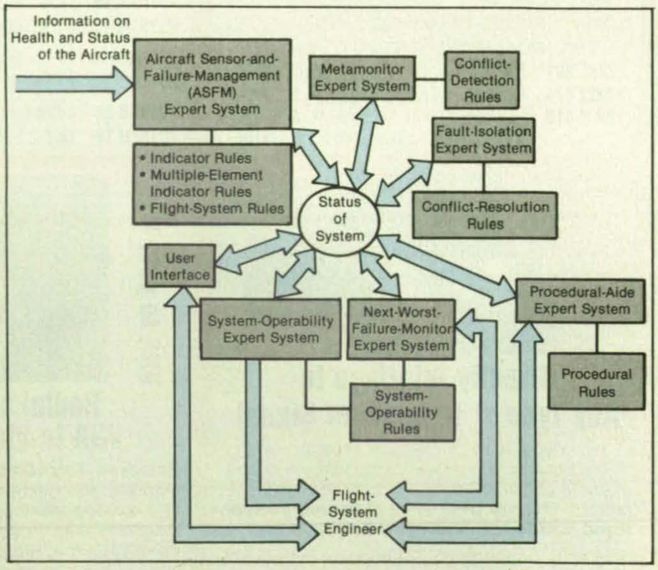


Figure 2. The **Internal Structure of the Flight-Status Monitor**, as envisioned in its software, includes several different representations of expert-system rules.

These expert systems provide detailed information on the status of the aircraft systems and perform a function comparable to that of an expert in flight systems.

The system-operability expert system uses knowledge of the effectiveness of the system and the detailed data on the status of the system to provide a high-level assessment of the ability of the flight-control system to control the aircraft, complete a specific mission, or function in a given mode. This assessment is performed by a backward-chaining mechanism, using hypotheses in an order established by the user. The order of the hypotheses is important because it provides a means for the expert system to determine priorities; the system uses this knowledge of priorities to determine the highest level at which the system is operable and provides this information to the user. The system-operability rules are also used to establish the worst consequences of any additional failure.

*This work was done by E. L. Duke of* **Ames Research Center**, *J.D. Disbrow of PRC Systems Services, Inc., and G. F. Butler of the Royal Aerospace Establishment. Further information may be found in NASA TM-101710 [N90-13995], "A Knowledge Based Flight Status Monitor for Real-Time Application in Digital Avionics Systems."*

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# Wideband Phase-Locked Angle Modulator

The modulator can be designed independently of the phase-locked loop.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

A modified configuration for a phase-locked angle modulator circuit makes it possible to design the filters in the modulating portion of the circuit independently of the filter in the phase-locked-loop portion (the "loop filter"). The bandwidth of the phase- or frequency-modulated output is not limited by the low-pass nature of the loop filter, as it is in a typical conventional phase-locked angle modulator.

The figure illustrates the conventional and modified phase-locked angle modulators. In the conventional circuit, the phase- or frequency-modulating signal, whichever the case may be, is applied at one of the two baseband positions of the feedback arm of the phase-locked loop. These are, respectively, the position immediately preceding or the position immediately following the loop filter. In the modified circuit, the modulating signal is applied through modulation filters to both baseband positions, so that the design of the modulator can be freed of the constraints that would otherwise be imposed by the loop filter.

An analysis of the transfer functions of the modified circuit shows that an appropriate choice of the modulation filters makes the output phase or frequency modulation independent of the transfer function of the loop filter. For phase modulation, this choice is $P(s) = s/K_OK_D$ and $Q(s) = 1$, where the symbols have the meanings indicated in the figure. The modulation filter denoted by this $P(s)$ is a differentiator with a time constant equal to $1/K_OK_D$. This choice makes the phase modulation of the output signal equal to $1/K_D \times$ the input modulating signal.

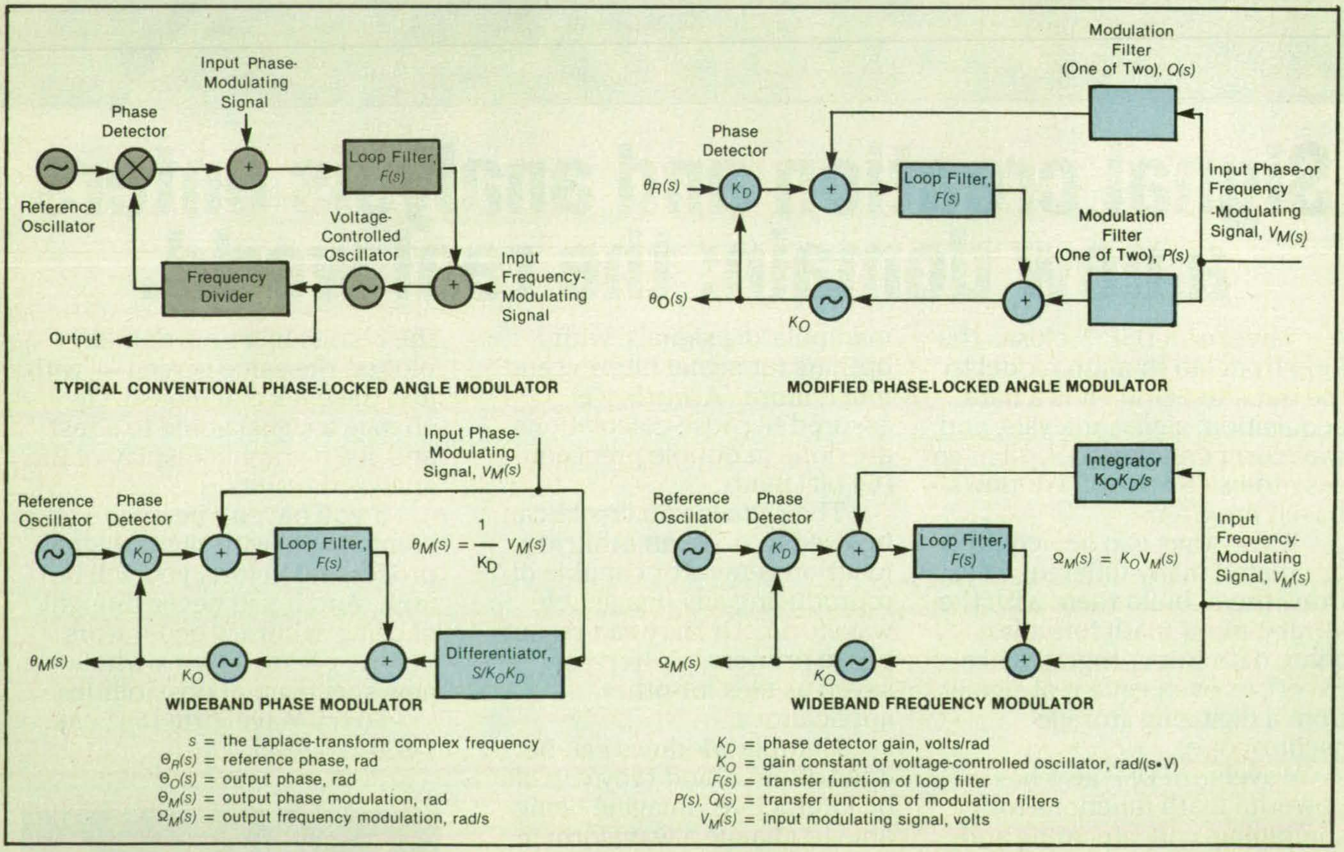
For frequency modulation, the choice is $P(s) = 1$ and $Q(s) = K_OK_D/s$. The modulation filter denoted by this $Q(s)$ is an integrator with a time constant equal to $1/K_OK_D$. This choice makes the frequency modulation of the output signal equal to $K_O \times$ the input modulating signal. As one can determine by examining the figure, the frequency modulator can be derived from the phase modulator by inserting an integrator in each of the modulating-signal-injecting arms.

This scheme is subject to the requirement to constrain the peak modulation index so that the total phase error at the input of the phase detector does not exceed the linear range of the phase detector. Also, because the phase-locked loop is a carrier-tracking loop, the modulation index must be constrained to prevent a carrier null at the input of the phase detector and to prevent saturation of the integrator or differentiator.

This scheme was applied to phase-modulate a phase-locked oscillator designed for low-noise performance at a carrier frequency of 2,290 MHz. Measurements showed that the 3-dB bandwidth of the output modulation spectrum was about 1.50 MHz, even though that of the phase-locked loop was only 75 kHz.

*This work was done by Lim Nguyen of Caltech for* **NASA's Jet Propulsion Laboratory**. *For further information, Circle 140 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 20]. Refer to NPO-18047.*




In the **Modified Phase-Locked Angle Modulator**, the modulating signal is applied at two points instead of at one point as it is in the conventional version. The wideband phase and frequency modulators are examples of the modified phase-locked angle modulator.

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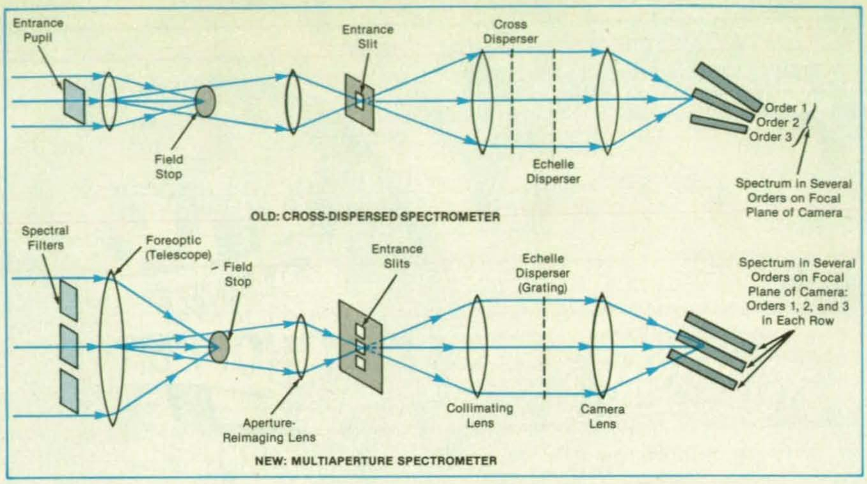
■ *London* ■ *Hamburg* ■ *Yokohama* ■ *California* ■ *Australia* ■ *Milan* ■ *Paris* ever, each grating acts as a partial polarizer, and therefore the two crossed gratings in a cross-dispersing spectrometer act partly like cross-polarizers, blocking much of the light that is needed to display the spectrum. In addition, the various orders of the spectrum in the output of a cross-dispersing spectrometer are not parallel.

The proposed multiaperture spectrometer (see figure) would use the available light more efficiently and display the various orders of the spectrum parallel to each other. To ensure that each entrance slit is illuminated by the same scene, the entrance pupil of the telescope that supplies the light to be analyzed would be made oversized and reimaged onto the plane of the entrance slits of the spectrometer. Inasmuch as the entrance pupil of the telescope and the entrance slits would be located at conjugate points with respect to each other, spectral-order-sorting bandpass filters could be placed at either location. Thus, the entrance aperture of the telescope would, in effect, be made into a series of apertures, each with its own filter.




The **Multiaperture Spectrometer** would produce parallel line images, each of which would be a highly spectrally resolved display of intensity vs. wavelength in the wavelength band of one of the orders of the spectrum produced by the grating.

*This work was done by Rudolf A. Schindler, Robert J. Pagano, and Fred G. O'Callaghan of Caltech for* **NASA's Jet Propulsion Laboratory**. *For further information, Circle 83 on the TSP Request Card. NPO-18011*

# Script-Factor Modeling of Absorption in a Solar Receiver

The script-factor formalism for gray-body thermal radiation is extended to sunlight.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

A method for the mathematical modeling of the reflection and absorption of solar radiation in a solar-energy receiver is derived by extending the gray-body script-factor method to the solar spectrum. The gray-body script-factor method is well established and is used conventionally to compute the infrared-radiation couplings among nodes of a solar receiver.

In the conventional gray-body script-factor method, each node is treated as a gray body (meaning that its absorptivity is assumed to equal its emissivity) with respect to the infrared portion of the electromagnetic spectrum, and the net rate of transfer of heat from node $i$ to node $j$ is given by

$$Q_{ij} = A_i \mathcal{F}_{ij} (B_i - B_j)$$

where $B_k = \sigma T_k^4$ denotes the infrared flux density that node $k$ would emit if it were a perfectly black body at absolute temperature $T$, $\sigma$ is the Stefan–Boltzmann constant, $A_i$ is the area of the $i$th node, and $\mathcal{F}_{ij}$ is the script factor, which summarizes the effects of all reflections within the cavity upon the radiative transfer of heat between nodes $i$ and $j$.

When solar radiation from a solar concentrator enters a receiver cavity, it undergoes multiple reflections within the cavity. It is necessary to compute the net solar power absorbed by each node, accounting for all internode reflections, in order to analyze the thermal conditions within the receiver in detail. The script-factor method is particularly well suited to this purpose. In extending this method to the incoming and reflected solar radiation (which has a spectrum different from that of the infrared gray-body radiation), one makes an analogy between the reflections of solar radiation and the reflections of infrared gray-body radiation.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Let the flux density of solar radiation initially incident on node $i$ be denoted as $S_i$. Let $\alpha_i$, $\epsilon_i$, and $\rho_i = 1-\alpha_i$ denote the solar absorptivity, infrared emissivity, and solar reflectivity of node $i$, respectively. The initially reflected flux, $S_i\rho_i$, is the imaginary solar "emission" of this node. Assuming that node $i$ behaves as a gray body with respect to the solar spectrum and that it reflects solar radiation diffusely, one can model the solar flux density reflected from node $i$ as solar gray-body radiation characterized by an effective solar black-body flux density

$$B_{i,s} = S_i\rho_i/\alpha_i$$

The script factor $\mathfrak{I}_{ij,s}$ for the solar spectrum is computed by the same method used to compute $\mathfrak{I}_{ij}$ for the infrared spectrum, except that the solar absorptivity, $\alpha_i$, is used in place of the infrared emissivity.

Then the net solar power transferred from node $i$ to all other nodes by numerous reflections among all the nodes is given by

$$Q_{refl,i} = A_i \sum_j (Bi,s-Bj,s)\mathfrak{I}_{ij,s}$$

A heat balance on a given node implies that the total solar power absorbed by that node is simply the difference between the solar power initially incident on that node (from the concentrator) and the net solar power transferred from that node to all other nodes. Therefore, the net solar power absorbed by node $i$ is given by

$$Q_{abs,i} = A_i S_i - Q_{refl,i}$$

*This work was done by Pradeep Bhandari of Caltech for* **NASA's Jet Propulsion Laboratory**. *For further information, Circle 102 on the TSP Request Card.*
*NPO-18018*

## 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.

### Spaceborne Microwave Imagers

Principles and practices are described.

A monograph presents a comprehensive overview of the science and technology of spaceborne microwave-imaging systems. Microwave imagers are used as versatile orbiting, remote-sensing systems to investigate the atmospheres and surfaces of planets. For example, they can detect surface objects through canopies of clouds, measure distributions of raindrops in the clouds that their views penetrate, find meandering rivers in rain forests and underground water in arid regions, and provide information on ocean currents, wakes, ice/water boundaries, aircraft, ships, buoys, and bridges.

The document begins by presenting general background information on the nature and capabilities of spaceborne microwave imagers. This is followed by a general description of microwave-imaging equipment, with emphasis on antennas, scanning mechanisms, and receivers. The geometrical and functional relationships between an orbiting imager and the scene under observation, and the use of both horizontally and vertically polarized microwave radiation are discussed.

The equations that describe the radiative transfer of power are derived from basic physical principles. The thermodynamic temperature (an effective microwave-brightness temperature of the scene viewed by the microwave imager, and distinguished from the thermometric temperature, which would be measured by a thermometer in contact with an object in the scene) is expressed in closed form as a sum of cosmic, surface, and upwelling contributions. The equivalence between microwave power and thermodynamic temperature is established. The laws of thermodynamics are then applied to show the directions and amounts of flow of microwave energy among multiple bodies.

Examples are presented to illustrate the detection of such surface features as emitting (warm) objects, cold objects, and metal objects (which stand out in microwave scenes because their high electrical conductivities alter radiation patterns). The bistatic (forward- and back-scattering) cross sections of aircraft, ships, and metal buoys are discussed, with descriptions of a mathematical model, calculations, and the underlying theory. Examples of the detection of ships, aircraft, and buoys in images produced by orbiting microwave radiometers are presented, along with computed signal-to-clutter ratios for these objects.

The main text concludes with a general discussion of concepts of spaceborne microwave imagers. Examples of existing and contemplated planetary imagers are presented. Principal elements of microwave technology that are essential for remote sensing of the surfaces and atmospheres of planets are identified.

*This work was done by J. M. Stacey of Caltech for* **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Spaceborne Microwave Imagers — Principles and Practices," Circle 30 on the TSP Request Card.*
*NPO-17094*

# Imide/Arylene Ether Copolymers

Films cast from solution are tough and flexible, and exhibit useful thermal and mechanical properties.

*Langley Research Center, Hampton, Virginia*

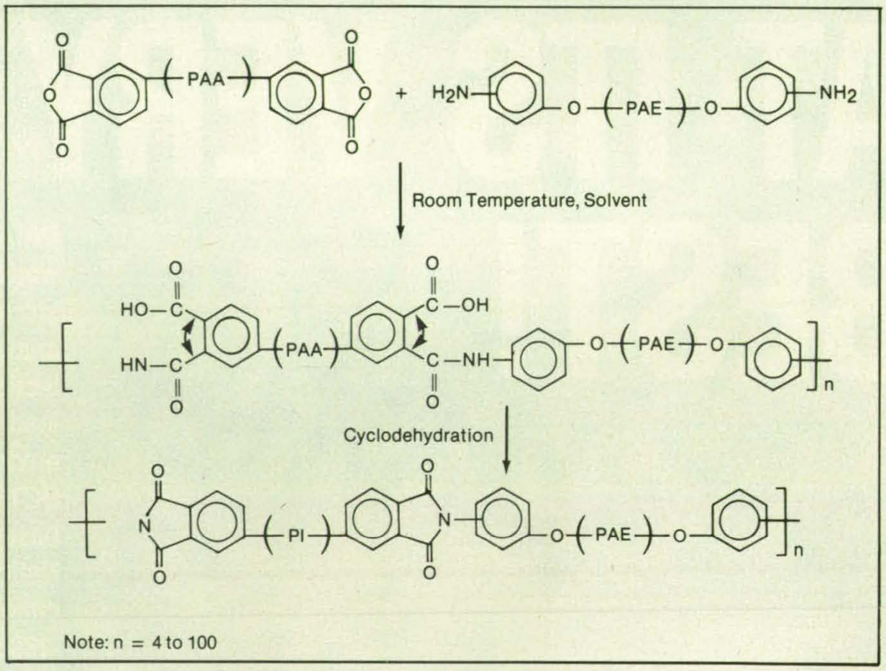
New imide/arylene ether copolymers have been prepared by reacting anhydride-terminated poly(amic acids) with amine-terminated poly(arylene ethers) in polar aprotic solvents. Each resulting copolymer may have one glass-transition temperature or two, depending on the chemical structure and/or compatibility of the block units. Most of the copolymers form tough, solvent-resistant films with high tensile properties.

Polyimides are condensation polymers commonly synthesized by the reaction of aromatic dianhydrides with aromatic diamines. The intermediate poly(amic acids) are either thermally or chemically cyclodehydrated to form the polyimides. Wholly aromatic linear polyimides are known for their exceptional thermal, thermo-oxidative, and chemical resistance, but are generally difficult to process as structural adhesives or composite matrices. Several polyimides are commercially available as films, moldings, adhesives, and composite matrices.

Poly(arylene ethers) are condensation polymers commonly synthesized by nucleophilic displacement of activated aromatic halides in polar aprotic solvents by alkali metal phenates. Poly(arylene ethers) are known for their good mechanical properties, good thermo-oxidative stabilities, relative ease of processing, and solubility in common organic solvents. Several poly(arylene ethers) are commercially available and are used as films, moldings, adhesives, and composite matrices.

In an attempt to take advantage of the attractive features of both types of polymers, a series of block copolymers that contain polyimide and poly(arylene ether) segments were synthesized. A wide variety of imide and arylene ether repeat units can be used to yield copolymers with specific desired properties. Furthermore, the length of the blocks, for both the imide and the arylene ether, is easily controlled. By varying the length of the blocks, one can alter the properties of the copolymer to produce materials with the desired physical and mechanical properties.

The imide/arylene ether copolymers were synthesized from the reaction of anhydride-terminated poly(amic acids) and amine-terminated poly(arylene ethers). After curing, the resulting block copolymers had glass-transition temperatures from 165 °C to 270 °C. Some had two glass transitions, corresponding to the arylene ether segment and to the imide segment, indicating a phase separation in the films due to incompatibility of block segments of higher molecular weight. Solution-cast, unoriented films of the copolymers were tough and flexible with tensile strength, tensile moduli, and elongation at break up to 16,200 psi (112 MPa), 431,000 psi (2.97 GPa), and 23 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.



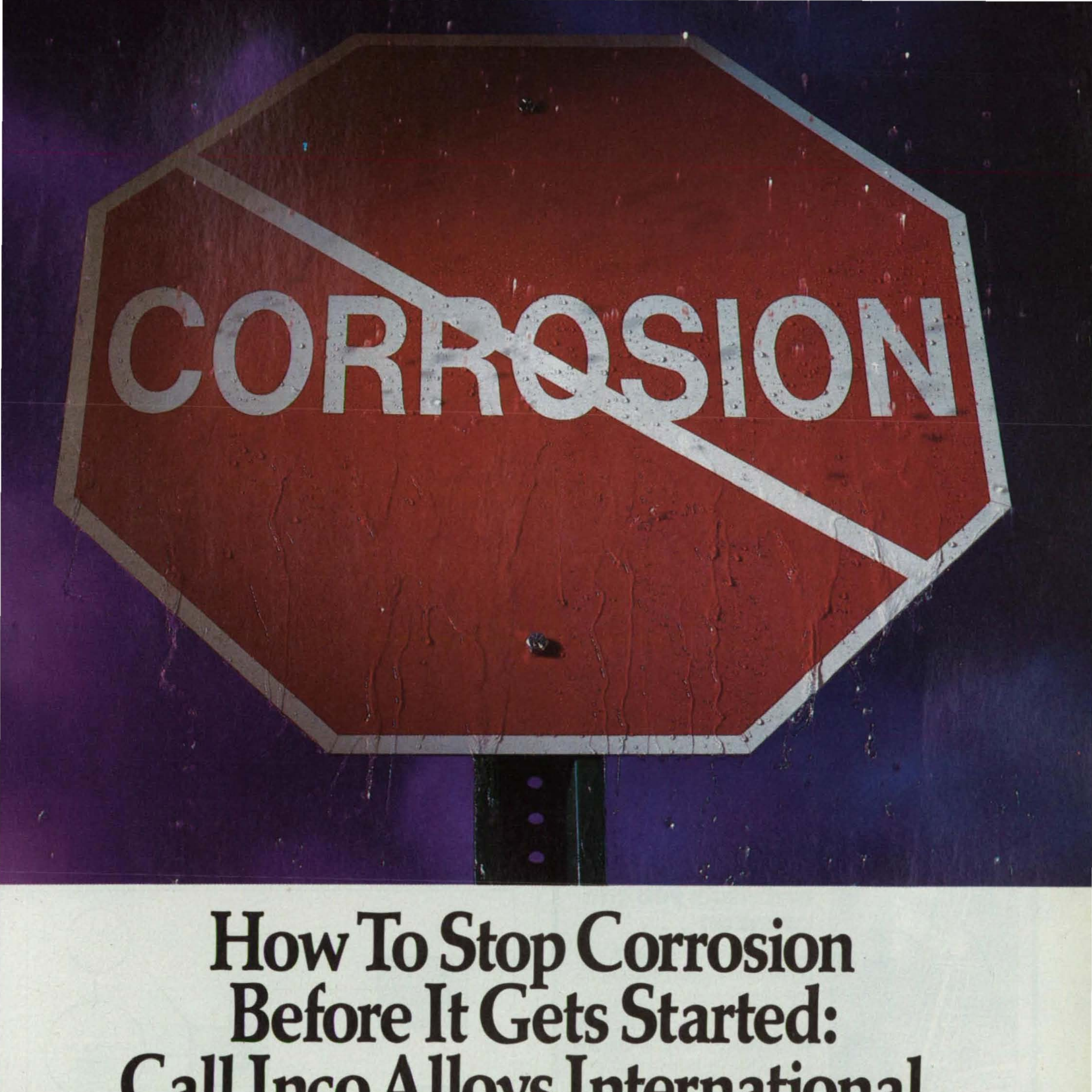

**Imide/Arylene Ether Block Copolymers** are synthesized by reacting anhydride-terminated poly(amic acids) with amine-terminated poly(arylene ethers) in polar aprotic solvents.

The general reaction sequence for the block copolymers is represented by the equation shown in the figure, wherein PAA represents a poly(amic acid) synthesized by reacting excess dianhydride with a diamine, and PAE represents a poly(arylene ether) synthesized by reacting an activated aromatic dihalide with a bisphenol. The solvent for copolymer preparation is preferably N,N-dimethylacetamide, but can be N-methylpyrrolidinone, *m*-cresol, N,N-dimethylformamide, dimethyl sulfoxide, or any of such ether solvents as diglyme. Cyclodehydration is accomplished chemically or by heating the intermediate poly(amic acid) at temperatures exceeding 150 °C.

Films were prepared from the new copolymers and found to have useful thermal and mechanical properties. The new materials are potentially useful as films, moldings, adhesives, or composite matrices. Because of the flexible arylene ether blocks, these copolymers are easier to process than polyimides are.

*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 130 on the TSP Request Card.*

*This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 20]. Refer to LAR-14159.*

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# Impregnating Coal With Calcium Carbonate

Gasification and combustion would be enhanced, and sulfur would be bound in calcium sulfide.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

A relatively inexpensive process has been proposed for impregnating coal with calcium carbonate to increase the rates of gasification and combustion of the coal and to reduce the emission of sulfur by trapping the sulfur in calcium sulfide. The process, which would involve aqueous-phase reactions between carbon dioxide ($CO_2$) (contained within the pore network of the coal) and calcium acetate, would be more economical than were previous ones in which $CO_2$ was adsorbed in the coal by first evacuating the coal, then exposing the evacuated coal to $CO_2$ at or near atmospheric pressure. In the new process, the coal would be impregnated with $CO_2$ by exposing it to $CO_2$ at high pressure.

The individual reactions and the overall reaction for the impregnation of the coal by calcium carbonate are represented by the following equations:

$$\underset{}{H_2O} + \underset{\text{(calcium acetate)}}{Ca(C_2H_3O_2)_2} + CO_2 \longrightarrow \underset{\text{(calcium carbonate)}}{CaCO_3} + \underset{\text{(acetic acid)}}{2C_2H_3O_2H}$$

$$2C_2H_3O_2H + \underset{\text{(calcium hydroxide)}}{Ca(OH)_2} \longrightarrow Ca(C_2H_3O_2)_2 + 2H_2O$$

$$\overline{Ca(OH)_2 + CO_2 \longrightarrow CaCO_3 + H_2O}$$

As the equations show, the calcium acetate consumed in the first reaction would be replenished in the second reaction. Consequently, the process would consume relatively cheap calcium hydroxide instead of relatively expensive calcium acetate.

Four versions of the process have been proposed. In the first version (see figure), the raw coal would be placed in a chamber filled with $CO_2$ at a pressure of 2, 5, or 10 atm (about 0.2, 0.5, or 1.0 MPa). The coal would then be depressurized and quickly placed in contact with a slurry consisting of $Ca(OH)_2$ suspended in an aqueous solution of calcium acetate. In the second version of the process, the coal would be pretreated by heating it to 50 °C for 24 h to remove moisture, which would otherwise interfere with the adsorption of $CO_2$. The coal would then be treated as in the first version. In the third version, either the raw coal or the coal heated as in the second version would be pulse-pressurized with $CO_2$ in a rapid sequence of pressurization and depressurization to replace water and preadsorbed gases with $CO_2$ prior to impregnation with calcium carbonate. In the fourth version, the raw or preheated coal would be pretreated for a short time with saturated calcium hydroxide solution. The pretreated coal would then be pressurized with $CO_2$ and treated with the calcium acetate solution and $Ca(OH)_2$ as in the other versions.

*This work was done by Pramod K. Sharma, Gerald E. Voecks, and George R. Gavalas of Caltech for* **NASA's Jet Propulsion Laboratory**. *For further information, Circle 61 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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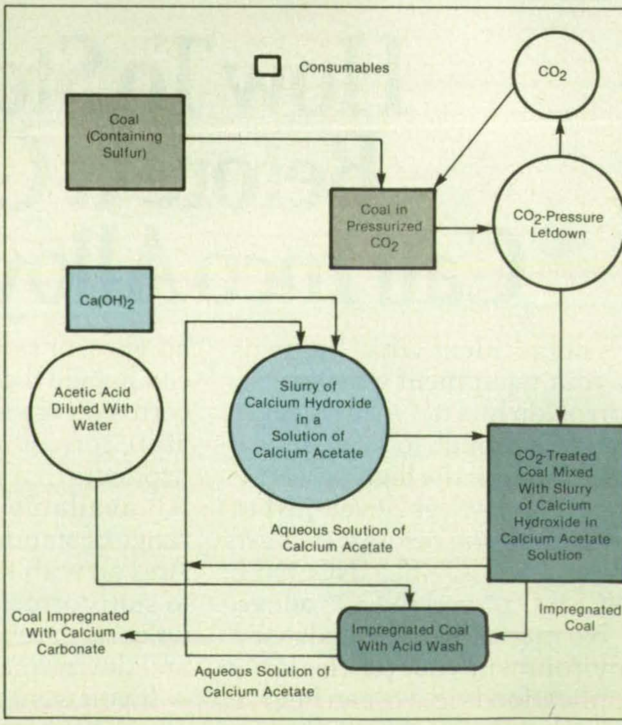
*Refer to NPO-17696, volume and number of this* NASA Tech Briefs *issue, and the page number.*

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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.

## Electronic Systems

### Estimating Rain Attenuation in Satellite Communication Links

Attenuation is computed with the help of a statistical model and meteorological data.

The frequency and intensity of rain attenuation on the communication between a satellite and an Earth terminal are important factors in the design of a satellite communication link. The NASA Lewis Research Center Satellite Link Attenuation Model (SLAM) program is a QuickBASIC computer program that evaluates the static and dynamic statistical assessment of the impact of rain attenuation on a communication link established between an Earth terminal and a geosynchronous satellite. This program will find application in the specification, design, and assessment of satellite communication links for any terminal location in the continental United States. SLAM is designed for use on IBM personal computers and compatibles with monitors capable of supporting an 80-column format and associated printers.

The basis for SLAM is the ACTS Rain Attenuation Prediction Model, which uses a log-normal cumulative probability distribution to describe the random process of rain attenuation on satellite links. The derivation of the statistics for the rain-rate process at the location of interest relies on long-term rainfall records compiled by the U.S. Weather Service during intervals as long as 55 years. The theory of extreme-value statistics is also utilized.

The information needed by the user to implement this program is (1) the longitude of the satellite in geosynchronous orbit, (2) the position of the Earth terminal in terms of latitude and longitude, (3) the height of the terminal above sea level, (4) the yearly average rainfall at the terminal site, and (5) the operating frequency of the communication link between the satellite and Earth terminal (this frequency must be within the range from 1 to 1,000 GHz, inclusive). On the basis of the location of the terminal (which can be anywhere within the continental United States) and the yearly average rainfall at the location, SLAM calculates the relevant prevailing rain statistics for the site by use of an internal data base.

The program then generates the data concerning the occurrence of rain attenuation on the satellite link. These data include (1) the three parameters that are needed to characterize the log-normal probability density function that is taken to describe the static (i.e., yearly) attenuation process, (2) an evaluation of the cumulative probability distribution that is derived from such a density function for selected link attenuations, and (3) an evaluation of the probability of the occurrence of selected durations of fades below selected fade depths. In addition, SLAM calculates the elevation and azimuth angles of the terminal antenna required to establish a link with the satellite, the statistical parameters that characterize the rain-rate process at the terminal site (also described as a log-normal process), the length of the propagation path within the potential rain region, and the projected length of this path onto the local horizontal. A user-support mailing address and telephone number are given in the accompanying document.

SLAM was implemented on an IBM PC with the MS-DOS 3.21 operating system. The program is written in Microsoft QuickBASIC and has a memory requirement of about 30K bytes. An executable code is provided. SLAM was developed in 1989.

*This program was written by R. M. Manning of* **Lewis Research Center**. *For further information, Circle 84 on the TSP Request Card.* LEW-14979

### Neural-Network Simulator

The F77NNS program implements a back-propagation algorithm.

The F77NNS (A FORTRAN-77 Neural Network Simulator) computer program simulates the popular back-error-propagation neural network. Written in ANSI-77 FORTRAN, F77NNS is designed to take advantage of vectorization when used on computers that have this capability, but it can also be used on any computer equipped with an ANSI-77 FORTRAN Compiler. Problems that involve the matching of patterns or the mathematical modeling of systems readily fit the class of problems that F77NNS is designed to solve.

An artificial neural network is formed from hundreds or thousands of simulated neurons connected to each other in a manner similar to that of biological nerve cells. Typically, the nodes of a network are grouped together into clumps called layers. A typical network includes an input layer through which the various environmental stimuli are presented to it, and an output layer that determines the response to the stimuli. The number of nodes in these two layers is usually tied to features of the problem being solved. Other layers, which form intermediate stops between the input and output layers, are called hidden layers.

The program trains a neural network by use of Rumelhart's back-propagation algorithm. The back-propagation training algorithm can require massive computational resources when applied to a large network like one capable of learning text-to-phoneme pronunciation rules as in the famous Sehnowski experiment. (The Sehnowski neural network learns to pronounce 1,000 common English words.) The standard input data define the specific inputs that control the type of run to be made, and input files define the neural network in terms of the layers and nodes, as well as the input/output (I/O) pairs.

The program has a restart capability so that a neural network can be solved in stages suitable to the user's resources and desires. F77NNS enables the user to customize the patterns of connections between layers of a network. The size of the neural network to which F77NNS can be applied is limited only by the amount of random-access memory available to the user. The program has a memory requirement of about 900 KB and was developed in 1989.

*This program was written by Paul H. Mitchell of* **Johnson Space Center**. *For further information, Circle 123 on the TSP Request Card.* MSC-21638

## Physical Sciences

### Program Processes SAR Data

The MacMultiview program computes polarimetric and other images.

MacMultiview is an interactive software tool for the Macintosh II family of computers that enables one to display, and make computations that use, polarimetric radar data collected by the Jet Propulsion Laboratory's imaging SAR (synthetic-aperture radar) polarimeter system. The system includes the single-frequency L-band sensor mounted on the NASA CV990 aircraft and its replacement, the multifrequency P-, L-, and C-band sensors mounted on the NASA DC-8 airplane.

MacMultiview provides two basic functions: synthesis of polarimetric images and computation of polarization signatures. The radar data can be used to compute a variety of images. The total-power image displays the sum of the polarized and unpolarized components of the backscatter for each picture element. The magnitude/phase-difference image displays the difference between the phases of the HH (horizontal transmitting and horizontal receiving polarization) signals and the VV (vertical transmitting and vertical receiving polarization) signals by use of color. Magnitude is displayed as intensity. The user may also select any combination of transmitting and receiving polarizations from which an image is synthesized. This image displays the backscatter that would have been observed, had the sensor been configured to use the selected transmitting and receiving polarizations.

MacMultiview can also be used to compute polarization signatures, which are three-dimensional plots of backscatter versus transmitting and receiving polarizations. The standard copolarization signatures (transmitting and receiving polarizations the same) and cross-polarization signatures (transmitting and receiving polarizations orthogonal) can be plotted for any rectangular subset of picture elements within a set of radar data. In addition, the ratio of copolarization and cross-polarization signatures computed from different subsets within the same set of data can also be computed.

Computed images can be saved in a variety of formats: byte format (headerless format, which saves the image as a string of byte values), MacMultiview (a byte image preceded by an ASCII header), and PICT2 format (standard format readable by MacMultiview and other image-processing programs for the Macintosh computer). Images can also be printed on PostScript output devices.

Polarization signatures can be saved in either a PICT format or a text file containing PostScript commands and can be printed on any QuickDraw output device. The associated Stokes matrices can be stored in a text file.

The only computers on which MacMultiview can be executed are those of the Macintosh II family that are equipped with 8-bit video (gray shades or color). The program also requires a minimum configuration of System 6.0, Finder 6.1, and 1 megabyte of memory. Macintosh Programmer's Workshop and Macintosh Programmer's Workshop C (version 3.0) are required for recompiling and relinking. The program is written in C and was developed in 1989.

*This program was written by Lynne Norikane and Howard Zebker of Caltech for* **NASA's Jet Propulsion Laboratory**. *For further information, Circle 108 on the TSP Request Card.* NPO-18048

### Calculating Thermophysical Properties of 12 Fluids

Properties are expressed via equations of state.

MIPROPS is a set of computer programs that gives the thermophysical and transport properties of selected fluids. Although these programs are written in FORTRAN 77 for implementation on microcomputers, they are direct translations of interactive FORTRAN IV programs that were originally developed for large mainframe computers. MIPROPS calculates the properties of fluids in both the liquid and vapor states over a wide range of temperatures and pressures. The fluids included are helium, hydrogen, nitrogen, oxygen, argon, nitrogen trifluoride, methane, ethylene, ethane, propane, isobutane, and normal butane.

All of the programs except the helium program incorporate the same equation of state. A separate program was necessary for helium, as the mathematical model for the thermodynamic surface of helium is of a different form. The input variables are any two of pressure, density, or temperature for the single-phase regions, and either pressure or temperature for the saturated-liquid or saturated-vapor states. The output is pressure, density, temperature, internal energy, enthalpy, entropy, specific heat capacities, and speed of sound. In addition, viscosity, thermal conductivity, and dielectric constants are calculated for most of the fluids. The user can select either a single point or a table of output values for a specified temperature range, and can display the data in either engineering or metric units.

This machine-independent FORTRAN 77 program was implemented on an IBM PC XT computer with an MS-DOS 3.21 operating system. It has a memory requirement of approximately 100K bytes. The program was developed in 1986.

*This program was written by T. F. Cleghorn and R. D. McCarty of* **Johnson Space Center**. *For further information, Circle 88 on the TSP Request Card.* MSC-21664

## Mechanics

### Program Calibrates Strain Gauges

Time required for acceptance tests of hardware is reduced.

Strain data are required for the processing of such pieces of aerospace hardware as the three bolts used to attach the external fuel tank to the Space Shuttle orbiter. The acquisition of these data has traditionally required a time-consuming and inefficient manual process that includes setting up a strain-gauge indicator, reading and recording strain data, and tabulating and plotting strain data versus a load or other parameter. The time and personnel requirements of the traditional method led researchers to develop a computer program to increase the efficiency of the acceptance test performed on these bolts.

The data-acquisition system reads the output from a Wheatstone full-bridge strain-gauge circuit and calculates strain by use of the shunt calibration technique. The program nearly instantaneously tabulates and plots strain data against load-cell outputs, thus saving hours of manual work per test run. The comparative speed and efficiency of this technique was empirically proven by a calibration test of one of the external-tank/orbiter attachment bolts. The use of the program dramatically reduced personnel and time requirements. Re-

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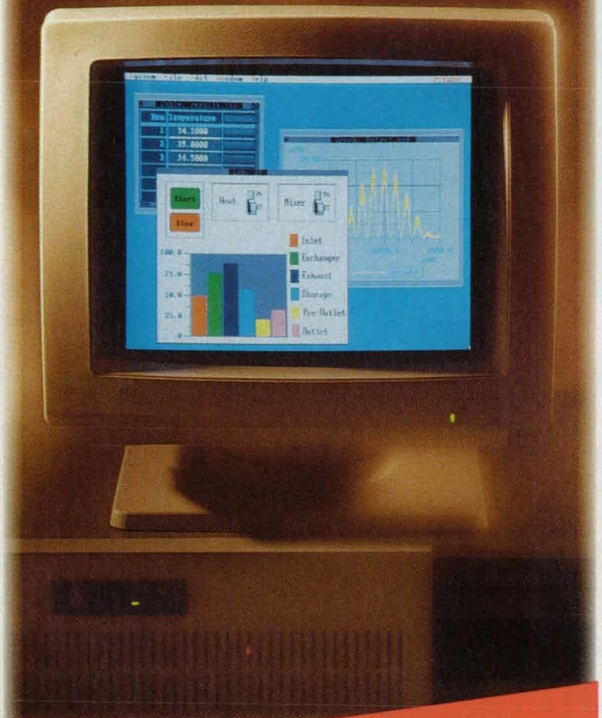


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searchers verified the accuracy and integrity of the program by comparing its output strain data to those of a calibrated strain-gauge indicator formerly used in the manual method. The program can also be modified to acquire strain data for other specimens wherever full-bridge strain-gauge circuits are used.

The program was developed in 1985 on a Hewlett Packard 9845B Microcomputer. It is written in HP BASIC and is available as a listing only.

*This program was written by Gary D. Okazaki of Rockwell International Corp. for* **Johnson Space Center**. *For further information, Circle 38 on the TSP Request Card.*
*MSC-21399*

## Integrated Analysis Capability Program

### This modular software system facilitates multidisciplinary analyses of structures and other systems.

The Integrated Analysis Capability (IAC) software system is intended to provide a highly effective, interactive analysis tool for the integrated design of large structures. With the goal of supporting the unique needs of engineering analysis groups concerned with interdisciplinary problems, IAC was developed to serve as a software interface between computer programs from the fields of structures, thermodynamics, controls, and the dynamics of systems on the one hand and an executive software system and data base on the other hand to yield a highly efficient multi-disciplinary system. Special attention is given to such users' requirements as handling data and online assistance with operational features and the ability to add new modules of the user's choice at a future date.

IAC contains an executive software system, a data base, general software utilities, interfaces to various engineering programs, and a software framework for building interfaces to other programs. IAC has shown itself to be effective in the automatic transfer of data among analysis programs. IAC 2.5, designed to be compatible as far as possible with level 1.5, contains a major upgrade in executive and data-base management system capabilities and includes interfaces to enable analyses of thermal problems, structures, optics, and the dynamics of control interactions.

The IAC software system is modular: (1) The executive module contains an input command processor, an extensive data-management system, and driver code to execute the application modules. (2) Technical modules provide "stand-alone" computational capability as well as support for various solution paths or coupled analyses. (3) Graphics and model-generation interfaces are supplied for building and viewing models. Advanced graphics capabilities are provided within such analysis modules as INCA and NASTRAN. (4) Interface modules provide for the required flow of data between IAC and other modules. (5) User modules can be arbitrary executable programs or job-control-language procedures with no predefined relationship to IAC. (6) Special-purpose modules are included: for example, MIMIC (Model Integration via Mesh Interpolation Coefficients), which transforms field values from one model to another; LINK, which simplifies incorporation of user-specific modules into IAC modules; and DATAPAC, a statistical-analysis package of the National Institute of Standards and Technology (formerly, the National Bureau of Standards).

The IAC data base contains structured files that provide a common basis for communication between modules and the executive system and can contain such unstructured files as NASTRAN checkpoint files, DISCOS plot files, object code, and the like. The user can define groups of data and relations between them. A full data-manipulation and query system operates with the data base.

The current interface modules comprise five groups:

1. Structural Analysis — IAC contains a NASTRAN interface for stand-alone analysis or certain structural/control/thermal combinations. IAC provides enhanced structural capabilities for normal-vibrational-mode and static-deformation analysis via special DMAP sequences. IAC 2.5 contains several specialized interfaces from NASTRAN in support of multidisciplinary analysis.
2. Thermal Analysis — IAC supports finite-element and finite-difference techniques for steady-state or transient analysis. There are interfaces for the NASTRAN thermal analyzer, SINDA/SINFLO, and TRASYS II. There is also an interface between the IAC data base and FEMNET, which converts finite-element structural-analysis models to finite-difference thermal-analysis models.
3. System Dynamics — There is a full interface between the IAC data-management capability and the DISCOS simulation program, which allows for either nonlinear time-domain analysis or linear frequency-domain analysis.
4. Control Analysis — Interfaces for the ORACLS, SAMSAN, NBOD2, and INCA programs provide for a wide range of techniques for the analysis and synthesis of control systems. Level 2.5 includes EIGEN, which provides the capability to obtain the eigenvalues of systems of large order, and BOPACE, which provides geometric capabilities and capabilities for finite-element analysis in the case of

a nonlinear material. Also included in IAC level 2.5 is SAMSAN 3.1, an engineering analysis program that contains a general-purpose library of over 600 subroutines for numerical analysis.

5. Graphics — The graphics package IPLOT is included in IAC. IPLOT generates vector displays of tabular data in the form of curves, charts, correlation tables, and the like. Either DI3000 or PLOT-10 graphics software is required for full graphic capability.

In addition to these analysis software tools, IAC 2.5 contains an IGES interface, which enables the user to read arbitrary IGES files into an IAC data base and to edit and put out new IGES files.

IAC is available by license for 10 years to approved U.S. licensees. The licensed program product includes one set of supporting documentation. Additional copies may be purchased separately.

IAC is written in FORTRAN 77 and has been implemented on a DEC VAX-series computer operating under VMS. IAC can be executed by multiple concurrent users in batch or interactive mode. The program is structured to enable users to delete easily those program capabilities and "how-to" examples they do not want, to reduce the size of the program. The basic central-memory requirement for IAC is approximately 750 KB. The following programs are also available from COSMIC as separate packages: NASTRAN, SINDA/SINFLO, TRASYS II, DISCOS, ORACLS, SAMSAN, NBOD2, and INCA. The development of level 2.5 of IAC was completed in 1989.

*This program was written by R. G. Vos, D. L. Beste, and J. Greg. of Boeing Aerospace Corporation and H. P. Frisch of* **Goddard Space Flight Center**. *For further information, Circle 7 on the TSP Request Card.*
*GSC-13341*

# Mathematics and Information Sciences

## Library of Subprograms in FORTRAN 77

### Subprograms can be called upon as needed to perform specific computations.

MATH77, Release 3.17, is a library of 412 FORTRAN 77 subprograms for use in numerical computation. Researchers at the Jet Propulsion Laboratory developed the library to facilitate scientific and engineering computation.

The wide variety of computers used to perform numerical computation in scientific laboratories requires a collection of mathematical subprograms that is portable among a significant number of computing environments. The MATH77 library provides this portability. Subprograms that provide machine and system characteristic parameters make the library operational on any computer system that supports the full FORTRAN 77 standard. The portability of the library and the high quality of its subprograms and user's manual make MATH77 an extremely versatile and valuable tool for all numerical computation applications.

The library contains subprograms that perform such tasks as the computation of special functions, the generation of pseudorandom numbers, linear least-squares analysis, singular-value analysis, the solution of equations, minimization, curve fitting, Hermite cubic interpolation, quadrature, ordinary differential equations, finding the roots of polynomials, fast Fourier transforms, special arithmetic propagating derivative values, basic statistics, and printer plotting. The library, demonstration drivers, and test drivers are stored in compressed form and are expandable with a program included in the package.

MATH77 was developed during 1980–89. It is written in FORTRAN 77 and is suitable for use on any computer system that supports the full FORTRAN 77 standard. The program and documentation are copyrighted products of the California Institute of Technology.

*This program was written by Charles L. Lawson, Fred T. Krogh, William Van Snyder, and Stella Y. Chiu of Caltech for* **NASA's Jet Propulsion Laboratory**. *For further information, Circle 119 on the TSP Request Card.* *NPO-18120*

## Software for Depiction of Three-Dimensional Objects

### This program enables the user to build, manipulate, and display hierarchical three-dimensional objects.

The use of hierarchy in a mathematical modeling environment is critical for effective simulation of real objects. For a model that involves a combination of several moving parts, hierarchy is necessary to establish the network of dependent relationships that govern the movements of the parts and the model as a whole. HME (the Hierarchical Modeling Environment) is a three-dimensional computer-graphics



 **Circle Reader Action No. 365** 

software system designed to give the user complete access to the total hierarchical mathematical model.

HME enables the user to build, manipulate, and display hierarchical three-dimensional objects dynamically. The program also includes created polygons in the hierarchy. The window-oriented user interface enables the manipulation of objects by use of the mouse, windows, menus, buttons, and sliders. A hierarchy window depicts the hierarchy of the mathematical model environment. The user can point at any node on the hierarchy and use a powerful set of standard options to edit, copy, create, or save that portion of the hierarchical environment. With HME, it is easy to establish and edit the proper coordination of eye points, sources of light, and connectivity of the model necessary for accurate depiction of the model.

HME is written in C language for Silicon Graphics IRIS workstations supporting the 4Sight windowing software system and at least version 3.1 of the operating system. The program requires approximately 650 KB of memory and was developed in 1989.

*This program was written by Frank Taylor and Debbi Boettger of McDonnell Douglas Corp. for* **Johnson Space Center**. *For further information, Circle 93 on the TSP Request Card.*
*MSC-21708*

## Aid for Simulating Digital Flight Control Systems

### A computer program translates descriptions of systems into programs for simulation.

The DIVERS translator is a computer program to convert descriptions of digital flight-control systems (DFCS) into a computer program written in the C language. DIVERS is language developed to represent design charts of DFCS. The DIVERS translator converts DIVERS source code into an easily transportable language, while minimizing the probability that the results will be affected by the interpretation of the programmer. The final translated program can be used as a standard of comparison to verify the operation of actual flight-control systems. DIVERS is applicable to the simulation of other control systems; for example, electrical circuits and logic processes.

The DIVERS language is designed to correspond directly to DFCS diagrams. The keywords (filter, summer, limiter, etc.) correspond to physical components. The signals (volts, flap elevation, temperature, time, etc.) are variables corresponding to lines that connect the components. The DIVERS keywords are subroutines implemented in C and stored in a dictionary and are defined by the user in terms of input signals, outputs, and lists of parameters. This enables each component to be thoroughly tested and verified before being used in an actual system. The enforced modularity reduces the risk of programmer-introduced errors. A list of parameters to each keyword can include constants and conditional expressions.

Signals are declared in terms of units, maximum and minimum values, type (real, integer, Boolean), and computer-memory requirements. The DIVERS code is translated into a C program that can be run with input signals from the terminal or an existing data file. The program cycles through a control system, prompting for input, and displaying all signals declared as "test variables". The user can alter a signal or retain its current value for the next cycle.

The DCHART program is included in the DIVERS package. Its purpose is to read DIVERS source code and make a diagram of the data flowing between components. The output is used to compare the DIVERS specifications with the original DFCS chart.

DIVERS is written in C for batch execution and is available for two different computers. The DEC VAX version has been implemented on a VAX 11/780 computer operating under VMS 4.2. The UNIX version has been implemented on a DEC PDP 11/60 with IS/1 UNIX and a central-memory requirement of approximately 99K. This program was developed in 1985.

*This program was written by Richard M. Hartman of Informatics, Inc., for* **Ames Research Center**. *For further information, Circle 144 on the TSP Request Card.*
*ARC-11710/ARC-11711*

## Software for Simulation of Development of Software

### Personnel, resources, errors, and other realistic factors are represented in the simulation.

SOFTREL is a prototype software package that simulates creation, detection, and repair of defects and faults during a software-development project. The user initiates the process by entering the staff and resource schedules. The factors considered in SOFTREL include (1) construction, integration, inspection, and correction of documentation; (2) construction, integration, inspection, and correction of code; (3) preparation and conduct of tests; (4) identification and repair of faults; (5) validation of repairs; and (6) retesting. Parameters include rates of building of new, reused, deleted, and added components of documentation and code; rates of generation of defects; rates and adequacies of inspections; rates and adequacies of corrections; and adequacies of validations.

SOFTREL is available in executable form only for the IBM PC under DOS 3.3 or higher. The program was developed in 1990. SOFTREL is a copyrighted work with all copyright vested in NASA.

*This program was written by Robert C. Tausworthe of Caltech for* **NASA's Jet Propulsion Laboratory**. *For further information, Circle 26 on the TSP Request Card.*
*NPO-18295*

## Tracing and Control of Engineering Requirements

### Requirements and progress of an engineering project can be documented in systematic manner.

TRACER (Tracing and Control of Engineering Requirements) is a data-base/word-processing software system created to document and maintain the order of both requirements and descriptions associated with an engineering project. For a project, there is normally generated a set of hierarchical documents in which the requirements of the documents of higher level levy requirements on the documents of the same or lower level. Traditionally, the requirements have been handled almost entirely by manual paper methods. One disadvantage of a typical paper system is that requirements written and changed continuously in different areas lead to misunderstandings and noncompliance.

The purpose of TRACER is to automate the capture, tracing, review, and management of requirements for an engineering project. The engineering project still requires communications, negotiations, interactions, and iterations among people and organizations, but TRACER promotes succinct and precise identification and treatment of real requirements separate from the descriptive prose in a document. TRACER enables the documentation of the requirements and progress of an engineering project in a logical, controllable, traceable manner.

The attributes of TRACER include the presentation of current requirements and status from any linked computer terminal and the ability to differentiate headers and descriptive material from the requirements. Related requirements can be linked and traced. The program also enables the printing of portions of documents, individual approval and release of requirements, and the tracing of requirements down into the specification of equipment. Requirement "links" can be made "pending" and invisible to others until the pending links are made "binding." Individuals affected by linked requirements can be notified of significant changes with acknowledgement of the changes required. An unlimited number of documents can be created for a project, and an ASCII-import feature enables the incorporation of existing documents. TRACER can automatically renumber section headers when inserting or deleting sections of a document and can generate signoff forms for any approval process as well as a table of contents.

TRACER is implemented on an IBM PC under PC-DOS. The program requires 640 KB of random-access memory, a hard disk, and PC-DOS version 3.3 or higher. It was written with CLIPPER. The executable program is also provided with the distribution.

IBM PC and PC-DOS are registered trademarks of International Business Machines. CLIPPER is a trademark of Nantucket Corp.

*This program was written by Philip R. Turner, Richard L. Stoller, Ted Neville, and Karen A. Boyle of Caltech for* **NASA's Jet Propulsion Laboratory**. *For further information, Circle 87 on the TSP Request Card.* *NPO-18215*

## Software-Design-Analyzer System

### CRISP-90 provides the software designer with a medium that facilitates alterations.

The CRISP-90 software-design-analyzer system, an update of CRISP-80, is a set of computer programs that constitute a software tool for the design and documentation of other software and that support top-down, hierarchical, modular, structured methodologies for design and programming. The quality of a computer program can often be influenced significantly by the design medium in which the program is developed. The medium must foster the expression of the programmer's ideas easily and quickly, and it must enable flexible and facile alterations of, additions to, and deletions from these ideas as the design evolves. The CRISP-90 software-design-analyzer system was developed to provide the programmer with such a design medium.

The design of a program in the CRISP-90 medium consists of short, English-like textual descriptions of data, interfaces, and procedures that are embedded in a simple, structured, modular syntax. The display is formatted into two-dimensional, flow-chart-like segments for a graphical presentation of the design. Together with a good interactive full-screen editing or word-processing program, CRISP-90 becomes a powerful software tool for the programmer.

In addition to being a text formatter, the CRISP-90 system prepares material, the manual extraction of which would be tedious and prone to error; examples of such material include a table of contents, a module directory, a structure (tier) chart, cross-references, and a statistical report on the characteristics of the design. Referenced modules are marked by schematic logic symbols to show conditional, iterative, and/or concurrent invocation in the program. A keyword-usage profile can be generated automatically and glossary definitions inserted into the output documentation. Another feature is the capability to detect changes that were made between versions. Thus, "change bars" can be placed in the output document along with a list of changed pages and a version-history report. Also, items can be marked as "to be determined," and each appears on a special table until the item is supplied.

The CRISP-90 software-design-analyzer system is written in Microsoft QuickBasic. The program requires an IBM-PC-compatible computer with a hard disk, 128K of random-access memory, and an ASCII printer. The program operates under MS-DOS/PC-DOS 3.10 or later. The program was developed in 1983 and updated in 1990.

Microsoft and MS-DOS are registered trademarks of Microsoft Corp. IBM PC and PC-DOS are registered trademarks of International Business Machines Corp.

*This program was written by Robert C. Tausworthe of Caltech for* **NASA's Jet Propulsion Laboratory**. *For further information, Circle 125 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 20]. Refer to NPO-18212.*

## Numerical-Optimization Program

### The ADS computer program is suitable for such applications as minimum-weight design.

The Automated Design Synthesis (ADS) computer program is a general-purpose numerical-optimization program for design engineering. Significant applications have already been found for this program in the synthesis of structures (minimum-weight design).

ADS provides a wide range of options for the solution of constrained and unconstrained function minimization problems. The user makes choices at each of three software levels to tailor the method of solution to fit the particular minimization problem. The three basic software levels are Strategy, which represents the overall minimization strategy; Optimizer, which represents the particular minimization algorithm; and One-Dimensional Search, which represents the method of applying the minimization technique. ADS relies on the user to formulate the problem and make appropriate selections from the solution options.

Strategy options in ADS include sequential unconstrained minimization using the exterior-penalty-function method; sequential unconstrained minimization using the linear-, quadratic-, or cubic-extended-interior-penalty-function method; the augmented Lagrange-multiplier method; sequential linear programming; the method of centers (method of inscribed hyperspheres); and sequential quadratic programming. Optimizer options include the Fletcher–Reeves algorithm for unconstrained minimization, either the Davidon–Fletcher–Powell (DFP) or Broydon–Fletcher-Goldfarb–Shanno (BFGS) variable-metric method for unconstrained minimization, and the regular or modified method of feasible directions (MFD) for constrained minimization. One-Dimensional Search options include constrained or unconstrained function minimization using only a golden-section method or a golden-section method followed by polynomial interpolation, and constrained or unconstrained function minimization using polynomial interpolation and/or extrapolation with or without first finding bounds on the solution.

ADS is invoked by a calling program supplied by the user. ADS returns control to the calling program when information on a function or gradient is needed. This provides considerable flexibility in capabilities for organizing programs and restarting execution of them. ADS can be used in four principal modes: (1) default control parameters and finite-difference gradients, (2) override default parameters (use finite-difference gradients) (3) default parameters and gradients supplied by the user, and (4) override default parameters and gradients supplied by the user. These options provide the user more control over the problem-solving procedure than would otherwise be available.

The ADS program is written in FORTRAN 77 and developed on a CDC CYBER 170-series computer. The program requires approximately 155K (octal) of 60-bit-word memory. The CDC version of ADS was developed in 1984 and updated in 1985. The VAX version is a port of the 1985 CDC version.

*This program was written by Garret N. Vanderplaats of the Naval Postgraduate School for* **Langley Research Center**. *For further information, Circle 32 on the TSP Request Card.*
*LAR-14500*

# NASA Software Update

**For a quarter century, NASA's Computer Software Management and Information Center (COSMIC) has served as the central distribution point for all software developed under NASA funding. Although computer technology has evolved rapidly over the years, the center's mission has remained constant: to ensure that programs written by NASA and NASA-contracted scientists and engineers are made available for reuse in the private sector.**

**Many of the programs created for NASA R&D projects have outstanding transfer potential. A program that calculates stress in the space shuttle also can calculate stress in an offshore drilling rig. Software that measures the pressure of air flowing over an aircraft wing can be modified to measure the pressure of water flowing over a fin. A program that determines the optimal design for a communication laser also will determine the optimal design for a surgical laser.**

**Before a program is offered to the public, it is reviewed by NASA's Center for New Technology Assessment. Once approved, most programs are made available within the US with few or no restrictions.**

**In addition to producing new programs, NASA continually updates and enhances existing software. Programs updated in the past year include:**

**NASA Structural Analysis System (NASTRAN)** This program has been continually maintained by NASA since its development in the 1960s. It has aided in the structural design of a wide range of objects, from high-impact printer parts to turbine engine blades, and is fully validated. Since the source code is included, NASTRAN can be modified or enhanced for new applications. It runs on IBM mainframe, CDC, and DEC computers. *Circle 70 on the TSP Request Card. GSC-12600*

**Systems Improved Numerical Differencing Analyzer and Fluid Integrator (SINDA '85/FLUINT)** This general thermal analysis program handles both simple and extremely complex heat transfer problems, including those with both solid and fluid components. Available for DEC and Sun computers, the program yields NASTRAN-compatible output. *Circle 71 on the TSP Request Card. MSC-21528*

**Thermal Radiation Analysis System (TRASYS)** Designed for solar heating design, TRASYS can handle partial shading of one surface by another, and translucent surfaces. It runs on a DEC computer and generates output compatible with SINDA '85/FLUINT. *Circle 72 on the TSP Request Card. MSC-21030*

**C Language Integrated Production System (CLIPS)** A tool for developing expert systems, CLIPS makes decisions in the same way a human expert would. The latest update incorporates a feature called COOL, the CLIPS Object-Oriented Language. Versions are available for the IBM PC, the Macintosh, and UNIX workstations. *Circle 73 on the TSP Request Card. MSC-21208*

**Transportable Application Environment (TAE Plus)** A programmer's tool for fast and easy development of user interfaces, TAE Plus allows applications to be moved from one computer to another without affecting the end user. It is based on X-Windows and Motif, and runs on DEC and Sun computers. *Circle 74 on the TSP Request Card. GSC-13276*

**Long-Term Orbit Predictor (LOP)** Designed for use on an IBM PC, this program is suited for lifetime analysis of orbiting spacecraft. *Circle 75 on the TSP Request Card. NPO-17052*

**Chemical Equilibrium and Transport (CET)** This powerful, machine-independent program calculates theoretical thermodynamic properties of chemical systems. It can aid in the design of compressors, turbines, engines, heat exchangers, and chemical processing equipment. *Circle 76 on the TSP Request Card. LEW-14166*

**Semi-Markov Unreliability Range Evaluator (SURE) and Pade Approximation With Scaling and Scaled Taylor Exponential Matrix (PAWS/STEM)** Together, these programs form a "reliability workbench," offering several theoretical approaches to the design of redundant systems used in situations where failure could be catastrophic. They run on DEC computers. *Circle 77 on the TSP Request Card. LAR-13789 and LAR-14165*

# Mechanics



## Reducing Water/Hull Drag by Injecting Air Into Grooves

A proposed method would require much less air than does the microbubble-injection method.

*Langley Research Center, Hampton, Virginia*

The concept of reducing the drag on a water vehicle by placing air in the boundary layer between the vehicle and the water is not new but has been unworkable because of the difficulty of stabilizing a layer of air on the surface of the hull. Attempted solutions to the air-stability problem required changes in the basic configuration of the hull to trap air — an approach not practical for most oceangoing vessels.

Previous work has shown that air in the boundary layer of a waterflow can, indeed, greatly reduce the skin friction. One technique consisted of the injection of microbubbles through a porous plate into a boundary layer. Although this technique has reduced friction by as much as 80 percent, the required flow of air is so large that it negates the drag-reduction benefits in practical situations. The disadvantage of microbubbles is that they are easily dispersed and fill the entire boundary layer. In theory, only the portion of air nearest the wall acts as a drag-reduction agent. Therefore, most of the air injected in the microbubble technique is wasted.

A proposed technique for the reduction of friction drag on a hydrodynamic body involves the use of grooves and combinations of surfactants to control the motion of a layer on the surface of such a body. The surface would contain many rows of side-by-side, evenly spaced, longitudinal grooves. These grooves would be generally triangular, with tip-to-tip spacing between 0.040 in. (1.0 mm) and 0.010 in. (0.25 mm) and depth from 0.10 in. (2.5 mm) to 0.010 in. (0.25 mm). The dimensions of grooves and sharpnesses of tips in a specific case would depend on the conditions of flow about the vessel.

Air-injection ports would be either drilled holes in the valleys of the grooves or thin slots, each reaching across several valleys to distribute air more evenly. Air injectors would be angled as tangentially to the surface as possible. Injection of air would be repeated downstream several unit lengths, depending on the particular type of vessel.

The ribbed surface would be roughened deliberately during fabrication or coated before use with an antiwetting surfactant to enhance its air-trapping ability. Polytetrafluoroethylene is the most-desirable coating material, although such other antiwetting agents as those based on hydrocarbons would also be effective.

In operation, the air would be injected continuously through the ports. The ribs would act to hold the injected air in a connecting sheet that would fill the grooves via transverse surface tension forces. The depth and spacing of the ribs would alter the interfacial tension at the surface, favorably controlling the gas phase, or air sheet, by holding a thin sheet of air at the wall, where it is most likely to be effective in reducing drag. At slow speeds of vessels through water, this technique would likely require approximately one-tenth or less of the amount of air required in the injection of microbubbles.

*This work was done by Jason C. Reed of Old Dominion University and Dennis M. Bushnell and Leonard M. Weinstein of* **Langley Research Center**. *For further information, Circle 150 on the TSP Request Card.*

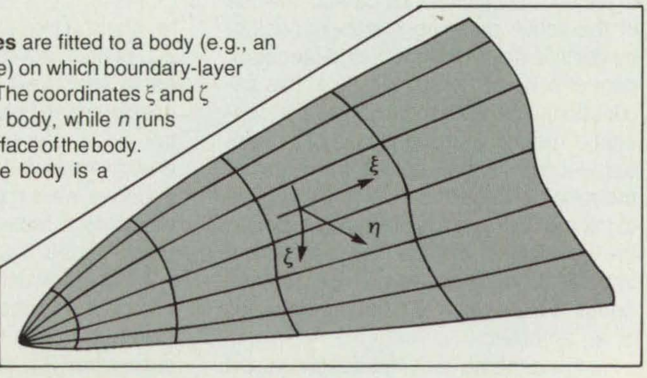
*This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 20]. Refer to LAR-14078.*

## A General-Coordinate Formulation for Boundary-Layer Flow

The general coordinates need not be orthogonal.

*Ames Research Center, Moffett Field, California*

A formulation for the solution of the equations of boundary-layer flow in general body-fitted curvilinear coordinates retains the velocities in Cartesian coordinates. This formulation may increase the stability of numerical simulations by avoiding coordinate source terms. Moreover, in this formulation, the curvilinear coordinates do not have to be orthogonal, and much of the software (including that for grids and boundary conditions) developed previously for use in numerical simulations of flow based on the




**Curvilinear Coordinates** are fitted to a body (e.g., an aircraft or a turbine blade) on which boundary-layer flow is to be computed. The coordinates $\xi$ and $\zeta$ lie on the surface of the body, while *n* runs perpendicularly to the surface of the body. Thus, the surface of the body is a surfact of constant *n*.

Navier–Stokes equations can be used.

The equations in the new formulation express the conservation of momentum along and perpendicular to the surface, the conservation of energy, and the conservation of mass, and include an equation of state for a perfect gas that has a constant ratio of specific heats. For example, the equation for the conservation of momentum perpendicular to the surface is $p_\eta = 0$, while the equations for the conservation of momentum along the surface are

$$\rho u_t + \rho U u_\xi + \rho V u_\eta + \rho W u_\zeta + (\xi_x p_\xi + \eta_x p_\eta + \zeta_x p_\zeta) = J\partial_\eta \{J^{-1}[\mu m_1 u_\eta + (\mu/3) m_2 \eta_x]\}$$

$$\rho v_t + \rho U v_\xi + \rho V v_\eta + \rho W v_\zeta + (\xi_y p_\xi + \eta_y p_\eta + \zeta_y p_\zeta) = J\partial_\eta \{J^{-1}[\mu m_1 v_\eta + (\mu/3) m_2 \eta_y]\}$$

$$\rho w_t + \rho U w_\xi + \rho V w_\eta + \rho W w_\zeta + (\xi_z p_\xi + \eta_z p_\eta + \zeta_z p_\zeta) = J\partial_\eta \{J^{-1}[\mu m_1 w_\eta + (\mu/3) m_2 \eta_z]\}$$

In these equations, the curvilinear coordinates are $\xi$, $\eta$ and $\zeta$; $\rho$ denotes density; $u$, $v$, and $w$ denote the Cartesian components of velocity along the $x$, $y$, and $z$ axes, respectively; $p$ denotes pressure, $\mu$ denotes viscosity; subscripts denote partial derivations with respect to the coordinates they represent;

$$m_1 = \eta_x^2 + \eta_y^2 + \eta_z^2;\ m_2 = \eta_x u_\eta + \eta_y v_\eta + \eta_z w_\eta$$

$J$ is the transformation Jacobian and $U$, $V$, and $W$ are contravariant velocities given by

$$\begin{pmatrix} U \\ V \\ W \end{pmatrix} = \begin{pmatrix} \xi_x & \xi_y & \xi_z \\ \eta_x & \eta_y & \eta_z \\ \zeta_x & \zeta_y & \zeta_z \end{pmatrix} \begin{pmatrix} u \\ v \\ w \end{pmatrix}$$

These six equations can be used to determine $p$, $u$, $w$, the specific total enthalpy $H$, $\rho$, and $v$. Generally, $p$ is uncoupled and determined from $p_\eta = 0$ and an outer-edge boundary condition so that $p = p_{edge}$ along $\eta$ coordinates. In more general cases, pressure is weakly coupled and can be determined from

$$s_\eta + \nabla\eta \cdot (\nabla\xi p_\xi + \nabla\eta p_\eta + \nabla\zeta p_\zeta) = 0$$

using the same outer-edge condition with the source term defined as

$$\begin{aligned} s_\eta &= -\rho U (u\partial_\xi \bar{\eta}_x + v\partial_\xi \bar{\eta}_y + w\,\partial_\xi \bar{\eta}_z) \\ &= -\rho V (u\partial_\eta \bar{\eta}_x + v\partial_\eta \bar{\eta}_y + w\,\partial_\eta \bar{\eta}_z) \\ &= -\rho W (u\partial_\zeta \bar{\eta}_x + v\partial_\zeta \bar{\eta}_y + w\,\partial_\zeta \bar{\eta}_z) \end{aligned}$$

where the overbar denotes scaling of metrics, e.g.,

$$\bar{\xi}_x = \xi_x / \sqrt{\xi_x^2 + \xi_y^2 + \xi_z^2}$$

In this case, pressure varies throughout the boundary layer.

*This work was done by Joseph L. Steger, William R. Van Dalsem, Argyris G. Panaras, and K. V. Rao of* **Ames Research Center***. Further information may be found in NASA TM-100079 [N88-24600], "A Formulation for the Boundary-Layer Equations in General Coordinates."*

*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.*

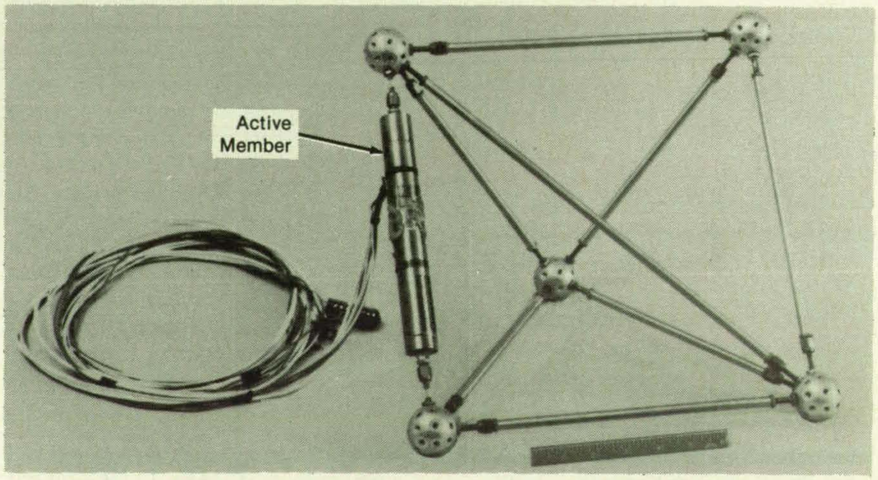
*ARC-12465*

# Two Techniques for Suppressing Vibrations in Structures

## The techniques are based on bridge feedback and a criterion for placement of actuators.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

Two techniques intended to be used together to suppress vibrations in a large, complicated truss structure involve a combination of active and passive damping. Research continues to develop a system that would use these and other techniques to suppress vibrations in, and help control the shape of, a truss structure in outer space that would support the precise, segmented reflector of a communication antenna. On Earth, the developmental techniques should be applicable to the suppression of vibrations in bridges and tall buildings.



**Part of a Truss Structure** contains an active damping member, which is a stainless-steel tube 8 in. (20.3 cm) long and 1 in. (2.5 cm) in diameter with an embedded stack of concentric piezoelectric wafers, an eddy-current differential proximity sensor, and a strain-gauge force sensor.

In addition to or in place of ordinary structural members, the truss or other structure includes active and passive damping members. Each active member includes a piezoelectric or other actuator collocated with a force sensor and a vibrational-velocity sensor (see figure). The first of the two new techniques calls for the use of the active damping members (which, by itself, is not new) in a bridge-feedback control scheme (which is new in this application). This scheme involves the concept of mechanical impedance of a member, defined as the Laplace transform of the ratio between the axial force applied to the member and the difference between the velocities of its ends. The mechanical impedance of an active member is analogous to the electrical output impedance of an amplifier.

In this scheme, local feedback is used to control the mechanical impedance, $Z_m$, of each active member in such a way as to effectively make it less stiff (and possibly more or less damping). The member could dissipate incident vibrational energy maximally if its mechanical impedance were the complex conjugate of mechanical impedance, $Z_L$, of the rest of the structure. Uncertainties in the knowledge of the structure make the use of the complex conjugate impractical, and instead, the control system synthesizes a suboptimal $Z_m$, the real (damping) part of which equals $|Z_L|$, the modulus of the impedance of the rest of the structure.

The second of the two new techniques is a scheme for the placement of the active and passive damping members. The problem of where to place each member of each type is one of combinatorial optimization. The criterion for optimization is maximization of a weighted sum of the passive-damping and active-damping contributions to the rate of dissipation of vibrational energy. The weighting factors are selected on the basis of design require-

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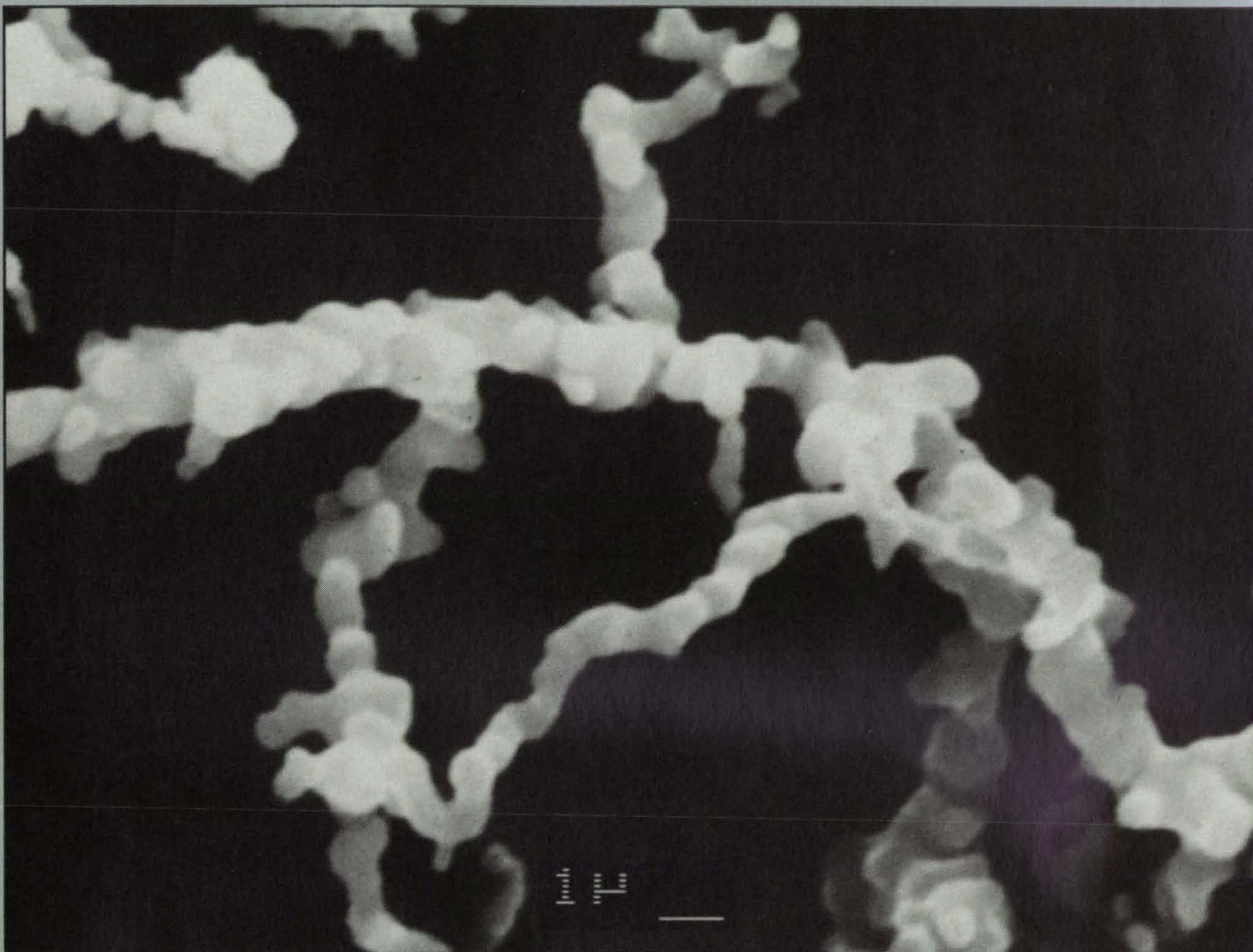


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ments and engineering experience. In this technique, one seeks a suboptimal solution by use of a simulated-annealing algorithm, which is one of class of heuristic, iterative algorithms that have been used in other optimation problems and that are named to reflect the fact that some aspects of them resemble some aspects of a mathematical model of annealing. In simulated annealing, one accepts nonimproving solutions according to probabilities determined from the Boltzmann function in the hope of escaping from or avoiding local optima and approaching the global optimum.

*This work was done by Gun-Shing Chen, John A. Garba, and Ben K. Wada of Caltech for* **NASA's Jet Propulsion Laboratory**. *For further information, Circle 159 on the TSP Request Card.*
*NPO-17889*

# Dynamic Analyses Including Joints of Truss Structures

A straightforward method is used to determine stiffness and damping coefficients.

*Langley Research Center, Hampton, Virginia*

Space structures larger than 300 ft (91 m) in diameter, such as the hoop-column antenna and proposed Space-Station structures (see figure), are being designed. These include truss substructures to span large distances because trusses provide high stiffness with low mass. The designs of many of these structures require accurate, dynamic analyses for prediction of loads, stability, shape control, and accuracy of orientation.

The designs of truss structures proposed for use in outer space specify joints that enable the erection or deployment of the truss members. Unlike in civil engineering structures, the designs of joints for space structures include finite tolerances between mating surfaces to enable the joints to rotate or to be latched. A tolerance results in a dead band within which a joint can be made to move with nearly zero applied force. The dead bands of joints are believed to affect the vibrational response of truss structures significantly, and detailed mathematical modeling may be necessary to incorporate these effects in the overall, or global, analysis. The joints influence the dynamic response of a truss in two major ways: first, by reducing the effective stiffness of the truss; and second, by introducing additional damping beyond that of a structure in which the members are rigidly connected but that is otherwise identical. Therefore, a method for mathematically modeling joints to assess the influences of joints on the dynamic response of truss structures was developed in a study. Only structures with low-frequency oscillations were considered in this study; thus, only Coulomb friction and viscous damping were included in the analysis.

The focus of this effort was to obtain finite-element mathematical models of joints that exhibited load-vs.-deflection behavior similar to the measured load-vs.-deflection behavior of real joints. Experiments were performed to determine stiffness and damping nonlinearities typical of joint hardware. An algorithm for computing coefficients of analytical joint models based on test data was developed to enable the study of linear and nonlinear effects of joints on global structural response.

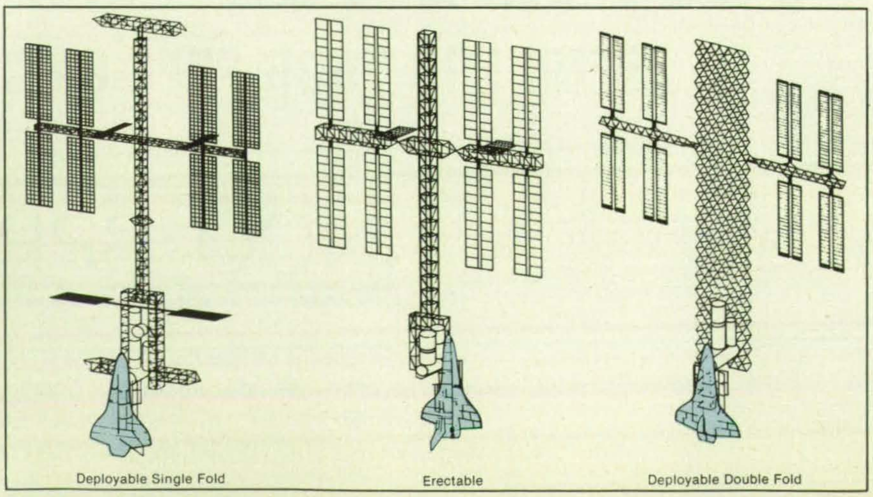
Spring, viscous-damper, and friction-damper elements were formulated and included in an existing finite-element computer code. Beams with joints were loaded, and their transient vibrational response was simulated with the finite-element program. The effects of linear and nonlinear joint stiffnesses on the amplitudes and frequencies of vibrations of beams were then studied. A truss structure with 32 joints was analyzed to study the effect of joints on its global vibrational response. Equations for predicting the sensitivities of deformations of beams to changes in stiffness of joints were derived. In addition, random perturbations were used to evaluate the effects of changes in stiffness of joints on the frequency of a bending vibrational mode of a truss.

The results of these analyses indicate that nonlinearities in the stiffnesses of the joints produced nonlinear dynamic response in beam and truss structures at certain values of these stiffnesses. For vibrations of constant amplitude, nonlinearities in the stiffnesses of the joints produced sinusoidal vibrational responses in beams and trusses, and the frequencies of vibration could be simulated with linearized stiffness of the joints. The random perturbations of these stiffnesses produced small changes in the global frequency, indicating that the average value of stiffness may be adequate to predict the global vibrational behavior of a structure. Sensitivity analyses of beams with joints were used to develop equations that show that there exist values of stiffnesses of joints above which the flexibilities of the affected joints can be neglected in analyses of the vibrations of truss structures that contain them. The relative stiffnesses of the joints compared with those of truss members are major parameters that determine the need for mathematical modeling of the joints.

The results of this study would be of value to designers of truss structures and framed structures in which the properties of joints have large effects, especially for cases in which deflection and vibration characteristics are major considerations in design. Besides the intended application to large space structures, applications in the nonaerospace community could include ground-based antennas and earthquake-resistant steel-framed buildings.

*This work was done by W. Keith Belvin of* **Langley Research Center**. *Further information may be found in NASA TP-2661 [N87-20567], "Modeling of Joints for the Dynamic Analysis of Truss Structures."*

*Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.* *LAR-14306*




**Proposed Space-Station Configurations** make extensive use of large truss structures.

# Lock for Valve Stem

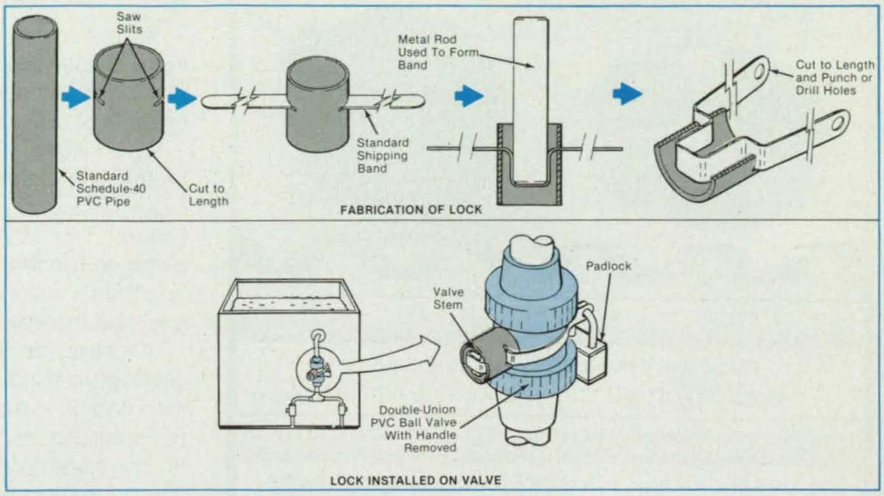
Readily available materials and handtools are used to make a simple but effective device.

*Marshall Space Flight Center, Alabama*

A simple, cheap device locks a valve stem so that its setting cannot be changed by unauthorized people. The device covers the valve stem; the cover is locked in place with a standard padlock. Only someone with a key to the padlock can then gain access to the valve and open, close, or otherwise change it.

The device is intended for use on a double-union polyvinyl chloride (PVC) ball valve. It is made from a piece of 1-in.-(2.5-cm)-diameter schedule-40 PVC pipe and a strip of 1/2-in. (1.3-cm)-wide band (of a type ordinarily used for shipping). The device is fabricated by use of standard handtools.

The pipe is cut to lengths and opposing slits are sawed in its wall (see figure). The shipping band, cut to length and with holes punched or drilled in its ends, is inserted through the slits. A metal rod is inserted in the pipe to form the band so that it can fit over the valve stem. The valve handle is removed from the valve stem, and the pipe-and-band assembly is slipped over the stem. The band is wrapped around the valve body so that its ends meet, and a padlock is slipped through the holes and locked. The valve is now secure.




The **Valve Lock** is made of PVC pipe and a packing band. Shears, a drill or punch, and a forming rod are the only tools needed.

*This work was done by Richard K. Burley and Kamal S. Guirguis of Rockwell International Corp. for* **Marshall Space Flight Center**. *No further documentation is available.*

*Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 20]. Refer to MFS-29764.*

# Lightweight Valve Closes Duct Quickly

A balloon expands to block the duct.

*Marshall Space Flight Center, Alabama*

An expanding balloon serves as a lightweight emergency valve to close a wide duct. The balloon valve weighs much less than does a conventional butterfly, hot-gas, or poppet valve capable of closing a duct of equal diameter.

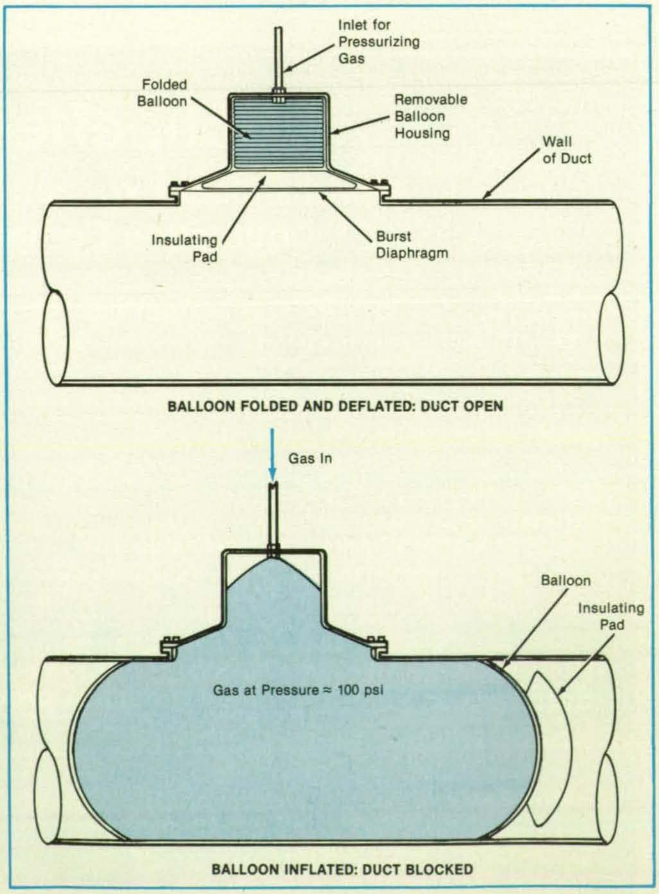
The balloon is initially folded like an accordion in a housing on the side of the duct (see figure). When it is necessary to close the duct, a control system injects a suitable gas into the balloon. The balloon expands, bursting through a protective diaphragm in the wall of the duct. The balloon fully inflates in less than a second, pressing against the inner surface of the duct and thereby sealing it.

After use, the housing is removed temporarily. The balloon is checked under pressure to ensure that it has not been punctured, then packed in the housing for reuse. The burst diaphragm is replaced, and the housing is reinstalled on the duct.

The housing can be made of the same material as that of the duct or of a lightweight composite; e.g., glass-, graphite-, or boron-reinforced epoxy. The balloon can be made of a material such as aluminized Mylar (or equivalent) polyethylene terephthalate.

*This work was done by Walter L. Fournier and N. Frank Burgy of United Technologies Corp. for* **Marshall Space Flight Center**. *For further information, Circle 139 on the TSP Request Card.*

*Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 20]. Refer to MFS-28511.*




The **Uninflated Balloon is Stored** in a housing on the duct. A pad resting on the burst diaphragm protects the balloon from the hot gases in the duct. Once the control system triggers a valve, the balloon inflates rapidly to block the duct.

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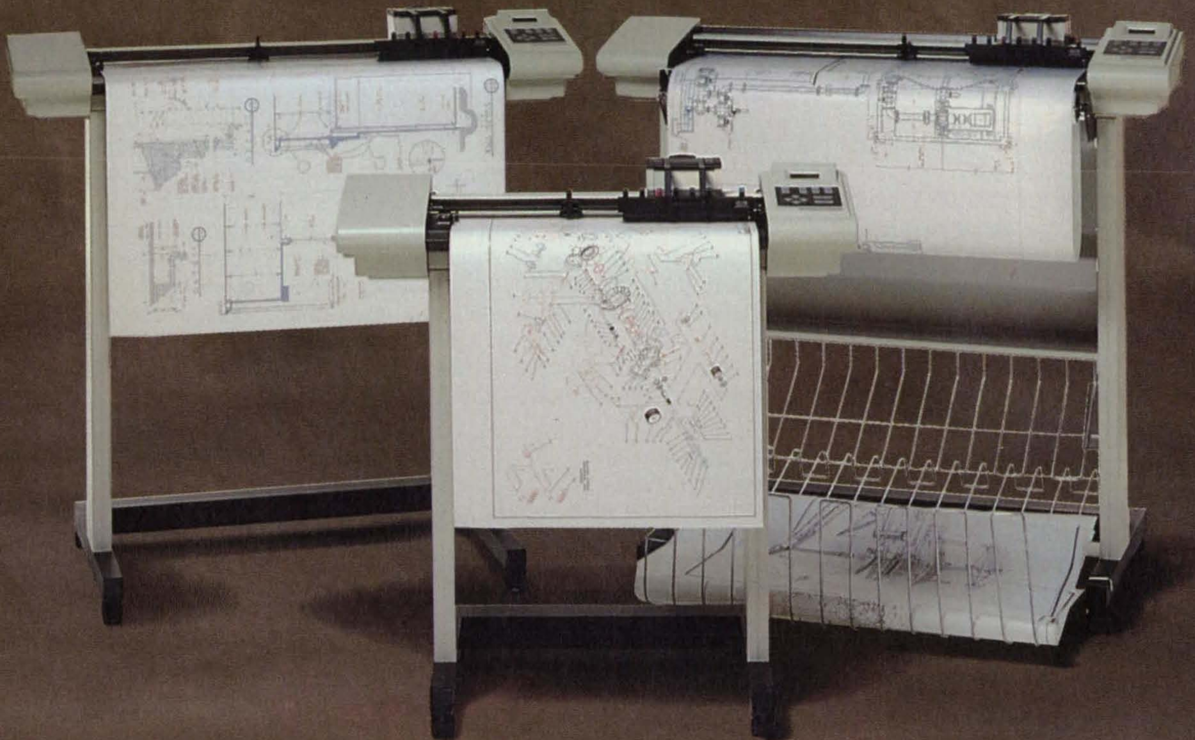

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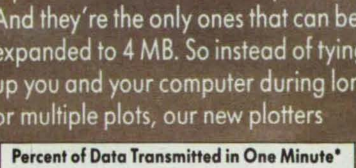


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# Numerical Simulation of Flow Through an Artificial Heart

Research in both artificial hearts and fluid dynamics benefits from computational studies.

*Ames Research Center, Moffett Field, California*

An algorithm that implements the Navier–Stokes equations of flow has been extended to simulate the flow of viscous, incompressible blood through an artificial heart. The ability to compute the details of such flow is important for two reasons: (1) internal flows with moving boundaries are of academic interest in their own right, and (2) many of the deficiencies of artificial hearts are attributable to the dynamics of flow. For example, high turbulent stresses can damage red blood cells.

Although blood is viscoelastic, in the initial formulation of the algorithm it is approximated by a Newtonian fluid to simplify the calculations. Later, as a first step toward the full simulation of non-Newtonian behavior, viscosity can be allowed to vary in space and time, and non-Newtonian effects can be represented by a simplified constitutive mathematical model of viscous stresses.

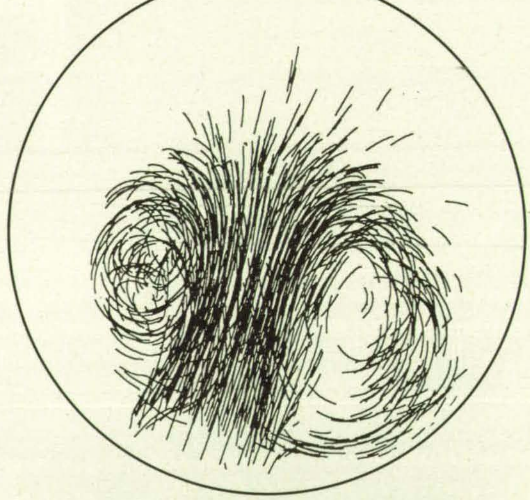
The Navier–Stokes equations are cast in primitive-variable form, using pressure and velocity as dependant variables. The equations are transformed into generalized curvilinear coordinates. The coordinate grid is formulated to conform to the pump chamber and to the piston, and to contain a constant number of grid points as it expands and contracts with the motion of the piston. To avoid further complications in this initial formulation, the motion of the valves is neglected, and the motion of the piston is altered so that it does not cross the valve openings.

The transformed equations of flow are treated via an artificial-compressibility, flux-difference-split, upwind-differencing numerical-integration scheme for convective fluxes. The resulting system of equations is more-nearly diagonally dominant than it would be if a central-difference scheme were used. The system of equations is solved by use of an unfactored line-relaxation scheme, which proves to have good stability and convergence characteristics. Time accuracy is maintained by iteratively solving the equations at each physical time step.

Despite the simplifying assumptions, the results of an early numerical simulation show some of the complicated features of the flow, and agree at least qualitatively with the experiment (see figure). To simulate the operation of the artificial heart in all its complexity, it will be necessary to eliminate the simplifying assumptions and incorporate more-advanced grid techniques and multiple zones to accommodate the valves. Furthermore, because simulations of this type now require much computer time, computers of increased speed and more-efficient algorithms could contribute greatly to progress in this field.

*This work was done by Stuart Rogers,*

**Two Distinct Vortexes** form in the flow entering an artificial heart through its inflow valve as the piston nears its lowest position.



COMPUTER SIMULATION

EXPERIMENT

*Paul Kutler, and Dochan Kwak of* **Ames Research Center** *and Cetin Kiris of Stanford University. Further information may be found in NASA TM-102183 [N89-24111], "Numerical Simulation of Flow Through an Artificial Heart."*

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*ARC-12478*

## 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.

### Mathematical Models of Turbulence in Hypersonic Flow

Essential features and statuses in applications are discussed.

A report discusses mathematical models of turbulence that are used in numerical simulations of complicated viscous, hypersonic flows. Such models are necessary because in a typical practical numerical simulation, the computer lacks the speed and/or memory necessary to calculate turbulent motion on all relevant scales of length and time. The report includes a survey of the essential features of the models and their statuses in applications.

There are several approaches to the modeling of turbulence, depending on how many of the scales of turbulence are included. In the approach described here, one models the turbulent motion at all scales. For this purpose, one solves the Reynolds-averaged Navier–Stokes equations. The numerical solutions, which represent long-time averages of both steady and fluctuating flow quantities, are usually steady in time.

The main text of the report begins with the derivation of the Reynolds-averaged Navier–Stokes equations and related equations. After a brief discussion of the various types of turbulence models, it focusses on eddy-viscosity models, which represent turbulent (Reynolds) stresses and fluxes of energy and matter as functions of strain rates or derivatives of velocities, by analogy to molecular stresses and fluxes. The eddy-viscosity function $\mu_T$ can be expressed by $\mu_T = \rho \ell q$, where $\ell$ is a length-scale function and $q$ is a velocity-scale function. The way $\ell$ and $q$ are determined defines the type of eddy-viscosity model to be used. If $\ell$ and $q$ are determined algebraically from mean flow data, the model is called a "zero-equation" model. If $\ell$ is determined algebraically but $q$ is determined from the turbulent-kinetic-energy or other field equation, the model is called a "one-equation" model. If both $\ell$ and $q$ are determined from field equations, the model is called a "two-equation" model.

The report describes some zero- and two-equation models, including explicit modifications of them to account for high speeds and compressibility. These include the Cebeci–Smith and Baldwin–Lomax models in the zero-equation category and the $k$–$\epsilon$ and $q$–$\omega$ models in the two-equation category.

Next, high-speed flows predicted with the help of various models are compared with experiments. Cases include flows with attached boundary layers, flows with interactions between shock waves and boundary layers, and flows with compressible shear layers. The report concludes with remarks about the status of turbulence modeling and recommendations for future studies.

*This work was done by J. G. Marvin and T. J. Coakley of* **Ames Research Center**. *Further information may be found in NASA TM-101079 [N89-26181], "Turbulence Modeling for Hypersonic Flows."*

*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-12609*



## Investigation of Tapered Tension/Torsion Strap

### A tapered strap provides more torque than a parallel one does.

A report describes the theoretical and experimental investigation of a simplified model of a tension/torsion strap. A tension/torsion strap has been proposed for use in a helicopter rotor blade to hold an otherwise freely pitching blade tip inward against centrifugal force and to apply torque about the pitch axis to regulate the pitching motions of the tip. This kind of design is intended to improve the aerodynamic performances of rotors and to reduce vibrations.

According to a previous concept, a tension/torsion strap would be made by arranging thin wires side by side in parallel and embedding them in an elastomeric filler. The torsional moment would be derived mainly from a component of the tensile load in the wires. Ignoring the aerodynamic effects, the strap and pitching blade tip would function analogously to a torsion pendulum except that the tensile load on the strap would be caused by the centrifugal force of the tip instead of by the weight of the pendulum.

The tapered tension/torsion strap was proposed to increase the torque generated by this type of strap (by increasing the torsional stiffness). According to this concept, the wires would be fanned out so that the strap would be wider at the inboard (anchored) end than at the outboard (pitching-tip) end. In this investigation, a two-wire torsional pendulum was used as the simplified model of a strap. When the suspension wires of such a pendulum are parallel in the steady state, it becomes a bifilar pendulum representing a constant-width tension/torsion strap. When the suspension wires are spread further apart at the upper (anchor) ends to form a V-shape, it represents the tapered tension/torsion strap.

The characteristics of the torsion-pendulum model were investigated by use of a simple mathematical model (small-angle approximation, no torsional stiffness in the wires, no stretching of the wires) and by measurements of the damping and of the torsional stiffness and natural frequency as a function of the separation between the wires at the upper ends. The results showed that, as expected, the torsional stiffness increases with the separation. The reason for this is that as the taper increases, so does the component of tension in the plane of rotation.

*This work was done by Alexander Louie of* **Ames Research Center**. *Further information may be found in NASA TM-101049 [N89-13746], "An Experimental and Analytical Evaluation of the Tapered Tension-Torsion Strap Concept."*

*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-12480*

## Processing Particle-Streak Imagery on a Personal Computer

### Streak patterns are used to obtain maps of flow-velocity vectors.

A report describes a simple flow experiment in which the streak images of particles suspended in the fluid and illuminated for short times were processed into maps of velocity vectors. The particle-streak concept is simple and dates back to the early part of this century but has not been considered viable until recently because the manipulation of the images to extract the velocity data has required excessive time and effort.

Advances in the digital processing of images have revived interest in the particle-streak method. In some applications, excessive emphasis has been placed on the automatic reduction of data, and a large portion of the significant image data is typically discarded to avoid the inclusion of erroneous data. To accumulate a sufficient number of data points to map a velocity field, repeated detection of a specific state in the image is required. Such repetition is, in practice, feasible only for steady flow. In the experiment described in this report, the authors used a semiautomatic data-reduction scheme, which can recover significant image data much more efficiently than a currently available automatic scheme can.

The experiment was performed in a towing tank filled with water seeded with neutrally buoyant particles. A circular cylinder 0.5 in. (12.7 mm) in diameter was moved along the tank at 0.31 in./s (0.79 cm/s) with its axis perpendicular to the motion. The flow around the cylinder was illuminated with a sheet of laser light and was photographed in 0.5-s exposures to obtain the streak images of the particles.

The photographs were acquired by a video camera, digitized, and stored in the memory and on the hard disk of a personal computer connected with the computer network at Ames Research Center. The image was then enhanced by manipulation of contrast, noise cleaning, filtering, statistical differencing, thresholding, and other techniques. The enhanced images of the streaks were examined by the experimenters; those judged to represent valid data were traced semiautomatically with a "mouse" to generate their binary images for use in calculating the velocity vectors. Coordinate transformations were applied to correct for distortions in the image, and velocity vectors at locations other than those of streaks were interpolated via a simple convolution with an adaptive Gaussian window.

The velocity-vector map was found to agree fairly well with the results of a Navier-Stokes calculation of the flow. Even in regions where the magnitude of the streak-image velocity did not agree with that of the Navier-Stokes velocity, the directions of the velocities agreed well. The discrepancy is attributed partly to errors in the processing of the images and partly to that there were not enough streaks in regions of large gradients in the velocity.

*This work was done by Y. C. Cho and B. G. McLachlan of* **Ames Research Center**. *To obtain a copy of the report, "Personal computer (PC) based image processing applied to fluid mechanics research," Circle 62 on the TSP Request Card.*
*ARC-12267*

## Computed Hypersonic Viscous Flows Over Delta Wings

### A conical Navier–Stokes algorithm accurately predicts shocks and pressure fields.

A report describes the development of an algorithm for the finite-volume (a type of finite-difference) solution of the conical Navier–Stokes equations of hypersonic viscous flow over a conical delta wing. The conical Navier–Stokes equations involve an approximation in which derivatives along rays that pass through the apex of the cone are set to zero. This approximation is justified by previous experimental observations that the viscous regions of supersonic flows over conical bodies are strongly dominated by the surrounding conical inviscid flows.

The conical Navier–Stokes equations in conservation-law form are derived, and the thin-layer approximation is introduced. The fluid is assumed to be a perfect gas similar to air, with viscosity, thermal conductivity, and Prandtl number dependent upon temperature according to Sutherland's formulas for the first two of these quantities.

The thin-layer Navier–Stokes equations are solved via a finite-volume formulation with state vectors stored at the centers of cells and fluxes defined at the faces of cells. Upwind differences are used for the inviscid flux derivatives, while central differences are used for the viscous flux vector. The initial conditions are chosen simply by setting all state vectors to free-stream values. This corresponds to an impulsively accelerated body in a supersonic flow. The solution is advanced to a steady state by an explicit, multistage scheme.

The conical Navier-Stokes equations and the algorithm were tested by using them to compute the mach 1.8 flow over an elliptical delta wing. The computation predicted primary and secondary leading-edge vortexes. The calculated pressure coefficient on the wing compared favorably with experimental data. Mach 10.17 flow over an isothermal flat delta wing was computed for angles of attack from 0° through 15°, and the extent of the viscous layer was predicted accurately for all angles of attack.

In the cases of hypersonic flow over an adiabatic wing, the calculation yielded spurious total temperatures in the boundary layer. This error is due to the van Leer flux-split formulation used in the algorithm. However, the overall comparison with experimental data in these cases was good. The conical Navier-Stokes equations can thus be expected to provide a good approximation for the flow over simple delta wings in supersonic and hypersonic flow.

A von Neumann stability analysis based on a one-dimensional flux-split model is used to predict the stability boundaries of the scheme. One-, two-, and three-stage schemes are considered for both first-order-accurate and second-order-accurate upwind formulations. The one-dimensional analysis shows that for the first-order-accurate formulation, the two-stage scheme is the most efficient. However, for the second-order-accurate formulation, the three-stage scheme is more efficient and is used in all the calculations. Also, the Courant-number restriction is strongly dependent on the stage coefficients and order of accuracy. In this study, a switch that involves a second difference in pressure was found to give sharp shocks while allowing nearly-second-order-accurate differencing in the boundary layer.

*This work was done by Stephen M. Ruffin of* **Ames Research Center** *and Earll M. Murman of the Massachusetts Institute of Technology. To obtain a copy of the report, "Solutions for Hypersonic Viscous Flow Over Delta Wings," Circle 6 on the TSP Request Card.* *ARC-12179*

## Navier-Stokes Computations on Zonal Grids

### Flows about a wing and an airplane are simulated.

A report describes numerical simulations of the transonic flow of air about an isolated wing and about the wing and fuselage (but not the tail assembly) of the F-16A aircraft. A fast, diagonalized Beam–Warming numerical-integration algorithm for the solution of the Euler and Navier–Stokes equations was applied via the Transonic Navier–Stokes computer program, using computational grids divided into zones of coarse and finer meshes.

As in previous studies, the thin-layer Navier–Stokes equations with no-slip surface conditions were applied on solid surfaces, while the Euler equations (of inviscid flow), which are simpler, are used elsewhere. The regions where viscosity is important also tend to involve high gradients of flow variables. To reduce the amount of computation required, the meshes were refined only to the degrees necessary in the near-surface, high-gradient regions.

The base grid was generated by an algorithm based on Poisson's equation and was divided into zones by a zoning algorithm. The grid about the wing consisted of four zones. The first included all points except those in the vicinity of the wing, which were contained in the second through fourth zones. The second zone, with a mesh finer than that of the first zone, contained all points in the vicinity of the wing except those in still finer meshes in the third and fourth zones, which were attached to the upper and lower surfaces respectively.

The grid about the airplane was divided into a total of 19 zones. These zones were essentially of three types; inviscid zones, viscous zones with clustering of the grids on faces that correspond to wing or fuselage no-slip surfaces, and viscous zones with clustering on pairs of adjacent faces that correspond to the wing/fuselage juncture.

The simulation for the wing was conducted both with and without inclusion of the effects of wind-tunnel walls, and the results of the two cases were compared with those of an experiment. The simulation with wall effects agreed well with the experiment, and the results show that when the effects of the wall are not considered, the predicted position of the shock is too far upstream.

The results of simulation for the aircraft are presented in plots of pressure coefficients as functions of position along various coordinate axes. For the most part, these plots show good agreement with experimental data.

*This work was done by Jolen Flores of* **Ames Research Center**. *Further information may be found in NASA TM-100080 [N88-24602], "Applications of the Navier–Stokes Equations to Wings and Complex Configurations Using a Zonal Approach."*

*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-12447

## Experiments on Schemes for Adaptive-Wall Wind Tunnels

### Ways to reduce testing time for adaptation are discused.

A report discusses an experimental investigation of the various convergence schemes for an adaptive-wall wind tunnel. In such a wind tunnel, the shape of the walls is changed, or controlled auxiliary flows are introduced through holes in the walls to compensate for the interference of the walls on the flow about the test model in such a way that the flow at the model approximates the flow that would be obtained if the walls were not present. Measurements of flow variables (e.g., pressures and/or velocities) at a small number of selected positions are used to adjust the auxiliary flows or other compensating mechanisms. A convergence scheme is an iterative or one-step scheme by which the adjustments make the conditions in the compensated flow impinging on the model converge on the free-stream conditions.

At present, ventilated adaptive-wall wind tunnels require complicated instrumentation and excessive testing time to perform adaptations. The purpose of the research described in the report was to establish faster convergence schemes with simpler instrumentation. To simplify the instrumentation, it was proposed to use the distribution of pressure on the side wall as the flow variable. As one of the alternatives to reduce the testing time, a one-step convergence scheme was proposed.

To explore the relative merits of different convergence schemes, the iterative and the one-step methods were implemented with normal and streamwise velocity components measured by a two-component laser Doppler velocimeter and also with resultant velocity distributions calculated from measurements of static pressures on the side wall. Emphasis was given to the convergence schemes with two-level compatibility assessment, which requires the measurement of one flow variable at two levels (unlike the one-level method, in which two flow variables have to be measured at one control level). Measurements were performed at mach numbers from 0.5 to 0.75 and at angles of attack from 0° to 4°.

In the iterative and the one-step methods, influence coefficients were employed for a systematic estimation of the pressure corrections. Different coefficients were used for suction and blowing. One aspect of the investigation was the determination of the practical limitations and the effectiveness of the influence coefficients at various mach numbers and angles of attack.

The results show that the side-wall-pressure measurements can, indeed, be used as the flow variables and that they yield the same unconfined-flow conditions as those obtained by measuring streamwise and perpendicular components of velocity with a laser Doppler velocimeter. The results justify the use of influence coefficients in the one-step and iterative convergence schemes. They also show that with the one-step convergence scheme, satisfactory adaptation can be obtained when the number of iterations is reduced to one (or sometimes two).

*This work was done by Z. Z. Celik of Stanford University and S. Bodapati of the Navy–NASA Joint Institute for Aeronautics for* **Ames Research Center**. *To obtain a copy of the report, "Experimental Investigations of the Various Convergence Schemes for an Adaptive Wall Wind Tunnel," Circle 59 on the TSP Request Card. ARC-12116*

## Artificial Intelligence in Computational Fluid Dynamics

### Four AI systems are compared.

A paper compares four first-generation artificial-intelligence (AI) software systems for computational fluid dynamics. On the basis of that comparison, the paper concludes that AI is most successful when it is applied to well-formulated problems that are solved by classifying or selecting preenumerated solutions. In contrast, the application of AI to poorly understood or poorly formulated problems generally results in a long development time and a large investment of effort, with no guarantee of success.

The paper focuses on knowledge-based ("expert") software systems. It analyzes their intended tasks, the kinds of knowledge they possess, the magnitude of effort required to codify the knowledge, how quickly they were constructed, their performances, and the return on investment.

The four software systems are the following:

1. The Expert Cooling Fan Design System (EXFAN) computes aerodynamical portions of the designs of turbomachinery components by starting with initial designs and repeatedly analyzing and revising until the design goals are met.
2. The PAN AIR Knowledge System (PAKS) aids users of PAN AIR, a panel-method program widely used in the design of airplanes. PAKS takes the user's goals and the geometry defined by the user and constructs a PAN AIR input deck.
3. The grid-adaptation program MITOSIS (referred to as "ADAPT" in this study since the actual name was unknown) adds robust failure recovery to a successive grid refinement/coarsening procedure, which depends on the local flow field.
4. The Expert Zonal Grid Generation (EZGrid) program partitions a two-dimensional flow field into four-sided, well-shaped zones that are then individually discretized.

The paper rates each system graphically with respect to several criteria. For example, it finds that the knowledge-amplification factor of EXFAN is quite high, while that of MITOSIS is rather low, and those of EZGrid and PAKS lie between the two extremes.

Three challenges for future development are proposed. The first is to identify additional aspects of computational fluid dynamics to which AI can be applied, and to refine or build on existing first-generation systems. The second is to increase the understanding and formalization of various aspects of computational fluid dynamics with a view toward the benefits that can be obtained in the long term by automating those aspects via AI. The third challenge is to identify the aspects of computational fluid dynamics that can be automated (for example, definition of geometry, design, generation of code, and selection of methodology), but the automation of which requires AI techniques that are still being developed (for example, geometric reasoning, representation of perceptual knowledge, constructive problem solving, learning, automatic programming, and qualitative physics). Starting work on this third challenge early will likely produce results sooner and will produce valuable feedback for researchers in AI.

*This work was done by Alison Andrews Vogel of* **Ames Research Center**. *Further information may be found in AIAA Journal 88A28036, Volume 26, No. 1, (January, 1988), pages 40 through 46, "Progress and Challenges in the Application of Artificial Intelligence to Computational Fluid Dynamics."*

*Copies may be purchased [prepayment required] from AIAA Technical Information Service Library, 555 West 57th Street, New York, New York 10019, Telephone No. (212) 247-6500. ARC-12445*

## Frequency-Domain Identification of Aeroelastic Modes

### Data from flight tests support the choice of the frequency-sweep method.

A report describes flight measurements and frequency-domain analyses of aeroelastic vibrational modes of the wings of the XV-15 tilt-rotor aircraft. The main text of the report begins with a description of flight-test methods. This is followed by a brief discussion of the methods of analysis, which include Fourier-transform computations using chirp z transforms, the use of coherence and other spectral functions, and methods and computer programs to obtain frequencies and damping coefficients from measurements. This is followed by a brief description of the results of flight tests and comparisons among various experimental and theoretical results. The report ends with a section on conclusions and recommended improvements in techniques.

The measurements were taken during flight tests in which dual flaperon exciters with automatic frequency-sweep controls were used to excite individual modes precisely. During the tests, the aircraft was equipped with the original metal rotor blades (as distinguished from new composite-material blades, with which subsequent tests are to be performed).

After the wing modes were excited with flaperon frequency sweeps, the frequency spectra of the resulting time-history data were generated with the chirp z transforms. Modal frequencies and damping were determined by fitting curves to frequency-response magnitude and phase data. In addition, theoretical analyses were performed with the help of the CAMRAD and ASAP computer progams to predict the modes by use of mathematical models of the aircraft. Estimates of frequency and damping were plotted and compared with values predicted by both CAMRAD and ASAP.

From the results of the measurements and analyses, the authors conclude that the combination of frequency-sweep excitation with frequency-domain analysis provides a reliable and efficient method for the determination of the aeroelastic modes of the XV-15 aircraft from flight data. Because of its good analytical results and its reduced flight time in comparison with other methods, the frequency-sweep method has been chosen to support flight tests of the aircraft equipped with the new composite blades.

*This work was done by C. W. Acree, Jr., and Mark B. Tischler of* **Ames Research Center**. *Further information may be found in NASA TM-101021 [N90-21756], "Identification of XV-15 Aeroelastic Modes Using Frequency-Domain Methods."*

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## Methods of Simulation of Incompressible Flow

### Numerical techniques for the solution of the Navier–Stokes equations are discussed.

A report discusses methods for the numerical solution of the Navier–Stokes equations of viscous, incompressible flow, with emphasis on the pseudocompressibility method. Viscous, incompressible flows are encountered in many realistic engineering problems in aerodynamics and hydrodynamics. The advanced computational techniques reviewed here contribute to improved designs by rapidly providing detailed information about conditions at all points in the flow fields of proposed designs.

The approach taken in this study is to use a primitive-variable formulation of the Navier–Stokes equations in generalized curvilinear coordinates and to solve the equations numerically by a finite-difference technique. The lack of a pressure term in the equation of continuity for incompressible flow poses an obstacle to the solution. The oldest and most commonly encountered method for satisfying the equation of continuity is to use Poisson's equation to find the pressure, in an iterative relaxation scheme in which the divergence-free condition is approached.

Another method is the fractional-step method. In the most common version of this method, one first solves for an auxiliary velocity field by use of a form of the momentum equation in which the pressure-gradient term can be computed from the pressure in the previous time step or can be excluded entirely. In the next step, the pressure is computed and used to map the auxiliary velocity onto a velocity field free of divergence.

In the pseudocompressibility method, the equation of continuity is modified by the addition of a derivative of pressure with respect to time, resulting in

$$\frac{1}{\beta}\frac{\partial P}{\partial t}+\frac{\partial u_i}{\partial x_i}=0$$

where $\frac{1}{\beta}$ is the pseudocompressibility, $P$ = pressure, $u_i$ = the $i$th component of velocity, $x_i$ = the $i$th spatial coordinate, and $t$ = time. Together with the equations of conservation of momentum in unsteady flow, this forms a hyperbolic/parabolic type of time-dependent system of equations. Solutions can be obtained through fast, implicit schemes developed for compressible flows, such as the approximate-factorization scheme by Beam and Warming or Briley and McDonald.

The report describes a finite-difference scheme for the simulation of flow in arbitrary three-dimensional coordinates, based on the pseudocompressibility method. A computer program that implements this scheme is used to calculate the flow in the hot-gas manifold of the Space Shuttle main engine. The results of the computation are found to compare favorably with data from tests and to offer information not readily available from experiments.

*This work was done by D. Kwak of* **Ames Research Center**, *J. L. C. Chang and R-J Yang of Rockwell International Corp., and S. E. Rogers of Sterling Federal Systems. Further information may be found in NASA TM-100038 [N90-20333], "Numerical Simulation Methods of Incompressible Flows and an Application to the Space Shuttle Main Engine."*

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## Computations of Impulsively Started Viscous Flow

Progress in understanding a commonly studied flow is discussed.

A report discusses the computation of the impulsively started flow of a viscous fluid about a circular cylinder. This and similar flow problems are studied quite commonly because they involve simple geometries and such important phenomena as the separation of flow, viscous drag, unsteady wakes, and vorticity. The validation of methods for the computation of these phenomena is an important step in the development of the ability to simulate flows in more complicated geometries; for example, in the design of airfoils. The cylinder model also has practical implications for such engineering problems as interactions of winds and currents with cylindrical structural members.

The report begins with an introduction that includes a brief history of the use of the Navier–Stokes equations to simulate impulsively started flows about circular cylinders. It describes the present study, which involves the combination of an analytic short-time solution with a predictor–corrector algorithm to march the unsteady Navier–Stokes equations forward in time. Unlike in previous solutions, a uniformly valid initial flow that satisfies the Navier–Stokes equations is used to start the calculation. The algorithm is very simple, using an implicit Euler forward integration scheme with an upwind biased, third-order approximation for the convection term. The initial development of the symmetric flow field is calculated up to a nondimensional time of about 7, based on the free-stream velocity and the radius of the cylinder.

The results of the computations are presented for three combinations of grid spacing and outer-boundary location. The results show that the stagnation pressure at the nondimensional time of 0.1 after the impulsive start, as computed in this study, agrees well with that computed by an analytic approximation in a previous study. At later times, the pressures computed in the two studies diverge. The stagnation pressure computed in this study initially differs from, but then converges with, the stagnation pressure computed for a similar but inviscid flow.

A detailed analysis of the force-density and acceleration vectors of the Navier–Stokes equations is presented in graphical form to make apparent the relative importance of the Navier–Stokes terms that represent unsteady acceleration, convection, viscosity, and the gradient of pressure. Specifically, these vectors at the nondimensional time of 0.14 are plotted at 12 points on a circle at 1.1 × the radius of the cylinder. These vectors indicate a strong balance between diffusion and unsteady effects in the direction parallel to the surface of the cylinder, and between convection and the gradient of pressure perpendicular to the surface of the cylinder. This verifies the essential uncoupling of the viscous, rotational flow field and the inviscid, irrotational flow.

*This work was done by Sanford S. Davis of* **Ames Research Center**. *Further information may be found in NASA TM-101037 [N89-21190], "Computational Studies of an Impulsively Started Viscous 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-12382*

## New Sensors for Flow Velocity and Acoustics

### Development programs promise more accurate measurements.

A paper describes two sensor-development programs at the Fluid Mechanics Laboratory at NASA Ames Research Center. One of the programs, for digital image velocimetry (DIV) sensors, is in progress. The other program, for advanced acoustic sensors for wind tunnels, has just been started.

DIV measures, in real time, the instantaneous velocity fields of time-varying flow or of a collection of objects moving with varying velocities. DIV uses high-speed video photography, image processing, and digital Fourier transformation to create an image of seed particles or moving objects from linearly superposed frames taken at fixed intervals. The velocities of the particles or objects are determined from the separations between subsequent images of them.

DIV differs from other techniques for measuring the velocity fields of fluids (such as particle-image velocimetry and laser-speckle velocimetry) in that its single-exposure images can be isolated from the combined image. Single-exposure images can be used to eliminate uncertainties caused by overlaps and undesirable distributions of particles.

The advanced acoustic sensors for wind tunnels are being developed to reduce the effects of interference from wind noise, noise from interactions between flows and sensors, flow-induced vibrations of sensors, deflections of acoustic waves by boundary layers induced by sensors, and reflections from walls and sensor supports. The advanced sensors include adaptive arrays of optical fibers in which signal processors automatically adjust the sensitivities of the arrays to enhance directivities and spectral responses.

A representative array includes a source of light, optical-fiber interferometers, and a photodetector connected to a signal processor. Sound modulates the phase of the light in the fibers. The modulated light is combined with unmodulated reference light, and the resulting interference signal is detected and sent to the signal processor, which extracts information about the acoustic signal.

*This work was done by Y. C. Cho of* **Ames Research Center**. *To obtain a copy of the report, "Sensor Development Program at NASA Ames Research Center," Circle 64 on the TSP Request Card.* ARC-12577

## Direct Finite-Difference Simulations of Turbulent Flow

### An upwind finite-difference scheme is compared with other numerical-integration schemes.

A report discusses the use of an upwind-biased finite-difference numerical-integration scheme to simulate the evolution of small disturbances and fully developed turbulence in the three-dimensional flow of a viscous, incompressible fluid in a channel. In contrast with simulations involving approximate mathematical models of turbulence, direct simulation involves the use of a computational grid sufficiently fine to resolve the motion of the fluid at all relevant length scales. This study was motivated partly by the need to simulate turbulent flows bounded by complicated shapes and partly by the observation that the main advantage of finite-difference schemes over the highly accurate spectral methods lies in the relative ease with which finite-difference schemes can be applied to complicated shapes. The purpose of this study was to demonstrate the superior performance of high-order-accurate upwind-biased finite-difference numerical-integration schemes in simulating turbulent flows and accurately predicting the higher-order statistics of such flows.

The main text begins by presenting the Navier–Stokes equations of flow and an upwind-biased finite-difference scheme for solving them. The scheme uses a staggered grid and is a variant of a partially implicit, fractional-step scheme used in a previous study. The accuracy of the integration method is first tested by computing the evolution of small-amplitude disturbances in channel flow. The scheme is then used to compute fully developed channel flow at a Reynolds number of 180 (based on wall shear velocity and the half width of the channel). The results of these calculations are compared with experimental data and with spectral calculations of the same flow in a previous study, and the agreement is found to be good. The dissipative nature of the upwind-biased scheme is found to control aliasing error without unduly affecting the accuracy of the solution for grids of reasonable size.

The results of simulations using a second-order-accurate central-difference numerical-integration scheme are also presented. The inadequacy of the second-order accuracy of the scheme (for the grid size chosen) is demonstrated using the test cases mentioned above. An additional limitation of this scheme is that its stability is ensured only because it conserves kinetic energy. Deviations in the differencing technique that retained second-order accuracy but not the energy-conservation principle resulted in unstable solutions.

The report ends by stating several conclusions, including the following: While the shortcoming of the upwind method (numerical dissipation) can be overcome by use of additional grid points, the limitations of the spectral method are more fundamental in nature. The use of central-difference schemes depends on whether general-purpose aliasing-error-control procedures can be found. The upwind-difference code requires approximately the same amount of computing time per grid point for each substep in the Runge–Kutta numerical-integration scheme as spectral simulations do. At present, it appears that the high-order-accurate upwind-biased method is a good candidate for direct simulations of turbulent flows associated with complicated shapes.

*This work was done by Man Mohan Rai of* **Ames Research Center** *and Parviz Moin of Stanford University. Further information may be found in AIAA paper 89A-25312, "Direct Simulations of Turbulent Flow Using Finite-Difference Schemes."*

*Copies may be purchased [prepayment required] from AIAA Technical Information Service Library, 555 West 57th Street, New York, New York 10019, Telephone No. (212) 247-6500.* ARC-12463

# Machinery

**Hardware, Techniques, and Processes**



## Direct-Link Prehensor

An operator-powered mechanical hand gives protection, dexterity, and proximity to the work.

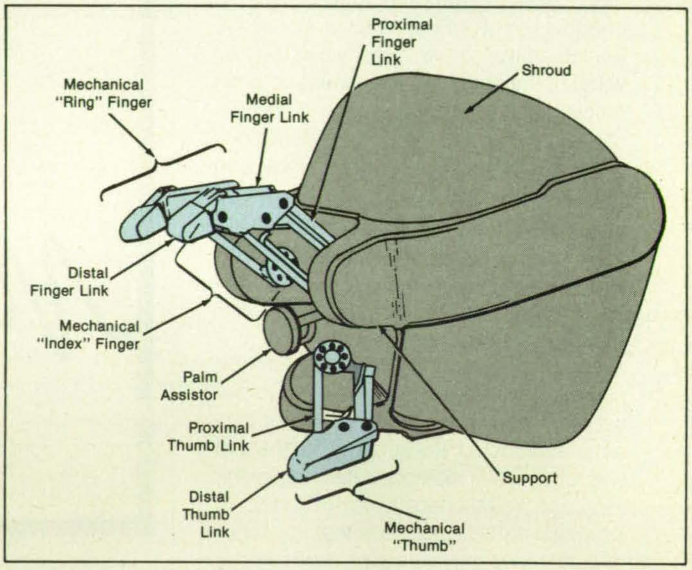
*Ames Research Center, Moffett Field, California*

A mechanical prehensor replicates the movements of an operator's hand and fingers just a few centimeters from the hand. Because it encloses the operator's hand in a protective shroud, the prehensor enables the operator to grasp, hold, and manipulate nearby objects in a hostile or hazardous environment. The operator moves the prehensor through direct mechanical linkages; no electric motors or electronic circuits are needed.

The prehensor has a "ring" finger, an "index" finger, and a thumb, mounted on a supporting frame (see figure). The ring and index fingers consist of three jointed links each, and the thumb consists of two jointed links. The thumb is positioned opposite the fingers in an anthropomorphic arrangement. A palm assistor — a disk projecting from the support frame — helps the mechanical fingers to hold objects, much like the palm of a human hand.

The shroud is made of a rigid, gas-impermeable material such as aluminum or molded fiberglass. It is joined to the supporting frame by welding, bonding, or other means that produce a gas-tight seal. At its wrist end, the shroud is joined to a sleeve of the operator's protective suit by a seal.

Within the shroud, rings engage the various phalanges of the operator's fingers. The operator's middle and ring fingers are used in tandem to move the mechanical ring finger of the prehensor, and the operator's index finger and thumb are used independently to move the mechanical index finger and thumb, respectively, of the prehensor.




**A Shroud Encloses the Operator's Hand**, protecting it from vacuum, high pressure, or hazardous materials. The external mechanical fingers are made of materials compatible with the external environment.

When the operator moves part of a finger, the movement is translated by mechanical linkages into similar movement of the corresponding part of the mechanical prehensor. For example, when the operator rotates the distal phalange of the thumb about its joint, the distal-control link rotates about the distal-control joint on the thumb mechanism. This actuates a distal-control pushrod, the action of which rotates the distal thumb link about the distal link joint on the mechanical thumb.

The ratio of motion of the mechanical finger links to the corresponding control links is 1 to 1.1. With this ratio, the mechanical links can reach useful positions that would otherwise result in collisions between components of the control linkages.

*This work was done by John W. Jameson of* **Ames Research Center**. *For further information, Circle 99 on the TSP Request Card.*

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*Refer to ARC-11666, volume and number of this* NASA Tech Briefs *issue, and the page number.*

## Monitoring Bearing Vibrations for Signs of Damage

Real-time spectral analysis is performed to detect telltale changes in vibrations.

*Marshall Space Flight Center, Alabama*

Real-time spectral analysis of vibrations is being developed for use in monitoring the conditions of critical bearings in rotating machinery. The underlying concept is simple and fairly well established: the appearance and growth of vibrations at frequencies associated with the rotations of various parts of a bearing system indicate wear, damage, and imperfections of manufacture. These frequencies include the fundamental and harmonics of the frequency of rotation of the ball cage, the frequency of passage of the balls, and the frequency of rotation of the shaft.

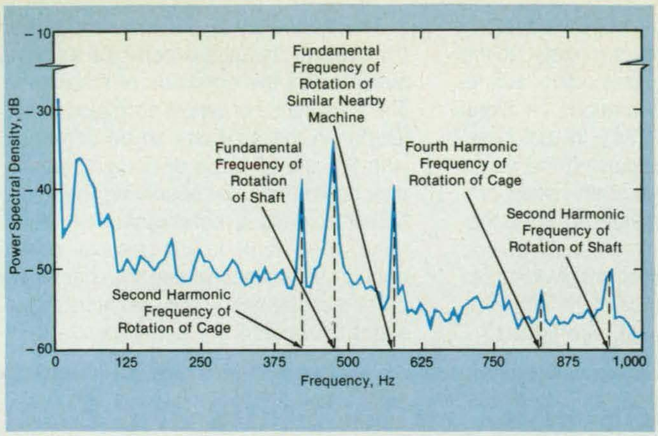
Vibrations that originate in a ball-bearing assembly can be sensed by strain gauges mounted on the outer race. Heretofore, the outputs of strain gauges have been recorded and analyzed after testing the machinery. In the developmental technique, the output of a strain gauge is processed by commercially available spectrum-analyzing equipment to obtain a power spectral density plot of the vibrations in real time (see figure).

A change in the plot — typically, an increase in amplitude at a particular frequency — indicates a particular type of damage.

Once this concept is developed into a reliable technique for the detection of incipient failures, it may become permissible to disassemble the machinery less frequently for inspection and/or replacement of bearings.

*This work was done by Carol L. Martinez of Rockwell International Corp. for* **Marshall Space Flight Center**. *For further information, Circle 15 on the TSP Request Card.*

*Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 20]. Refer to MFS-29734.*




This **Instantaneous Power Spectral Density** was computed from the output of a vibration-sensing strain gauge in a high-pressure oxygen turbopump of the type used in the Space Shuttle. The spectrum includes vibrations synchronous with the rotation of a similar nearby machine—a high-pressure fuel turbopump.

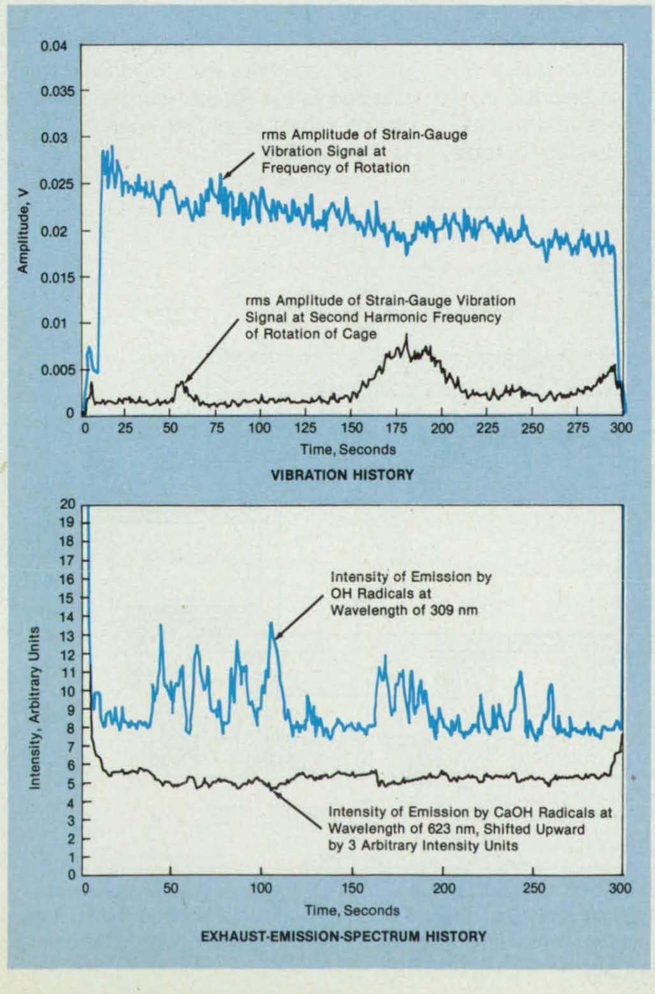
# Monitoring Engine Vibrations and Spectrum of Exhaust

Vibration- and emission-spectrum "signatures" indicate the condition of the engine.

*Marshall Space Flight Center, Alabama*

Real-time computation of the intensities of peaks in the visible-light emission spectrum of exhaust has been combined with real-time spectral analysis of vibrations into a developmental monitoring technique that provides up-to-the-second information on the conditions of critical bearings in an engine. The technique was conceived to monitor the conditions of bearings in a turbopump that supplies oxygen to the Space Shuttle main engine and is based on previous observations that both vibrations in the bearings and the intensities of visible light emitted at specific wavelengths by the exhaust plume of the engine can indicate wear and incipient failure of the bearings. The concept may be applicable to monitoring the "health" of other machinery (e.g., automotive engines and industrial furnaces) via the spectra of vibrations and elec-

**Histories of Intensities of Peaks** at two frequencies in each of two spectra indicate the "health" of a turbopump bearing in a rocket engine. Displays like these can be produced on the screen of a personal computer in real time from the output of an emission spectrometer and vibration-analyzing equipment. No further modification of the engine under test is required.



tromagnetic emissions from exhausts.

This monitoring concept is related to the one described in the preceding article, "Monitoring Bearing Vibrations for Signs of Damage" (MFS-29734). In this case, however, instead of displaying the broad vibrational spectrum at a given instant, one displays plots that provide an up-to-the-second history of the intensities in (a) two narrow bands of the spectrum of vibrations and (b) two narrow bands of the emission spectrum of the exhaust (see figure).

The frequency bands are selected on the basis of previous experience as being indicative of the condition of the engine: The appearance of certain anomalous wavelengths in the exhaust can be correlated with the appearance of certain frequencies of vibration. By observing the evolution of the plots, a test engineer can determine when damage has become severe enough to warrant turning the machinery off or disassembling the machinery to inspect or replace the bearings.

*This work was done by Carol L. Martinez, Michael R. Randall, and John W. Reinert of Rockwell International Corp. for* **Marshall Space Flight Center**. *For further information, Circle 161 on the TSP Request Card.*

*Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 20]. Refer to MFS-29733.*

# Dynamic Tester for Rotor Seals and Bearings

## A simplified apparatus measures performance under vibration.

*Marshall Space Flight Center, Alabama*

A testing apparatus measures some of the dynamic parameters of rotor seals and bearings. It tests damping seals, damping bearings, conventional seals (such as labyrinth seals), and conventional bearings (such as ball bearings). It can be used with a variety of pumped liquids, from water to liquid oxygen or hydrogen.

Designed primarily to test the bearings and seals of turbopumps, the tester rotates the shaft at high speed while liquid flows much as it would in a real turbopump. Meanwhile, the tester subjects the bearings and seals to vibration. It measures pressures at various points to determine leakage and dynamic parameters that depend on pressure. It also measures the deflections of the components.

The version illustrated in the figure contains a set of four damping seals and two damping bearings to be tested. The liquid enters a hollow shaft under high pressure from both ends. The liquid flows out of the shaft along several paths, including through a reaction turbine, which generates a torque that drives the shaft without axial thrust. Small discharges of liquid at opposite ends of the shaft negate any residual axial load.

The four damping seals to be tested are formed by the liquid that flows between the shaft and a grooved bushing that surrounds the shaft. The liquid flows into the damping seals through radial holes in the shaft. A pair of rods tangent to the bushing (only one is shown in the figure) vibrates the seals at frequencies different from the rotational frequency. Strain gauges on the rods measure the forces applied by the vibrator and the torque on the test seals from fluid-rotation drag.

Pairs of orthogonal proximity probes on opposite ends of the shaft measure the deflections and vibrations of the shaft. Similar pairs of probes on opposite ends of the bushing measure the vibrations and deflections of the seal.

An array of pressure gauges at critical locations measures inlet and discharge pressures. The back pressure in cavity A controls the shaft speed. The back pressure in cavity B controls the pressure drop across the test seals.

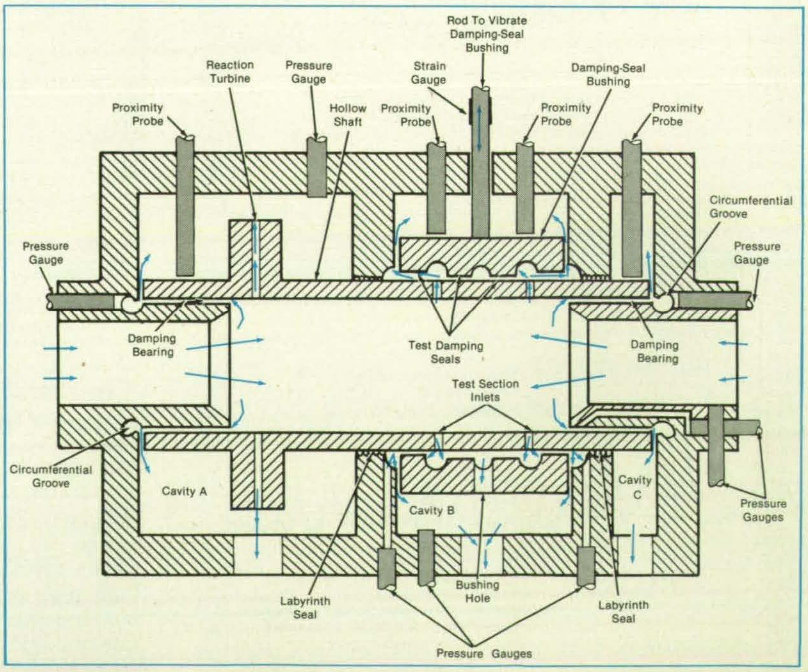
Flowmeters measure the discharge of liquid from cavities A, B, and C, which are separated by labyrinth seals. The flow from chamber A is used to calculate the turbine torque. The flows from chambers B and C are used to determine the leakage through the damping seals and the damping bearings.

Because the tester contains no rolling-element bearings, it is highly reliable at high speeds. The shortness of its shaft eliminates resonances in the testing-speed range. It is simpler than previous testers were: it uses only one liquid; it has no gears, drive motors, or quill shafts; a single back-pressure valve controls shaft speed. Instrumentation is inserted from outside for ease of access and maintenance; electrical connectors are outside the housing, away from the test liquid. Because it produces no axial thrust, rubbing is eliminated and special hydrostatic thrust bearings are unnecessary.

The bearings can be machined off-center in the bushing to determine the effects of eccentricity. Because four bearings are mounted, their eccentricities can be arranged symmetrically with respect to the midsection of the bushing; this eliminates excessive loads on the damping bearings.

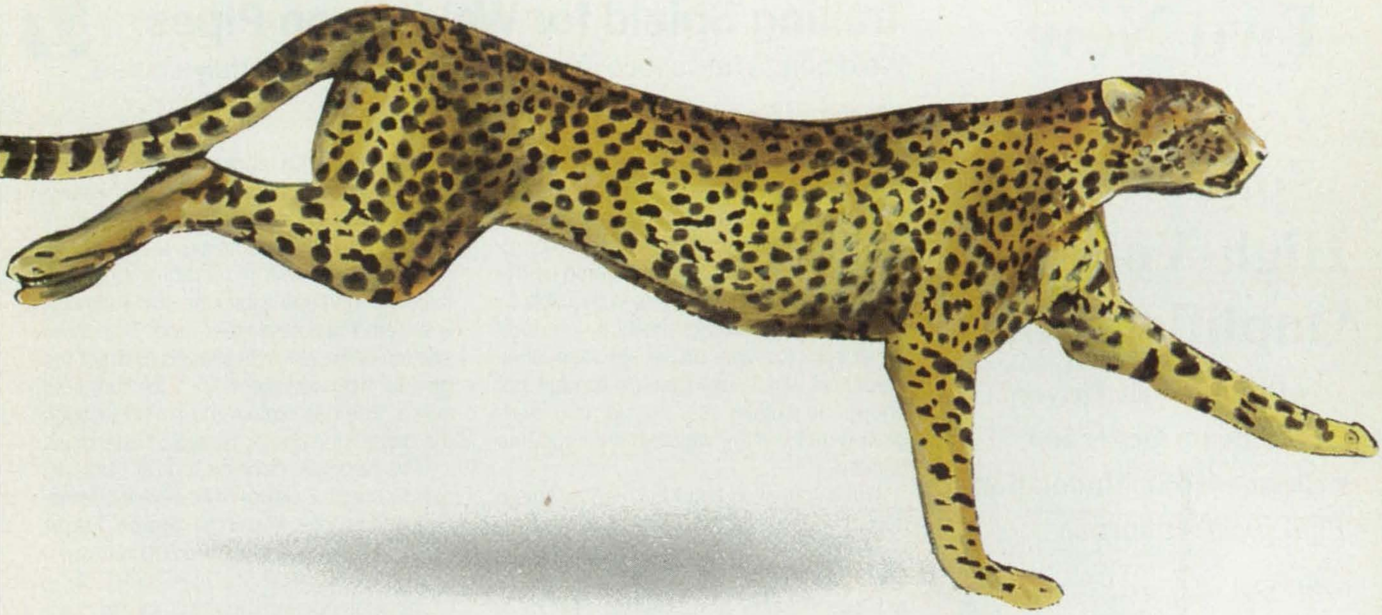
*This work was done by George L. von Pragenau of* **Marshall Space Flight Center**. *For further information, Circle 22 on the TSP Request Card.*

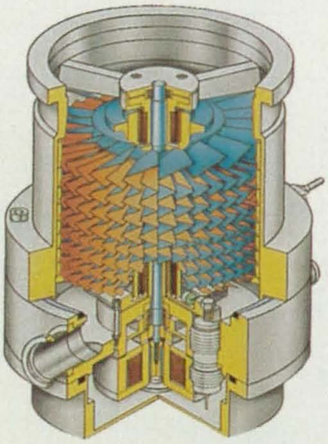
*Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 20]. Refer to MFS-28493.*




**High-Pressure Liquid Flows** by diverse routes through the tester. Flow through the reaction turbine drives the hollow shaft. Flow through the radial holes in the shaft to the inner surface of the bushing forms the damping bearings. Flows at the ends of the shaft balance residual axial thrust.

# Extraordinary runner.





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***The Sensible Solution***

## Trailing Shield for Welding on Pipes

Weld beads remain covered with inert gas until safely cooled.

*Marshall Space Flight Center, Alabama*

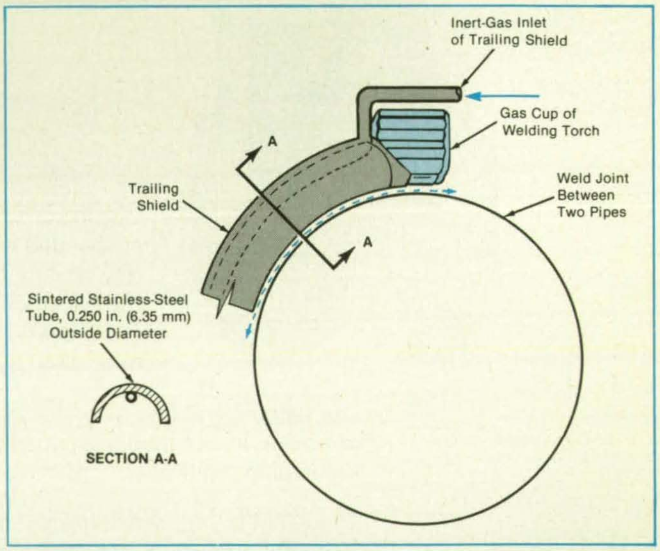
A trailing shield ensures that a layer of inert gas covers the hot, newly formed bead between two tubes or pipes joined by plasma arc welding. The inert gas protects the weld bead from oxidation by the air until it is cooler and less vulnerable to oxidation. The trailing shield is intended especially for use on nickel-base alloy pipes, on which weld beads remain hot enough to oxidize after the primary inert-gas purge from the welding-torch cup has passed.

Unlike previous shields, the new shield does not require a silicone-cloth skirt to keep outside air from entering the gap between the edges of the shield and the workpiece. Instead, the internal contour of the shield creates a steady flow of inert gas to the bead so that no air can reach it. It provides better protection against oxidation than does a skirted shield.

The new shield is a segment of curved, open-walled aluminum pipe that trails the welding-torch cup (see figure). The segment is contoured to match the circumference of the pipes to be welded while maintaining a uniform 0.125-in. (3.2-mm) gap. The inert gas enters the shield through a sintered stainless-steel tube. The cross section of the shield is shaped to direct the gas to the workpiece in tight turbulent swirls. The gas leaves the shield through the gaps at the edges, excluding exterior air.

*This work was done by John B. Coby, Jr., and Kenneth J. Gangl of Rockwell International Corp. for* **Marshall Space Flight Center**. *No further documentation is available.*

*Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 20]. Refer to MFS-29743.*




The **Tubular Shield Partially Encircles** a pair of pipes at a weld joint between them. Inert gas diffuses into the shield through a porous tube, covering the hot weld joint. The shield follows the welding torch as it advances.

## Smaller Coaxial-View Welding Torch

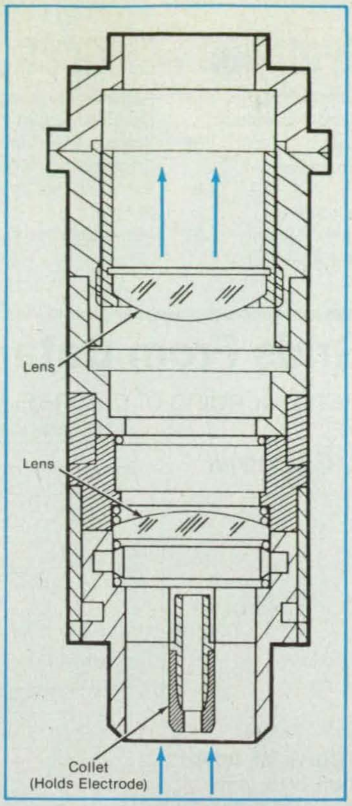
This torch resembles an ordinary torch without optics.

*Marshall Space Flight Center, Alabama*

A coaxial-view torch for gas/tungsten arc welding has only two-thirds the length and width of its predecessor. The shape and size of the new torch are similar to those of a commercial arc-welding torch (Linde HW-27 or equivalent), even though it contains a lens system (see Figure 1). In addition, the collet that holds the electrode has unique design that allows greater passage of light than earlier designs did.

Because the redesigned torch is so much smaller, it can be used in small

Figure 1. The **Optics in the Welding Torch** are concentric with the electrode. The principal virtue of this design is its relative smallness.




spaces that were previously inaccessible. In addition, because it is so like the commercial version, it can be introduced into production welding operations with a minimum of disturbance.

The torch, mounted on a welding robot (see Figure 2), forms an image of the weld seam and of the molten pool around the electrode axis. The image is used for remote monitoring by an operator or for closed-loop computer control of the robot.

The optical components in the torch are self-aligning, standard-sized parts. These components can be changed easily to obtain different magnifications.

*This work was done by Kenneth J. Gangl of Rockwell International Corp. for* **Marshall Space Flight Center**. *No further documentation is available.*

*Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 20]. Refer to MFS-29744.*

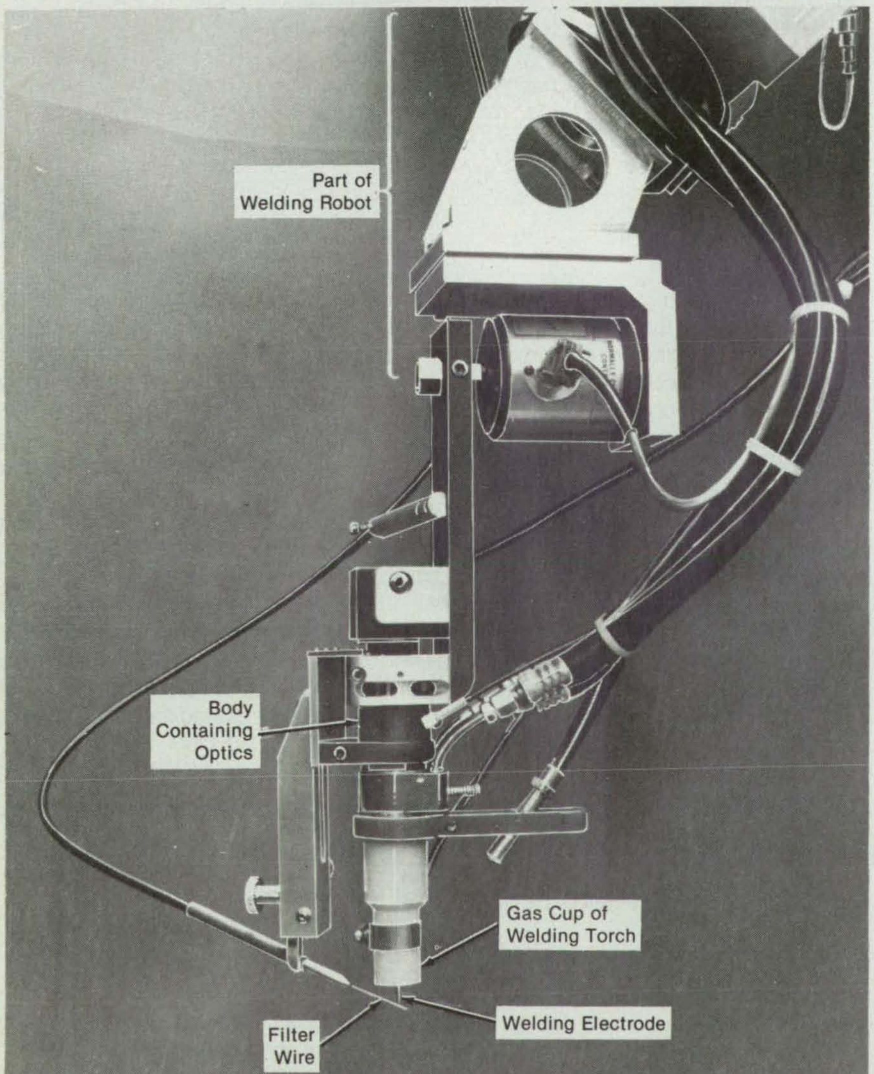



Figure 2. The **Welding Torch**, with its integral optical system, is mounted on one end of a welding robot.

# Mathematics and Information Sciences

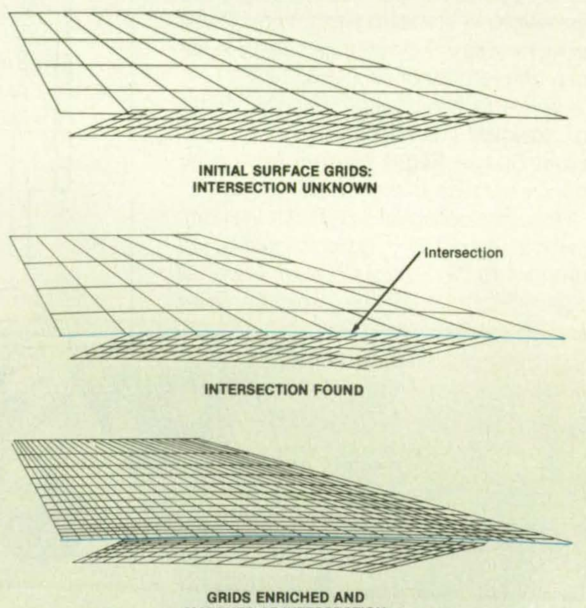


## Generation of Surface Grids From Data Points

Grids are constructed by interpolation and blending of patches.

*Ames Research Center, Moffett Field, California*

A computational procedure generates grids on complicated three-dimensional surfaces (e.g., those of airplanes) from sets of data points (e.g., those generated by computer-aided design systems) that lie on and specify those surfaces. Such grids are needed to compute flows over the surfaces. Starting with grouping of possibly sparse surface points into lines and/or patches, the procedure involves interpolation within and blending of lines and/or patches and possibly the redistribution and reassembly of patches to obtain a finished system of zonal patch grids that match at the boundaries between them. The procedure can be semiautomated via a computer program that performs all steps except the selection of patches and interpolation points, which are left to the discretion of the user.




The **Curve of Intersection** of a vertical surface grid of 8 by 5 points with a horizontal surface grid of 21 by 5 points is initially unknown. An iterative procedure finds the curve of intersection. Additional grid points and lines are then interpolated and matched at the intersection.

The original data on the surface points cannot usually be used in raw form and must be preprocessed. For example, a fuselage might be represented by sets of points that vary widely among different cross sections, wing/fuselage intersections may be undefined, and there may not be enough points to represent the surface accurately in areas of large curvature. In addition, it is necessary to group the data into the network of patches, which is to serve later as the basis for a global block structure. To perform the necessary preprocessing, the procedure includes an algorithm, called the "geometry data processor," which acts like a data editor in that it provides for the insertion, deletion, and redistribution of surface data points. It can also smooth a sectional curve by interpolating and segmenting it into any number of pieces. These functions are all performed in conjunction with interpolation between data points on curves via piecewise parametric cubic polynomials.

Once the initial geometric data have been preprocessed, an algorithm called the "surface grid generator" interpolates each patch to a grid of *m* by *n* points with distribution functions on its boundaries (*m*, *n*, and the distribution functions are specified by the user). Here, the interpolation technique of the geometry data preprocessor is extended to bicubic parametric interpolation. The surface grid generator also finds the intersection of two surfaces via a parametric equation, based on the interpolation scheme, for the intersection of one surface with a curve in the other surface (see figure). The equation is solved by the Newton–Raphson method; convergence is usually obtained within three to four iterations.

*This work was done by Raymond Ching-Chung Luh of* **Ames Research Center**. *Further information may be found in NASA TM-101046 [N89-13747], "Surface Grid Generation for Complex Three-Dimensional Geometries."*

*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-12481*

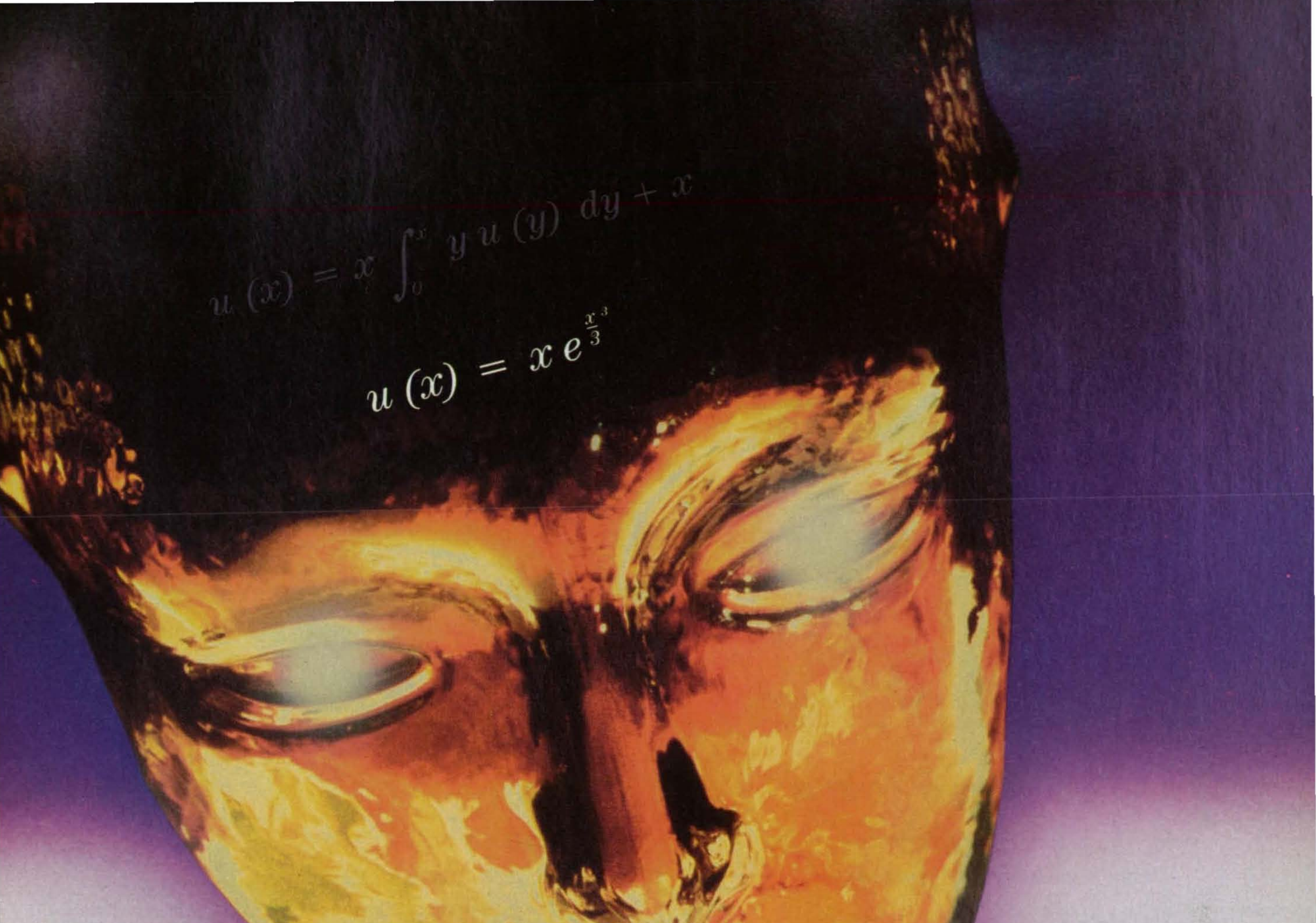
## Algorithm Reveals Sinusoidal Component of Noisy Signal

The product of the analysis is presented in easy-to-interpret graphical form.

*Marshall Space Flight Center, Alabama*

An algorithm performs a simple statistical analysis of a noisy signal to yield a preliminary indication of whether or not the signal contains a sinusoidal component. The algorithm is suitable for the preprocessing or preliminary analysis of vibrations, fluctuations in pressure, and other signals that include large random components. The algorithm is implemented on a personal computer by an easy-to-use program.

The success and utility of the algorithm depend on several assumptions. One is that the signal has been digitized at a sampling rate high enough to capture any sinusoidal component, and preferably considerably higher than the frequency of oscillation of the sinusoidal component. The second assumption is that the prob-

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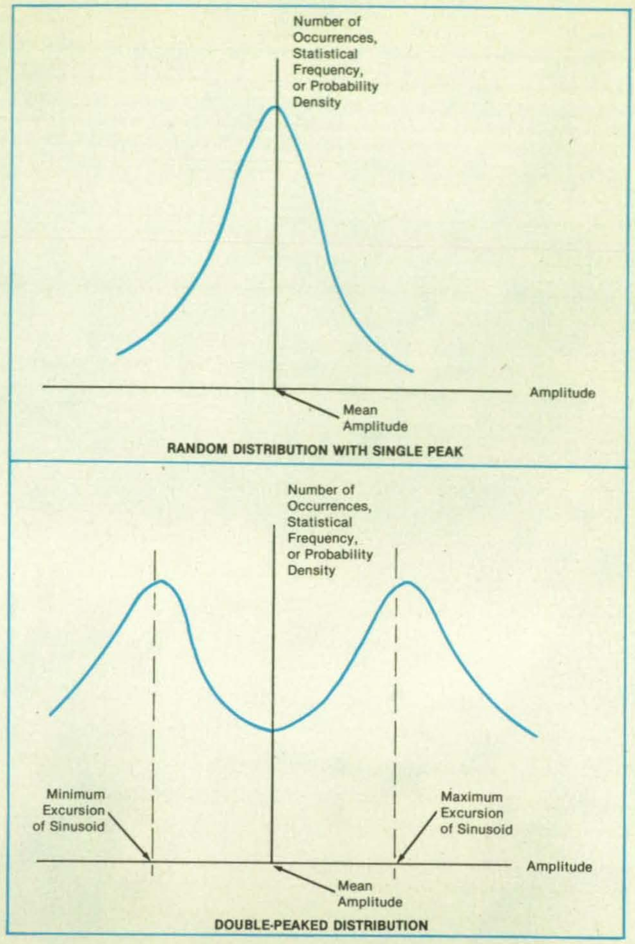



Figure 1. These **Statistical Distributions** are easily distinguishable. Thus even a non-expert user can examine the output of the algorithm and draw a preliminary conclusion as to whether or not a signal contains a sinusoidal component.

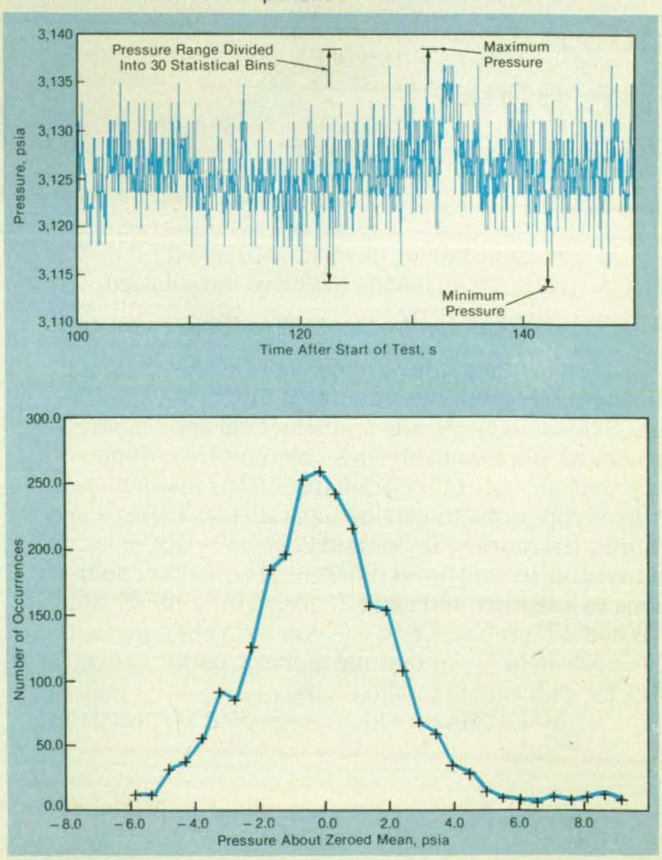



Figure 2. The **Raw Signal Data** of the upper plot were processed by the algorithm to obtain the statistical distribution of the lower plot.

ability distribution (statistical frequency vs. amplitude) of the random (noisy) component of the signal has only one peak at a mean amplitude (e.g., a Gaussian distribution). The third assumption is that only one sinusoidal or approximately sinusoidal component is present.

The algorithm begins by scanning all the samples in the time series to identify the maximum and minimum signals. Then it divides the amplitude interval between the maximum and minimum signals into subintervals (statistical bins), the number of which is specified by the user. Next, the algorithm creates a crude probability distribution by sorting the samples into bins according to their amplitudes. This distribution is presented graphically as a histogram. If many data are available, the histogram can be fairly fine-grained, approaching a smooth probability distribution.

Figure 1 illustrates how to interpret the graphical output. If the signal oscillates randomly about a single mean, then the plot shows a single (e.g., Gaussian) peak. If a sinusoidal component is present, then there are two peaks — one at each of the two extremes of the sinusoidal oscillation.

Figure 2 illustrates an application to real data. The upper plot represents sampled measurements of pressure in the combustion chamber of a rocket engine during a test firing. The data in the upper plot were processed by the algorithm to obtain the lower plot. The lower plot has only one main peak, suggesting that the pressure signal contains little or no sinusoidal component.

*This work was done by Lloyd C. Kwok of Rockwell International Corp. for* **Marshall Space Flight Center.** *For further information, Circle 153 on the TSP Request Card.*

*MFS-29688*

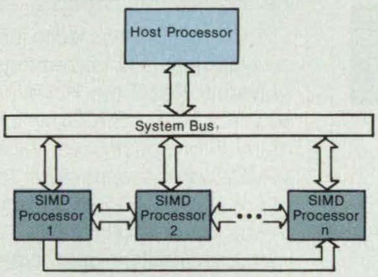
# Fast Parallel Computation of Manipulator Inverse Dynamics

Multilevel parallelism is exploited by an MIMD–SIMD special-purpose parallel architecture.

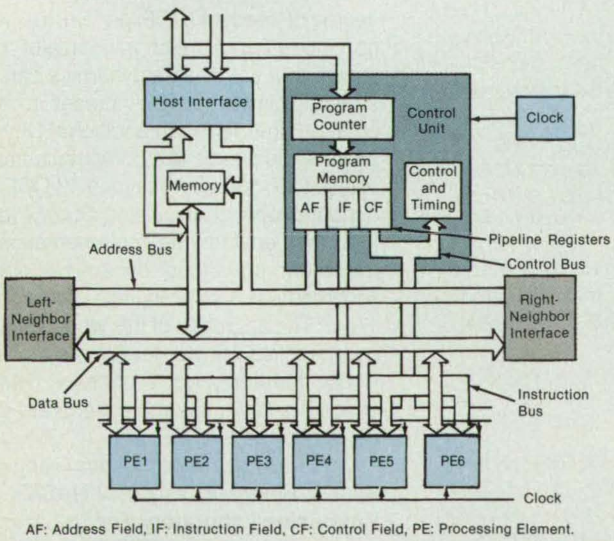
*NASA's Jet Propulsion Laboratory, Pasadena, California*

A method for fast parallel computation of the inverse dynamics problem, which is essential for real-time dynamic control and simulation of robot manipulators, is undergoing development. The method enables the exploitation of a high degree of parallelism and, hence, the achievement of a significant computational efficiency, while minimizing various communication and synchronization overheads as well as the complexity of the required computer architecture. Unlike previous methods developed for this purpose, this one does not represent an attempt to exploit the possibly suboptimal capabilities of any specific parallel computing architecture for the problem. Instead, this method first starts by analyzing parallelism at several computational levels in the Newton–Euler formulation of the inverse dynamics problem and by designing algorithms for efficient exploitation of parallelism. A special-purpose parallel architecture is then designed and developed for efficient im-

The **Universal Real-Time Robotic Controller and Simulator (URRCS)** consists of an internal host processor and several SIMD processors with a ring topology. The architecture is modular and expandable: more SIMD processors can be added to match the size of the problem. The SIMD processors can operate asynchronously and in a MIMD fashion.




THE URRCS ARCHITECTURE




AF: Address Field, IF: Instruction Field, CF: Control Field, PE: Processing Element.

THE SIMD PROCESSOR ARCHITECTURE

plementation of the algorithms.

A hierarchical graph-based approach is proposed to study parallelism at several computational (or, abstraction) levels, the algorithm and the architecture for exploitation of the algorithm, the relationships between various algorithmic and architectural features, and efficient design tradeoffs. At each level, an algorithm is regarded as the application of a parallel model of computation that transforms the computation into a graph. Each node of the graph represents an operation or a set of operations on a subset of data, and the directed arcs represent the data dependencies among the nodes. The graph is then mapped on an abstract parallel architecture wherein the nodes represent the processors and the arcs represent the communication structure of the architecture.

The mapping process is continued by proceeding through levels of increasing detail, further refining the features of the abstract architecture by making efficient algorithmic/architectural design tradeoffs at each level. The behaviors of the algorithms are described in terms of the flow of data through the graph, which defines the computation time and the sequencing of the abstract architecture. The exact features of the target architecture are defined by optimizing the abstract architecture for maximum exploitation of the properties of the algorithms while minimizing the architectural complexities.

This approach has led to the successful development and implementation of the Universal Real-Time Robotics Controller and Simulator (URRCS), which is an algorithmically specialized, highly parallel MIMD/SIMD architecture (see figure), where MIMD and SIMD stand for "multiple-instruction/multiple-data" and "single-instruction/multiple-data" types of parallel architecture. The practical implementation of the Newton–Euler formulation for a six-degree-of-freedom (DOF) general (i.e., with no optimization) robot manipulator has shown that the inverse dynamics can be computed in 187 $\mu$s. The increase in computation time for each additional DOF is 23 $\mu$s, which leads to a computation time of less than 500 $\mu$s, even for a 12-DOF redundant robot manipulator. Such a performance enables the implementation of the most advanced dynamics-control schemes with a sampling rate greater than 1 kHz. The approach of this work has also been applied for the development of the Robot Mathematics Processor (RMP), which is a faster and more elaborate successor to the URRCS.

*This work was done by Amir Fijany and Antal K. Bejczy of Caltech for* **NASA's Jet Propulsion Laboratory**. *For further information, Circle 5 on the TSP Request Card. NPO-18080*

**Hardware, Techniques, and Processes**



# Instrument Measures Ocular Counterrolling

A compact, battery-powered, noninvasive unit replaces several pieces of equipment and an operator.

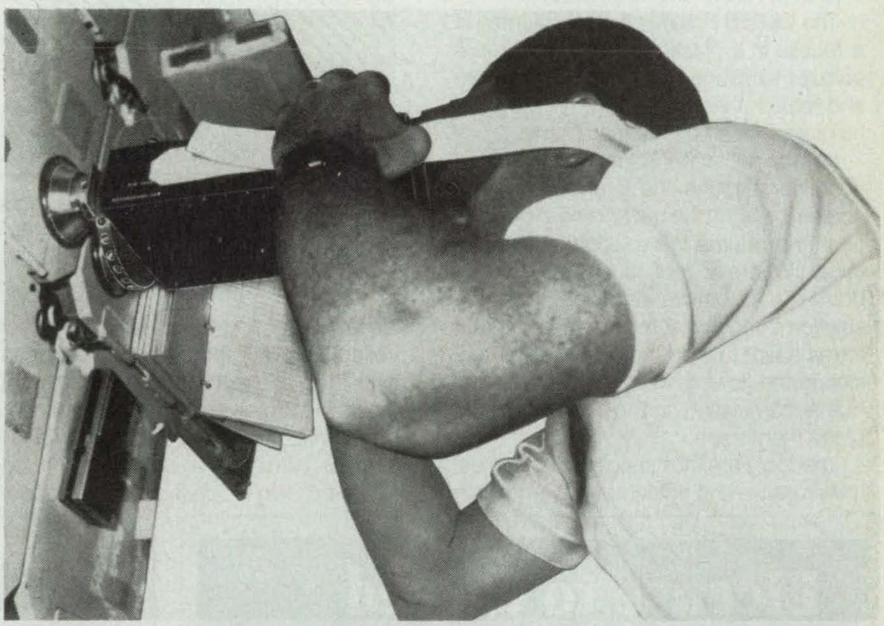
*Lyndon B. Johnson Space Center, Houston, Texas*

An instrument that looks like a pair of goggles with a small extension box measures ocular counterrotation, which is the torsional motion of the eye in the direction opposite that of the tilt of the head relative to the ground and/or caused by muscle-stretch receptors in the neck. The instrument, called the "otolith tilt-translation reinterpretation" (OTTR) goggles, is used in studies of space motion sickness. The instrument was developed to test the OTTR theory, which suggests that, after the central nervous system has adapted to microgravity, otolith signals elicited by tilts of the head in normal Earth gravity are interpreted as indications of linear translation. The OTTR goggles can also be adapted to use on Earth and determine the extent of impairment in patients who may have impaired otolith functions.

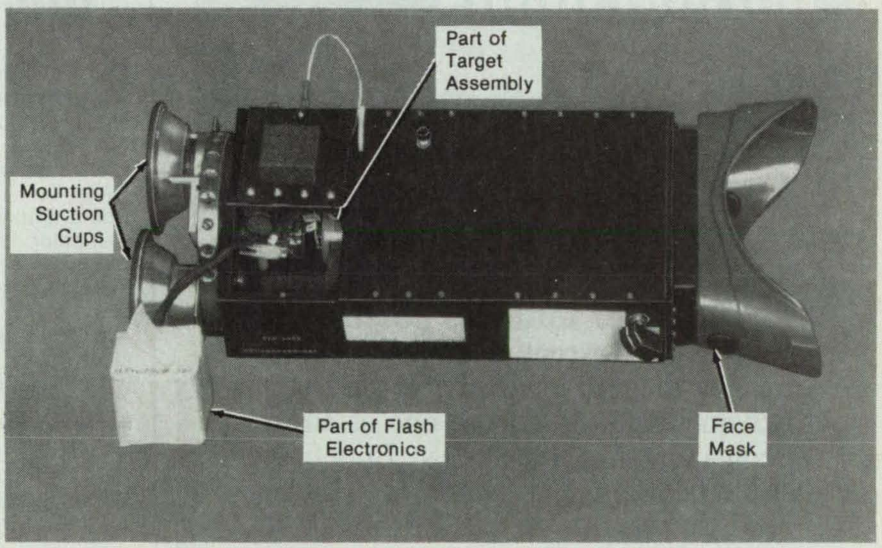
Excluding mounting suctions cups and the face mask that make contact with test subject or patient, the main part of the instrument is contained in a box 10.5 by 5.5 by 2 in. (26.7 by 14 by 5.1 cm). It measures the torsion of the eye by measuring the relative motion of an afterimage briefly imprinted on the retina by a flash of light. Previously, such measurements had to be performed in a darkened laboratory by one or two operators in addition to the test subject, who was restrained on a large tilt table. Assorted photographic equipment on test stands was employed.

The new instrument contains electronics, flash, target, display, and mechanical components in a single unit. It is mounted on a wall or cabinet with suction cups and operated by the test subject alone. The subject presses against the face mask to close out ambient light. A strap encircling the subject's head helps to maintain a tight fit (see figure).

The subject turns on the angle-indicating display in the goggles and sets a target to 0° (that is, perpendicular). The display is then turned off. Next, a cue light in the middle of the target is turned on; the subject focuses on this light and presses the flash button. The flash imprints the image of the target on the retina. Thereafter, a light is strobed twice per second to maintain the afterimage. The subject straightens the head and rotates the target until it becomes aligned with the afterimage. The subject turns on the display once more and records its position. This procedure is done for initial head angles of 0°, 15°, 30°, and 45°.



**SUBJECT SELF-ADMINISTERING TEST**




**INSTRUMENT ALONE, SHOWING SOME COMPONENTS**

The **Compact, Battery-Powered Instrument** enables a subject to self-administer tests for ocular counterrolling.

*This work was done by Barry M. Levitan and Millard F. Reschke of* **Johnson Space Center** *and Lawrence N. Spector of Krug International. For further information, Circle 50 on the TSP Request Card.*
*MSC-21711*

# Capillary-Effect Root-Environment System

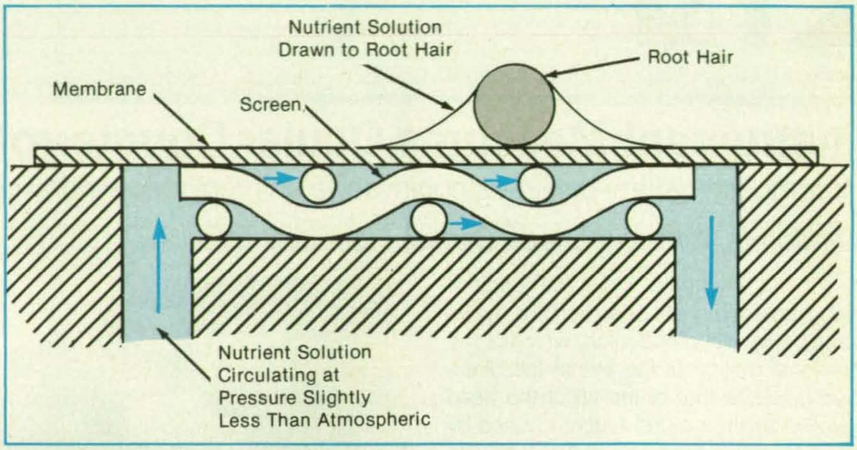
Capillary forces in a membrane prevent excess flow.

*John F. Kennedy Space Center, Florida*

The capillary-effect root-environment system (CERES) is an experimental apparatus for growing plants in nutrient solutions. Although the apparatus was conceived for use in the microgravity of space, it may also find terrestrial application in germinating seedlings, because it can protect them from extremes of temperature, moisture, and soil pH and from overexposure to fertilizers and herbicides.

The CERES includes a plastic screen in a recess in a plastic plate (see figure). A porous membrane is placed over the screen and sealed at the edges of the recess. Root hairs are placed on the membrane.

Hydroponic water solution flows from a container through the interstices of the screen, beneath the membrane. A peristaltic pump returns the solution to the container. Where a root touches the membrane, its adsorptive attraction draws the solution through the membrane so that it forms a film around the root. A slight tension in the flowing water prevents excessive accumulation on the outside surface of the membrane.




**Nutrient Solution Is Circulated** at a slight tension in a cavity filled with plastic screen and covered by a porous plastic membrane. By adsorptive attraction, the root draws solution through the membrane.

The roots are thus supplied continuously with water and nutrients as well as with air, while the flow of the solution is controlled. Capillary forces in the membrane help to regulate the flow. Tomato plants grown in a prototype of the apparatus were similar in size and shape to those grown in a more conventional hydroponic trough with a thin film of flowing nutrient solution. Root hair was strongly developed and roots were healthily branched.

*This work was done by Bruce D. Wright of Colorado State University for* **Kennedy Space Center**. *For further information, Circle 68 on the TSP Request Card.* *KSC-11350*

# New on the Market

Pictured above is a new **pre-engineered construction system** from Crystal Mark Inc., Glendale, CA, that produces rigid frameworks using extruded aluminum frame members and aluminum diecast corners fastened by concealed bolts. Complex enclosures can be created from over 50 angled extrusions and matching corner castings.
**Circle Reader Action Number 790.**

Virtual Prototypes Inc., Montreal, Quebec, has released version 2.0 of VAPS (Virtual Applications Prototyping System), a **pictorial software tool** for user-interface prototyping, automatic code generation, real-time simulation, and training. Suited for design of avionics and console displays, VAPS rapidly creates and animates display consoles using graphical objects. An advanced communications package enables its virtual prototypes to interface with other software programs. VAPS 2.0 runs on Iris 4D, Indigo, RS/6000, SPARCstation, and HP 9000 Series 700 computers.
**Circle Reader Action Number 800.**


BeamGrabber, a new **laser beam diagnostic system** from Photon Inc., Santa Clara, CA, quickly and cost-effectively tunes laser cavities and qualifies the energy distribution of optical beams. At rates up to 60 Hz, BeamGrabber captures, digitizes, and displays beam distribution patterns while arithmetic processors provide continuously updated, numeric beam values. Cameras serving as beam detectors are re-engineered to provide linear read-out across the entire active area. BeamGrabber features automated beam tracking functions, a touch-button control panel, and high-speed I/O ports.
**Circle Reader Action Number 792.**

Sun Microsystems, Mountain View, CA, has introduced the SPARCengine® IPX™, the first **single-board computer** to include built-in graphics along with a RISC processor and networking. Powered by a 40 MHz microprocessor, the SPARCengine IPX offers 24.2 SPECmarks performance. It supports the OpenWindows™ environment, which features the intuitive OPEN LOOK® graphical user interface and 15 DeskSet™ productivity tools.
**Circle Reader Action Number 794.**


Alpha Omega Instruments Corp., Norton, MA, has introduced a line of **thermoelectric cooler controllers** for use with a variety of modules. The bipolar temperature controllers feature a linear-constant current source, proportional and integral temperature control, front-panel temperature adjustment, TEC current, and loop gain. Applications include cooling of laser diodes, IR detectors and arrays, integrated circuits, CCDs, thin-film chemistry, and aerospace components.
**Circle Reader Action Number 798.**

A new **RGB CCD color video camera** developed by American Innovision Inc., San Diego, CA, displays, analyzes, and archives true-color low-light images. The camera features user-selected sensitivity, a high-resolution monitor display, and archiving capability on optical disks, tape, and hard or floppy disks. The camera has been used for microscopic low-light applications such as fluorescent antibody studies and DNA probe analysis.
**Circle Reader Action Number 796.**

A low-cost, miniature **Hall-effect magnetic field sensor** is available from FW Bell Inc., Orlando, FL. Priced at $8.50, the solid-state GH-600 Hall generator provides magnetic sensitivity from 50 to 120 mV. It features high input impedance and requires a low current.
**Circle Reader Action Number 788.**





# New on the Market

Maxwell Laboratories Inc., San Diego, CA, has developed a line of miniature double-ended **capacitors** for use in pulsed electronic circuits of high-power lasers. Constructed of foil polypropylene, the capacitors have up to 25 times the capacitance of ceramics and exhibit a smaller temperature coefficient of capacitance. Additional applications include filters for high-voltage DC power supplies, electrostatic copying machines, electron microscopes, and CRT power supplies.
**Circle Reader Action Number 716.**

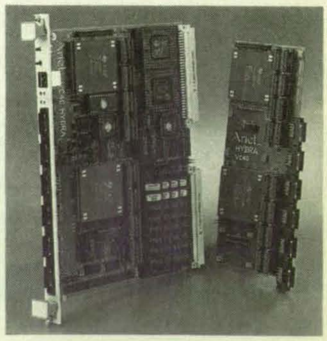
A **video optical inspection system** designed by Flexbar Machine Corp., Islandia, NY, enables users to view surface finishes at the macro or micro level, to determine deviations from standard dimensions, and to verify tolerances. It incorporates a compact video camera, micro-zoom or macro-zoom lenses, and a video monitor. An optional video micrometer superimposes a calibrated screen on the monitor for accurate and repeatable measurements of distances and dimensions.
**Circle Reader Action Number 718.**

The Light Brigade, Renton, WA, has produced a series of **fiber optics training videos**. The first in the series, *Introduction to Fiber Optics*, covers optical theory and fiber structure. Other tapes describe fiber optic cable and preparation, splicing and characterization, testing and troubleshooting, lasers and detectors, and applications.
**Circle Reader Action Number 728.**

The Video/1 product family from Psitech Inc., Fountain Valley, CA, provides high-speed compression, decompression, and display for real-time video applications. A **JPEG processing card,** accepting any RS-170, NTSC, Pal, or Secam signal, captures an image frame and stores up to 8 MB of local memory. It supports compression ratios of up to 200:1. An **image display card** decompresses and displays images on a high-resolution buffer at 30 frames per second for full motion or still video capabilities.
**Circle Reader Action Number 722.**

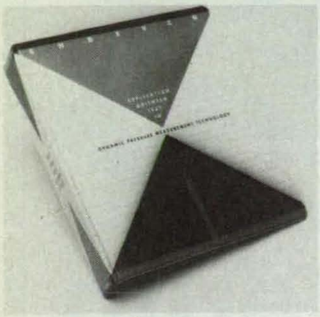
Photometrics, Tucson, AZ, has produced a digital, cooled **CCD camera** integrated with powerful image processing software running under Windows 3. The model ATC200 camera provides 12, 14, or 16 bits/pixel over spatial resolutions from 512 x 512 to 2048 x 2048 pixels. It is suited for applications requiring low-light imaging, low contrast detection, or wide dynamic range.
**Circle Reader Action Number 724.**

A 5-GHz **fiber optic transmitter** introduced by Ortel Corp., Alhambra, CA, uses a distributed feedback laser with a single optical line to make dispersive effects virtually nonexistent, improving transmission quality over long distances. The model 3540A transmitter is equipped with an optical isolator that reduces overall loss in the fiber optic link by 10 Db. The device transmits analog microwave signals over single-mode fiber at 1300 nm optical wavelength.
**Circle Reader Action Number 726.**



Ariel Corp., Highland Park, NJ, has introduced the V-C40, a **VMEbus coprocessor board** that delivers twice the processing power and four times the input and output bandwidth of current 6U VMEbus coprocessor cards. Its four TMS-320C40 DSP chips deliver processing power of 1.1 BOPS and data movement of 1.3 Gbytes/sec. Each chip has two independent 32-bit address buses and six 20-MB/sec parallel interprocessor communication ports. Applications include speech and pattern recognition, simulation, and virtual reality.
**Circle Reader Action Number 720.**

# New Literature



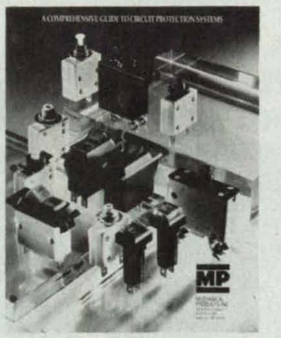
*Dynamic Pressure Measurement Technology*, a new textbook from Endevco Corp., San Juan Capistrano, CA, emphasizes applications and practical techniques for **measuring dynamic pressure phenomena**. Featuring over 150 illustrations, the text reviews the basics of pressure transducer selection, installation, signal conditioning, and calibration.
**Circle Reader Action Number 710.**

Rexroth Corp., Rockford, IL, has released a catalog of **pneumatic servo systems** and components. The 20-page publication describes features, specifications, dimensions, and applications, as well as programming capabilities and configurations. The systems provide positioning accuracy up to ±.0004" and speeds up to 11.5 ft/sec using modular NC-controlled linear actuators, which serve as building blocks for custom multi-axis systems.
**Circle Reader Action Number 708.**


A four-color brochure from Hobart Tafa Technologies Inc., Concord, NH, describes HAWCS II, an innovative **robotic motion and process control system**. The hardware and software system enables complete control of robotic thermal spray or welding cells from a single console. HAWCS II can be incorporated into turnkey systems for thermal spraying (plasma, electric arc, HVOF, or combustion), welding (VPPA, MIG, Dabber, TIG, or PTA), and waterjet stripping of metal coatings.
**Circle Reader Action Number 712.**

A six-page **optical table** specifications guide is available from Kinetic Systems Inc., Roslindale, MA. The publication details the performance characteristics and configurations of the VIBRAPLANE line of optical tables and describes isolated and nonisolated support systems.
**Circle Reader Action Number 714.**

A catalog from Mechanical Products Inc., Jackson, MI, features high-precision **circuit breakers** in configurations from 0.05A to 200A. The new Series 24 switchable circuit breaker offers single- and two-pole protection and a lighted power switch or optional toggle handle.
**Circle Reader Action Number 702.**




A full-color brochure describes **precision machining services** available from Westinghouse Electric Corp.'s Electro-Mechanical Division, Pittsburgh, PA. The firm's automated flexible machining cells machine parts up to 2500 pounds at tolerances of 0.0001 inches. Operators are experienced in machining nuclear-grade components and work with a variety of materials including Inconel, carbon steels, and many grades of stainless steel.
**Circle Reader Action Number 706.**

***Principles of Temperature Control***, a 24-page tutorial, is offered free of charge by West Instruments, East Greenwich, RI. The booklet's four sections discuss the control system, load characteristics, control modes, and process control characteristics.
**Circle Reader Action Number 704.**

# Subject Index

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## ADVERTISERS INDEX



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**Editor's note: A subject index of all tech briefs published in 1991 will appear in next month's issue.**


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# PATENTS NASA

Over the past three decades, NASA has granted more than 1000 patent licenses in virtually every area of technology. Sales of licensed inventions exceed $10 million, and royalties paid to NASA approach $1 million. The Space Agency has a portfolio of 3000 domestic and foreign patents and pending applications available now for license by businesses and individuals, including these recently patented inventions:

## Real-Time Data Compression of Broadcast Video Signals

*(US Patent No. 5,057,917)*
Inventors: **Mary Jo W. Shalkauser**, **Wayne A. Whyte**, and **Scott P. Barnes**

A new cost-efficient system digitally codes and decodes broadcast video signals in real time using differential pulse-code modulation. It employs nonuniform quantization and multilevel Huffman coding to substantially reduce the bit/pixel ratio, and a nonadaptive predictor to improve the edge encoding performance.
**Circle Reader Action Number 741.**

## Process for Application of Powder Particles to Filamentary Materials

*(US Patent No. 5,057,338)*
Inventors: **Robert M. Baucom**, **John J. Snoha**, and **Joseph M. Marchello**

A novel process uniformly and continuously applies polymer powder particles to a filamentary material to produce a uniform composite prepreg. A tow is fed under controlled tension into a spreading unit and spread pneumatically into a band. It then is coated with polymer particles from a fluidized bed and fused prior to take-up on a package. The process does not impose severe stress on the filamentary material, nor require long, high-temperature residence times for the polymer.
**Circle Reader Action Number 743.**

## Mechanized Fluid Connector and Assembly Tool System with Ball Detents

*(US Patent No. 5,058,929)*
Inventors: **Ronald C. Zentner** and **Steven A. Smith**

A versatile fluid connector and powered assembly tool is easily operable using one hand. It features a self-aligning structure for quick and accurate attachment and removal of the tool from a modified plumbing union used to join pipe segments, and an electric drive motor that enables control of speed, torque, and direction of rotation.
**Circle Reader Action Number 745.**

## Regenerative Cu/La Zeolite-Supported Desulfurizing Sorbents

*(US Patent No. 5,057,473)*
Inventors: **Gerald E. Voecks** and **Pramod K. Sharma**

The inventors have produced metal ion-exchanged zeolites that remove more than 50 percent of the organosulfur compounds from diesel fuel and other fluid hydrocarbons at moderate temperatures, resulting in cleaner emissions. The zeolites can be repeatedly regenerated without loss of activity, providing an efficient desulfurization system for use in petroleum refining, natural gas processing, utilities, and chemical processing plants.
**Circle Reader Action Number 747.**

## Brominated Graphitized Carbon Fibers

*(US Patent No. 5,059,409)*
Inventor: **Ching-Cheh Hung**

Bromination of graphitized carbon fibers results in a three-fold increase in their electrical conductivity. Mr. Hung's process employs low-cost, high break elongation carbon fibers that have a low degree of graphitization. The fibers, which are inert to bromine at room or higher temperature, are brominated at -7° to 20°C and then debrominated at ambient temperature. Repetition of this process can bring the bromine content to 18 percent.
**Circle Reader Action Number 749.**

## Rapidly Quantifying the Relative Distention of a Human Bladder

*(US Patent No. 5,058,591)*
Inventors: **John A. Companion**, **Joseph S. Heyman**, **Beth A. Mineo**, **Albert R. Cavalier**, and **Travis N. Blalock**

A small, inexpensive bladder monitor addresses incontinence problems in mentally retarded persons and can assist those who have lost bladder control as the result of diabetes, cerebral palsy, advanced age, or other reasons. An ultrasonic transducer worn near the bladder is excited by a microprocessor-controlled pulser to launch an acoustic wave. The wave interacts with the bladder walls and is reflected back to the transducer for processing. The resulting signal is digitized and stored in data memory. Software determines the relative distention of the bladder based on the subject's past history and can transmit a signal to sound an alarm.
**Circle Reader Action Number 751.**

## Passivation of High-Temperature Superconductors

*(US Patent No. 5,059,581)*
Inventor: **Richard P. Vasquez**

Mr. Vasquez has developed a technique for passivating high-temperature superconductors without degrading their superconducting properties. The surface of a superconductor such as $YBa_2Cu_3O_{7-x}$ is passivated by reacting native Y, Ba, and Cu metal ions with an anion such as sulfate or oxalate to form a surface film that has a solubility in water of no more than $10^{-3}$ M. The passivating surface layer can be formed by wet chemical techniques, by gas-phase reaction, or by deposition.
**Circle Reader Action Number 753.**

*For more information about the inventions described above, including licensing procedures, circle the corresponding number on the Reader Action Request Form (page 83).*

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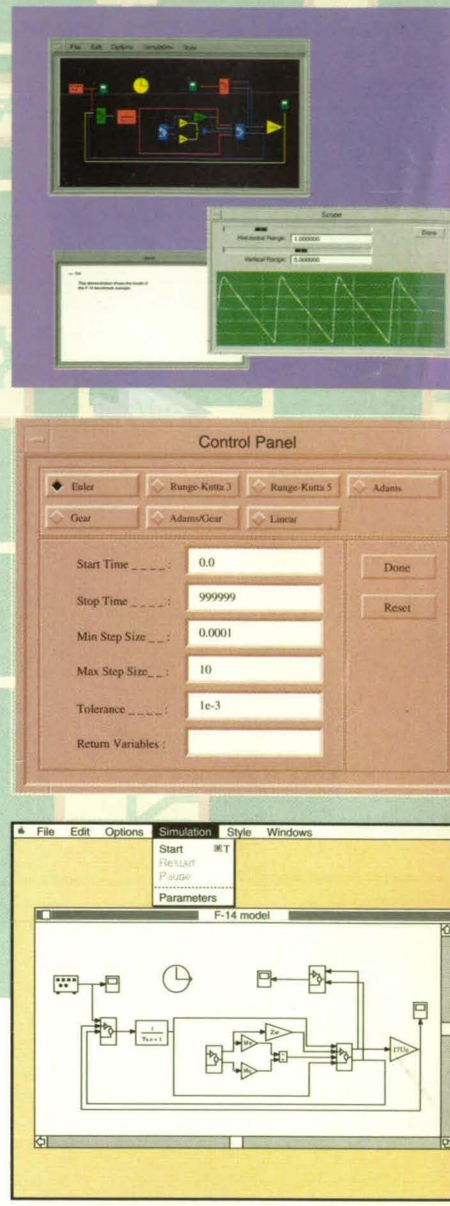
## *Block Diagram Software for Nonlinear Simulation of Dynamic Systems*




*(Top) Use the Scope block to see the "real-time" response of this F-14 model during the simulation; (Center) Specify simulation parameters via dialog boxes or the MATLAB command line; (Bottom) SIMULAB takes full advantage of the X/Motif and Macintosh windowing systems.*

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