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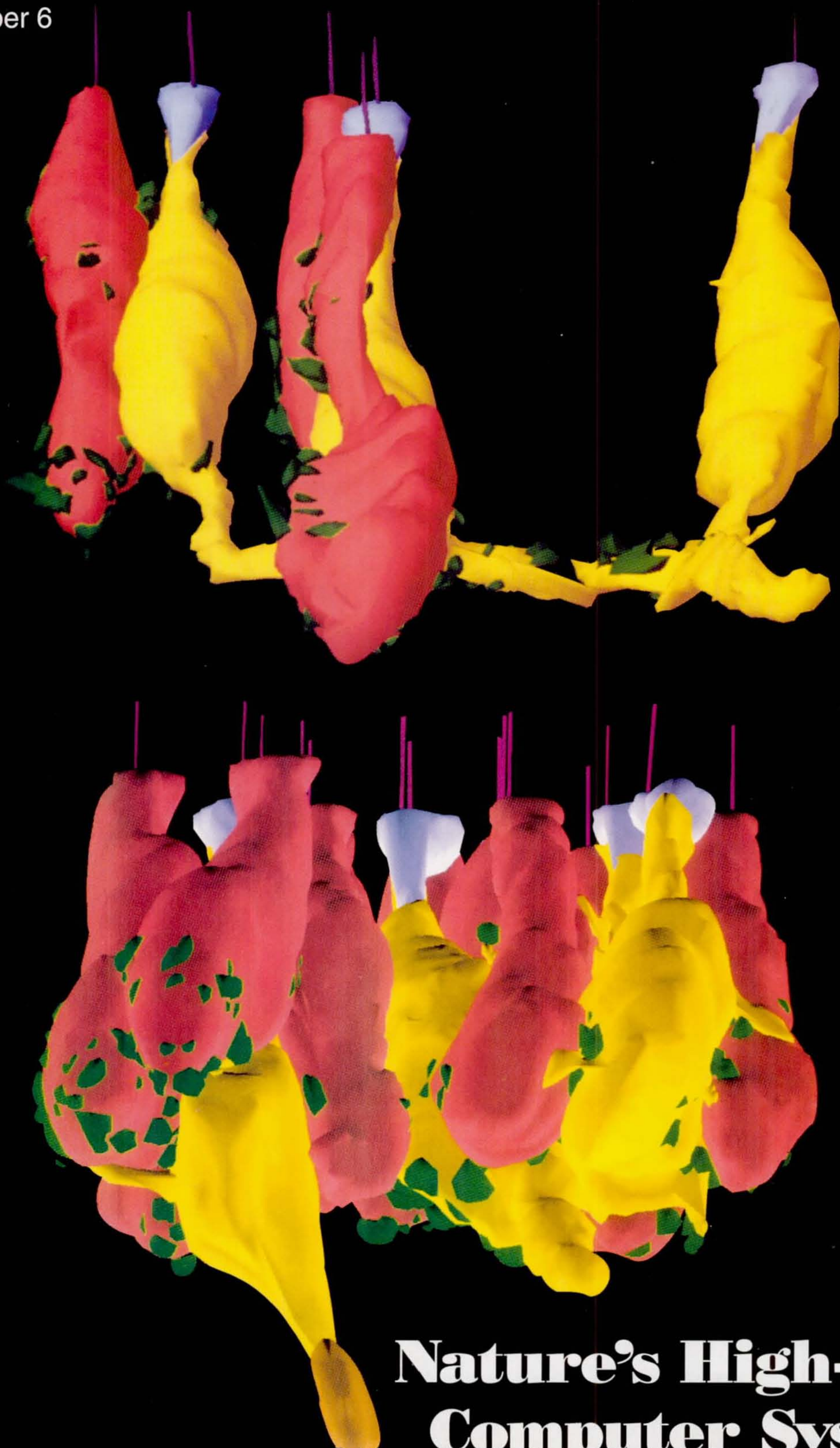
Volume 15 Number 6

Transferring Technology
to Industry and
Government
June 1991



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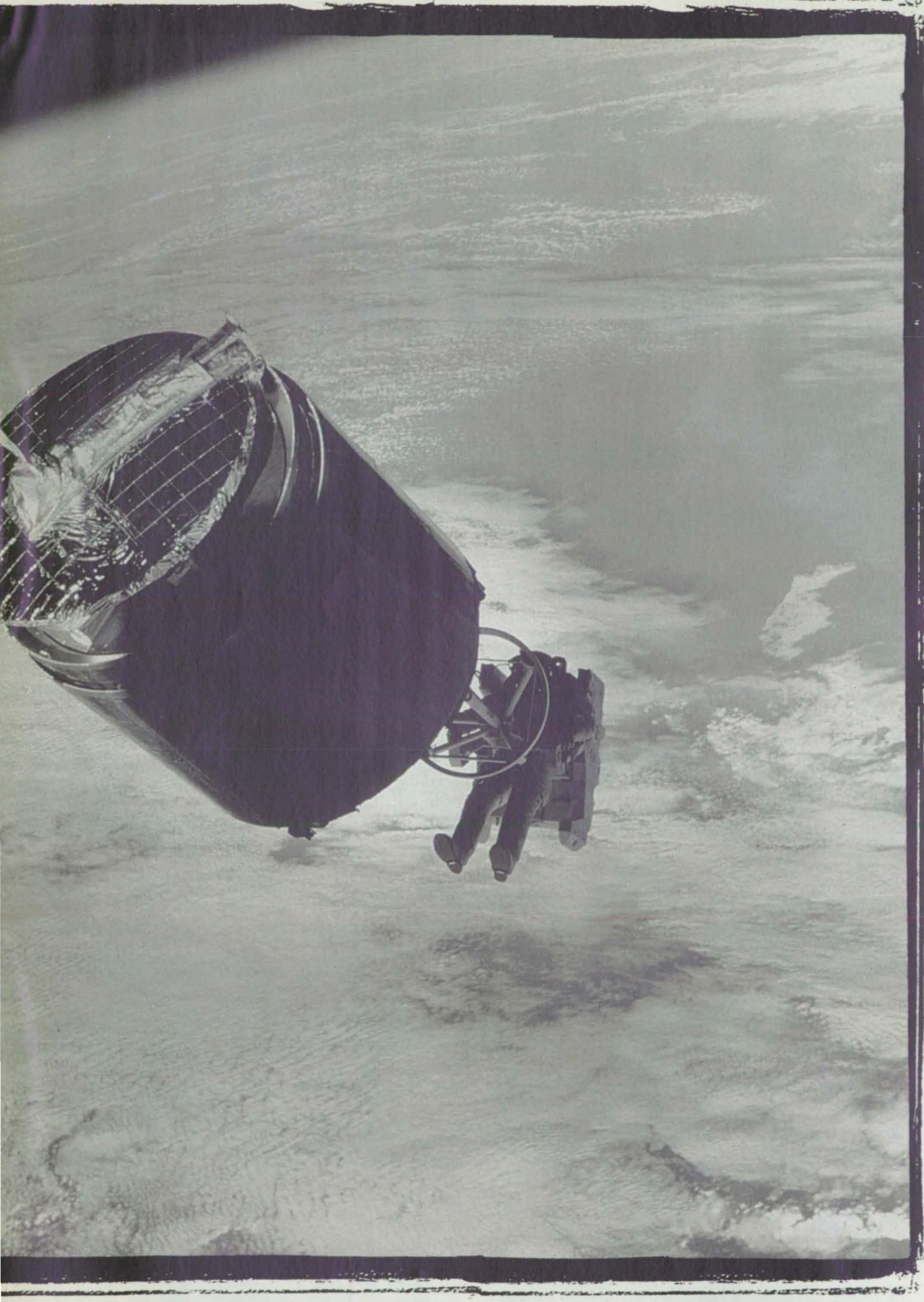

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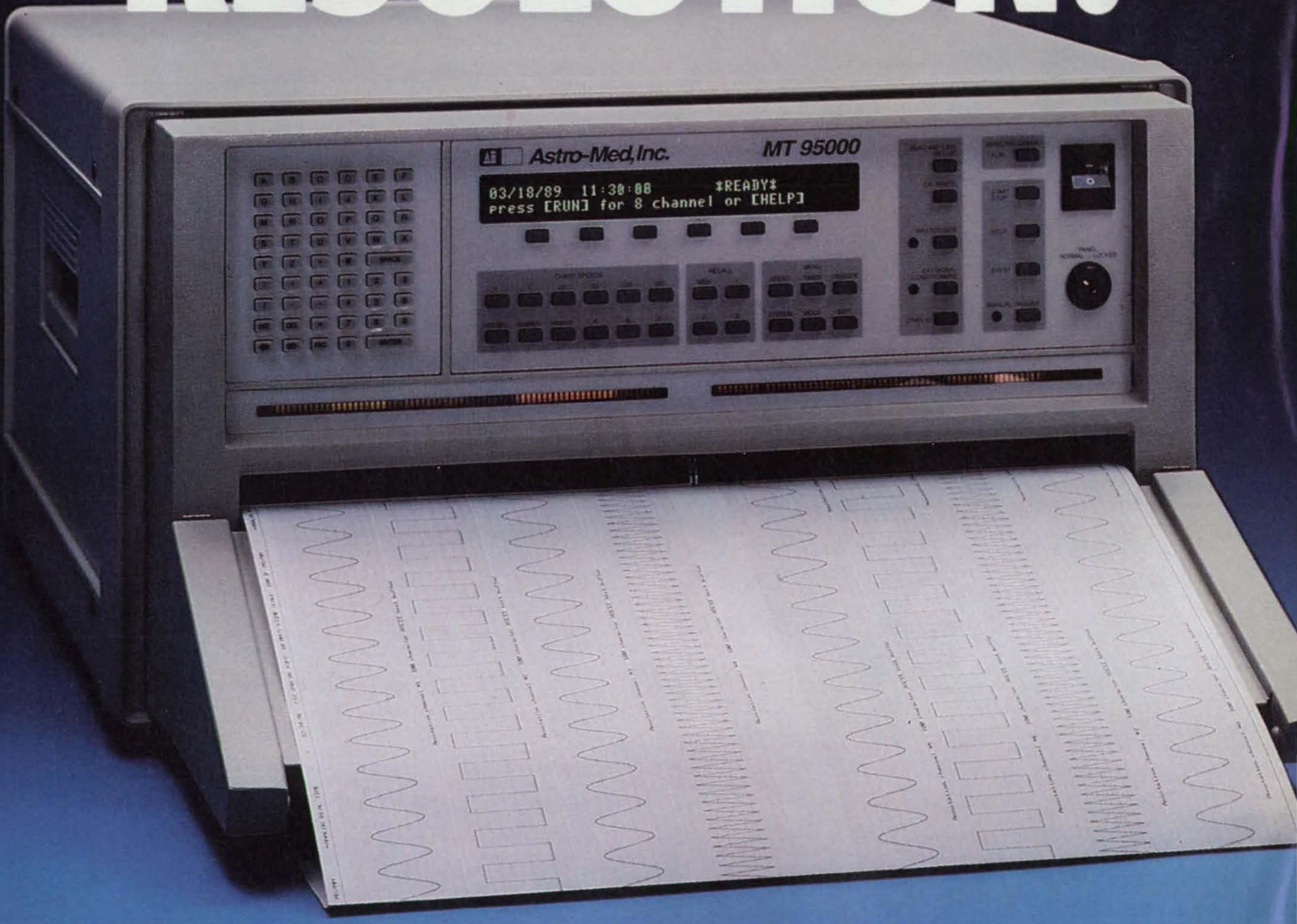

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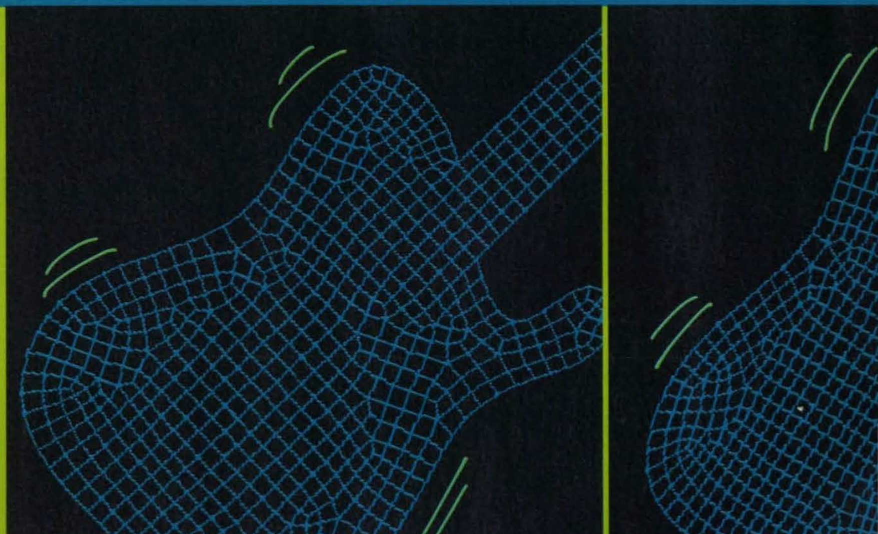

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June 1991
Volume 15 Number 6

BPA ABP

Photo courtesy Ames Research Center

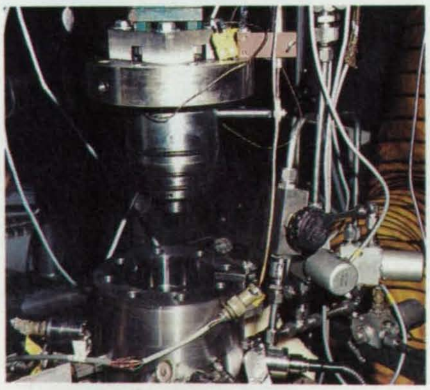
New research on biological neural networks could lead to the development of "thinking" computers that closely mimic the brain in capability and fail-safe design. *Turn to page 10.*

SPECIAL FEATURES

TECHNICAL SECTION

DEPARTMENTS

On The Cover: These simulations illustrate two basic configurations of the receptor cells and nerve terminals of the inner ear's gravity-sensing end organs, the vestibular maculas. The image above shows one functional unit of this simple neural network. Computer-aided reconstruction has revealed that the vestibular maculas are organized for weighted, parallel distributed processing of information, and may provide a blueprint for designing more intelligent and powerful computers.
(Photos courtesy Ames Research Center)



Marshall Center engineers have developed an apparatus for testing O-ring gaskets under a variety of temperature, pressure, and dynamic loading conditions. *See page 138.*

Photo courtesy Marshall Space Flight Center

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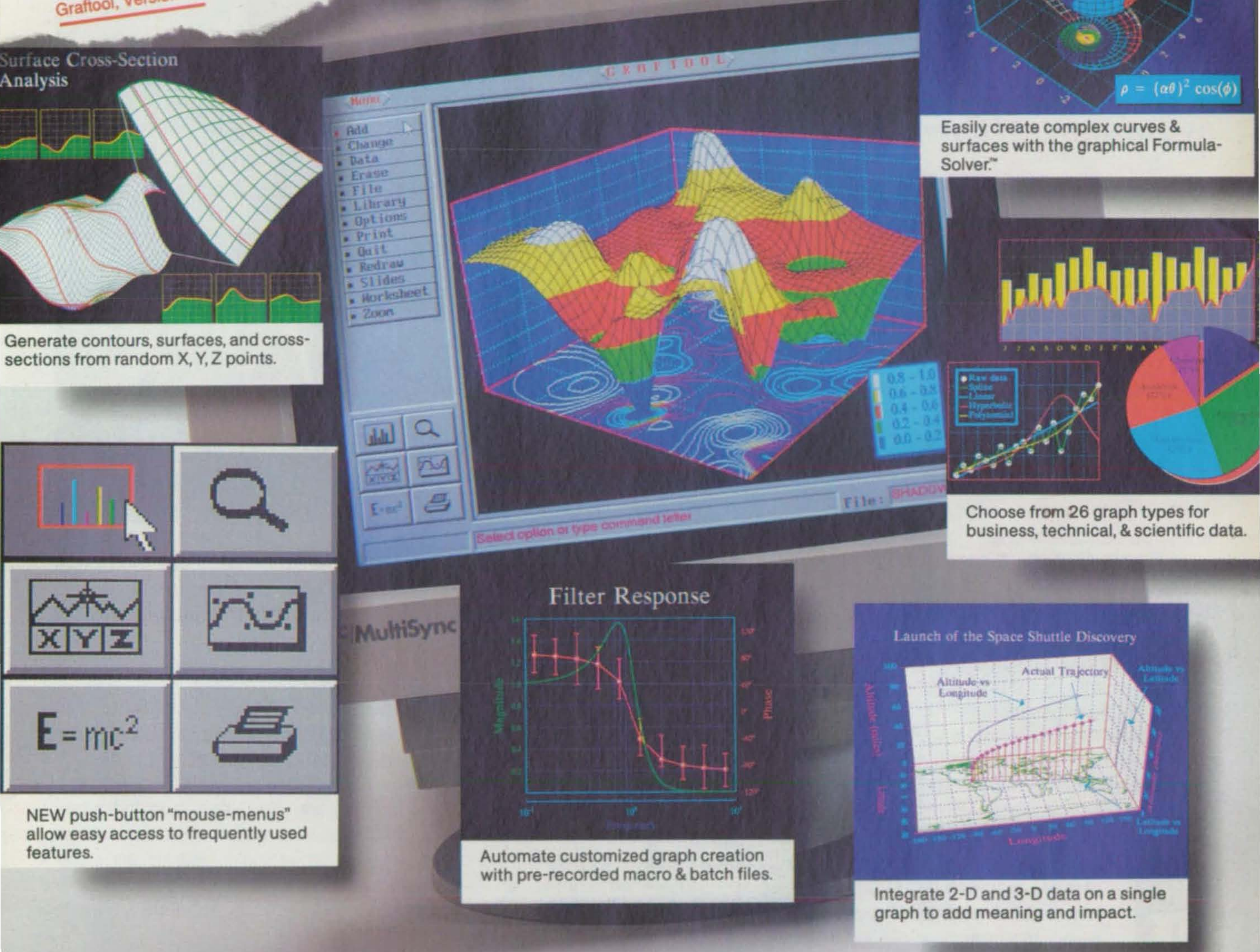

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Biological Neural Networks: Models For Future "Thinking" Machines

by Dr. Muriel D. Ross

Photo courtesy Ames Research Center

Dr. Muriel Ross heads a research team studying the 3D makeup of a biological neural network to uncover the basic principles of neural organization and functioning. Such research could lead to the development of highly-intelligent parallel-processing computers.

One of the more interesting debates of the present day centers on whether human intelligence can be simulated by computers. Some argue that there is something unique, even mystical, about the human mind, and therefore intelligent behavior cannot be duplicated by machines. Others disagree on the premise that brains are simply collections of neurons and can be understood in physical and mathematical terms, perhaps not soon, but in the foreseeable future.

At the NASA-Ames Biocomputation Center, we work under the premise that neurons individually are not smart at all. Rather, they are physical units which are impinged upon continuously by other matter that influences the direction of voltage shifts across their membranes. Some influences are in the direction of depolarization (excitation) while others are in the direction of hyperpolarization (inhibition). It is only through the actions of a great many neurons — billions in the case of the human nervous system — that intelligent behavior emerges.

NASA's INNOVATORS

Understanding even the simplest neural system requires painstaking analysis of the architecture and physiology of its parts. Our goals should be to gain insight into those features that are fundamental to all neural networks and then to develop the algorithms that define the responses. This effort will result in new applications of biological system attributes to artificial systems and in advances in computer design. The research requires the interaction of neurobiologists, neurophysiologists, physicists, modelers, mathematicians, and theoreticians; in short, a formidable array of specialists. It also requires the development of highly-specialized computer technologies. We have assembled a team at NASA-Ames to promote the technology needed to understand the neurobiology, both in its own right and as a guide to future computer advances. We also are working on the physical and mathematical interpretations essential to the development of a silicon chip for potential inclusion in robots.

The biological neural networks we study — the vestibular maculas of the inner ear — are among the simplest of the mammalian neural networks to understand and model. At the same time, they are complex enough to be useful for deriving principles of neural network organization. Because the basic structure of vestibular maculas does not differ between species, we have used the rat utricular macula as a model system.

Macular end organs act as linear bioaccelerometers. They consist of a test mass suspended in a gel-like liquid above a detecting unit. The test mass features tiny crystallite particles called otoconia which are unevenly distributed above the detector. The detecting unit is a neural network structured for weighted, parallel distributed processing of information. It contains two types of hair cells, a system of nerve endings with branches and collaterals, and small nerve fibers that end on type II hair cells and on other neural elements within the macula.

The hair cells function as detectors. At their apical surfaces, they bear a tuft of thread-like sensors known as stereocilia and a special sensory hair called the kinocilium. The tufts are always organized in hexagonal arrays, but the size and height of the individual stereocilia vary from site to site. Ordinarily, the stereocilia are in staircased order, with the tallest bordering the kinocilium, which is attached to the otoconial layer. Since the kinocilium is capable of motility, we believe it agitates this layer. Translational linear acceleratory force affects the otoconia differently according to their individual masses and the background of activity already occurring. The result is that complex waves are constantly emitted, with or without the addition of transient accelerations, and the detecting units respond according to their stereociliary configurations.

Fourier analysis of various tuft organizations shows that the stereociliary tufts are highly-directionally-tuned by their hexagonal organization and height. In another astonishing correlation to human-engineered devices, it seems that nature invented the equivalent of a sensitive phased array antenna millions of years ago. Analysis of the repeating lattice angles of stereociliary tufts shows that they range between 115° and 125°. The optimum repeating lattice angle for man-made antennas is a 120° rhombus.

These and other findings mean that we are well on our way towards understanding — and expressing in mathematical and engineering terms — the basis of detection of incoming linear acceleratory signals by this biological system. We also are improving our understanding of the neural network organization by using computer technology to reconstruct parts of the network and to produce symbolic models that mimic their functioning. This research currently is tedious and labor-intensive, requiring photographing serial sections in a transmission electron microscope; reassembling the micrographs into montages of the section; tracing objects of interest from the montages; digitizing the tracings into a computer; and reassembling the tracings into shaded images. In the Biocomputation Center, we are developing two image processing systems to eliminate the photography and to make digitization more rapid and accurate. The first system captures, enhances, and digitizes electron microscope images directly, then stores them on an optical disk. The second system assembles the digitized images as montages and aligns them to a common coordinate system. A user interacts with the computer to produce files of contour data from which 3D models are generated.

Using current reconstruction techniques, we have demonstrated the smallest functional units of the network, its receptive fields, which consist of the calyceal endings of a nerve fiber together with the hair cells that synapse with them. We also have reconstructed parts of the neural network. Our basic findings are that no two of the receptive fields are identical and that the network varies in complexity from site to site.

The key question is can we reduce the network's complexities to meaningful engineering and mathematical expressions that capture, uncompromisingly, the architectural and functional foundations of the system without simply reproducing it. For if we are to improve artificial computer technologies and produce thinking machines, we must accomplish this without replicating the billions of neurons and their connectivities present in a human brain. We must reduce brain organization to its basics and build from there. Perhaps in some ways the artificial brains can be made to outstrip the biological!

As part of this effort, we have produced a dynamic, symbolic model of a small portion of the neural network. The model has six layers: stimulus, type I hair cells, type II hair cells, calyces, impulse initiation zone, and neuronal discharge. The effects of varying individual parameters, such as direction of input, length of nerve branches, or resting discharge rate, can be determined quantitatively and qualitatively by the model. We now are adding feedforward and feedback loops to study the effects of lateral inhibition on the output of

(continued on page 131)

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 sections 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 14). NASA's patent-licensing program to encourage commercial development is described on page 14.

Casting of Multilayer Ceramic Tapes

High-density ceramic tapes are made by centrifugal casting at accelerations of 1,800 to 2,000 times the normal gravitational acceleration. These tapes are used in capacitors, fuel cells, and electrolytic separation of oxygen from the air. The high casting force in the centrifuge produces very uniform and tightly packed ceramic layers.
(See page 110)

Quasi-Optical Millimeter-Wavelength Resonator

A quasi-optical reflection cavity can be scaled to wavelengths too small for conventional waveguide technology. The design can be scaled easily to frequencies as high as 1 THz.
(See page 16)

Rapid Dry Etching of Photoresists Without Toxic Gases

An experimental dry etching technique may have the potential to strip photoresists from semiconductor wafers without damaging the semiconductor materials. No hazardous or toxic chemicals are used.
(See page 104)

Interface Circuit for Printer Port

A new interface converts the signals at a standard IBM PC or equivalent printer port to those of a general-purpose bus. The interface is very simple, requiring only six integrated circuits, and provides for moderately fast rates of transfer of data.
(See page 26)

Tool Removes Coil-Spring Thread Inserts

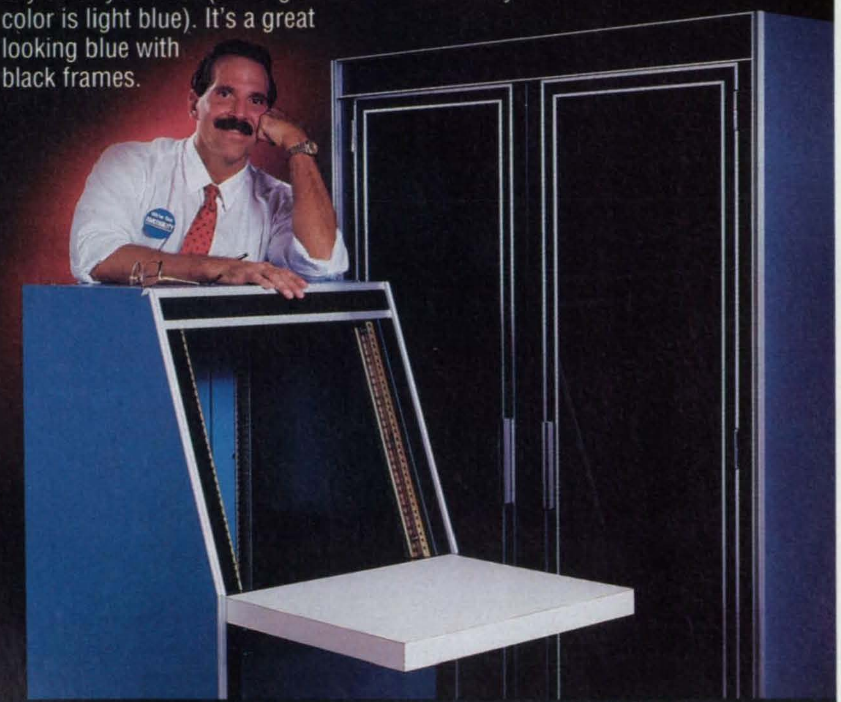
A tool removes coil-spring thread inserts from threaded holes. The tool eases the removal and avoids further damage to the threaded inner surface of the hole.
(See page 106)

Self-Aligning Sensor-Mounting Fixture

A mounting fixture for an optical weld-penetration sensor enables accurate and repeatable alignment. Designed for use on a gas/tungsten arc-welding torch, the fixture replaces a multipiece bracket that was inaccurate and fragile and required time-consuming custom setup.
(See page 107)

Compact Pinch Welder

A hand-held spot welder uses compressed air to drive its opposed electrodes into the workpiece. It provides a higher, more repeatable clamping force than does a manually driven gun and thus produces weld joints of higher quality.
(See page 109)



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

Ames Research Ctr.
Technology Utilization Officer: Geoffrey S. Lee
Mail Code 223-3
Moffett Field, CA 94035
(415) 604-4044
Patent Counsel:
Darrell G. Brekke
Mail Code 200-11
Moffett Field, CA 94035
(415) 604-5104

Lewis Research Center
Technology Utilization Officer: Anthony F. Ratajczak
Mail Stop 7-3
21000 Brookpark Road
Cleveland, OH 44135
(216) 433-2225
Patent Counsel:
Gene E. Shook
Mail Code LE-LAW
21000 Brookpark Road
Cleveland, OH 44135
(216) 433-5753

John C. Stennis Space Center
Technology Utilization Officer: Robert Barlow
Code HA-32
Stennis Space Center, MS 39529
(601) 688-1929

John F. Kennedy Space Center
Technology Utilization Officer: Thomas M. Hammond
Mail Stop PT-PMO-A
Kennedy Space Center, FL 32899
(407) 867-3017
Patent Counsel:
Bill Sheehan
Mail Code PT-PAT
Kennedy Space Center, FL 32899
(407) 867-2544

Langley Research Ctr.
Technology Utilization Officer: Joseph J. Mathis Jr.
Deputy Head, TU Office
Mail Stop 139A
Hampton, VA 23665
(804) 864-2484
Patent Counsel:
George F. Helfrich
Mail Code 279
Hampton, VA 23665
(804) 864-3523

Goddard Space Flight Center
Technology Utilization Officer: Donald S. Friedman
Mail Code 702.1
Greenbelt, MD 20771
(301) 286-6242
Patent Counsel:
R. Dennis Marchant
Mail Code 204
Greenbelt, MD 20771
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Jet Propulsion Lab.
NASA Resident Office
Technology Utilization Officer: Arif Husain
Mail Stop 180-801
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(818) 354-4862
Patent Counsel:
Thomas H. Jones
Mail Code 180-801
4800 Oak Grove Drive
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(818) 354-5179
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Fax (205) 544-3151
Patent Attorney:
Jerry L. Seemann
Mail Code CC01
Marshall Space Flight Center, AL 35812
(205) 544-0021

Lyndon B. Johnson Space Center
Technology Utilization Officer: Dean C. Glenn
Mail Code IC-4
Houston, TX 77058
(713) 483-3809
Patent Counsel:
Edward K. Fein
Mail Code AL3
Houston, TX 77058
(713) 483-4871

NASA Headquarters
Technology Utilization Officer: Leonard A. Ault
Code CU
Washington, DC 20546
(202) 557-5598
Assistant General Counsel for Patent Matters: Robert F. Kempf, Code GP
Washington, DC 20546
(703) 557-5598

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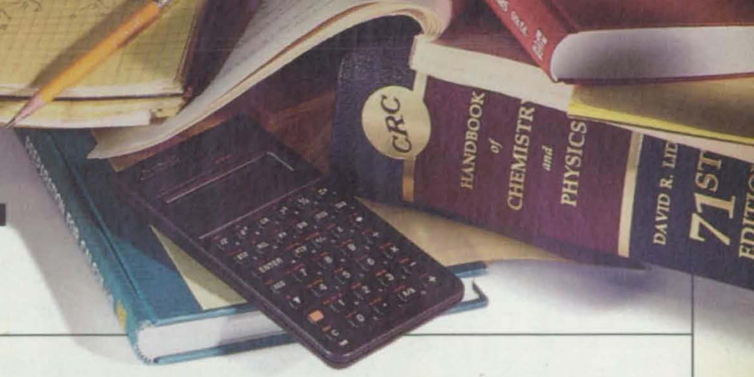

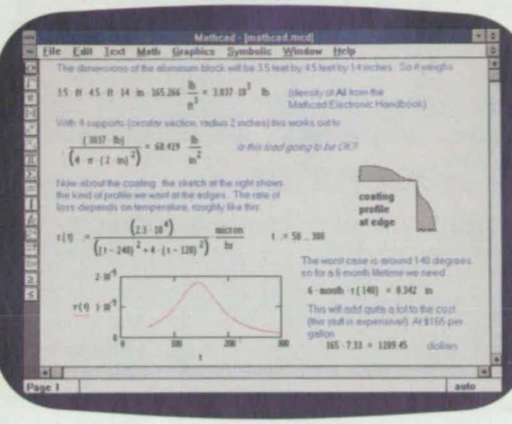

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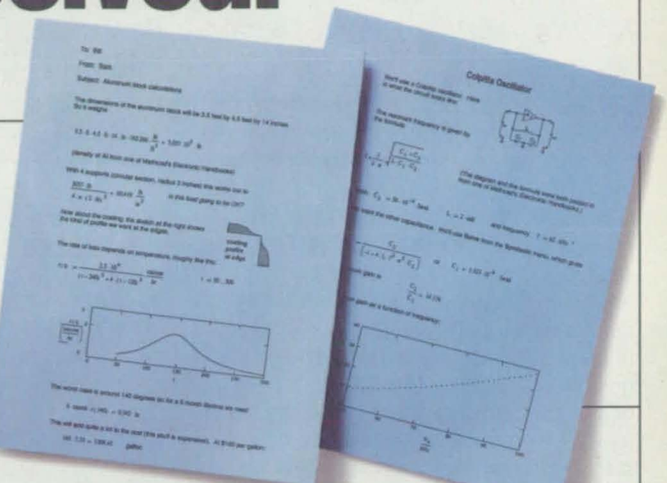
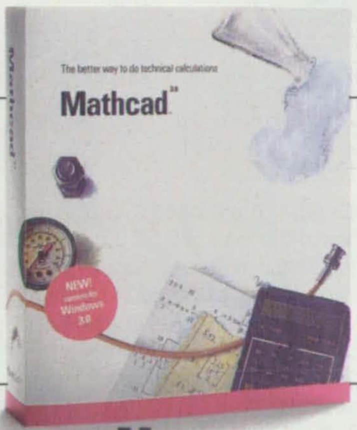


Easy.



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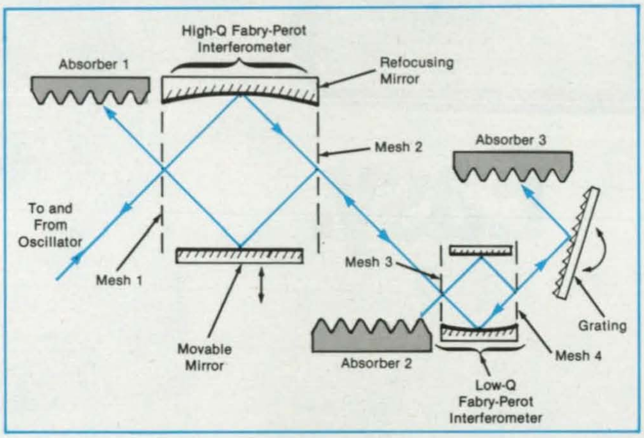
Quasi-Optical Millimeter-Wavelength Resonator

The design can be scaled to wavelengths too small for conventional waveguide technology.

NASA's Jet Propulsion Laboratory, Pasadena, California

A quasi-optical reflection cavity serves as a prototype resonator for oscillators at millimeter and submillimeter wavelengths. Conventional waveguide resonators for this frequency range are lossy, and it is difficult to fabricate them. The quasi-optical resonator (see figure) incorporates a folded Fabry–Perot interferometer of high Q and high finesse, another folded Fabry–Perot interferometer of lower Q and low finesse, and a Littrow-mounted diffraction grating. (Q, a measure of the sharpness of the resonant spectral peaks, is defined as 2π times the electromagnetic energy stored in the resonator divided by the electromagnetic energy dissipated in the resonator during one cycle of oscillation. Finesse is defined as Q divided by the number of wavelengths along the round-trip reflection path.)



The **Quasi-Optical Millimeter-Wavelength Resonator** exploits diffraction and reflection effects to achieve high Q. This type of resonator is useful mainly at wavelengths too short for conventional waveguide techniques but too long for optical techniques.

The electromagnetic beam from the oscillator is coupled into the resonator quasi-optically; e.g., via a feed horn. At an angle of incidence of 45°, the beam first strikes metal mesh 1, which serves as one of the partially reflecting surfaces of the high-Q folded Fabry–Perot interferometer. The other partially reflecting surface is mesh 2. The reflectivity and spacing of the meshes are designed to obtain the desired comb-pattern transmission spectrum. Those parts of the spectrum of the incoming beam that are not within the narrow peaks of this transmission spectrum are reflected by mesh 1 to absorber 1.

The portion of the beam that passes through the high-Q Fabry–Perot interferometer is filtered similarly in the low-Q Fabry–Perot interferometer. The characteristics of meshes 3 and 4 and the other parameters of this interferometer are chosen so that its transmission spectrum includes at most half the peaks of the transmission spectrum of the high-Q interferometer. The rest of the spectrum incident upon mesh 3 is reflected to absorber 2.

The diffraction grating reflects the desired part of the beam back along itself toward the source and performs the final spectral filtering. The Littrow mounting is chosen to effect the desired back-reflection. The mounting angle, period, and other parameters of the grating are chosen so that only one of the spectral peaks that remain after the second grating is reflected back toward the source. The rest of the spectrum incident upon the grating is reflected onto absorber 3.

The prototype resonator was designed, fabricated, and tested at a frequency of 63 GHz. It exhibited a Q of 6,600 and a round-trip loss of 2.52 dB. With attention to some details (e.g., nonuniform illumination, ohmic loss, and spillover loss) that were not considered in the design of the prototype, it should be possible to achieve Q's as high as 10,000. The design can be scaled easily to frequencies as high as 1 THz.

This work was done by Margaret A. Frerking and Karen A. Lee of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 76 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 14]. Refer to NPO-17919.

Thermal Strap and Cushion for Thermoelectric Cooler

The strap would flex in three orthogonal directions to absorb stress and vibration.

NASA's Jet Propulsion Laboratory, Pasadena, California

A relatively inexpensive cushioning strap has been proposed for use as the thermal contact between a thermoelectric cooler and a device to be cooled, such as a laser diode, infrared detector, or charge-coupled device for imaging. The strap would provide high thermal conductance while minimizing thermal and mechanical stresses on the thermoelectric cooler, which is fragile.

The strap would be used as an alternative to a flexible thermal strap made of silver. The silver straps use usually used on flight systems whose requirements for optical alignment and thermal conductance are more stringent than for most applications. The silver straps require expensive fixtures and assembly techniques, such as custom vacuum electron-beam welding. The new thermal strap, in con-

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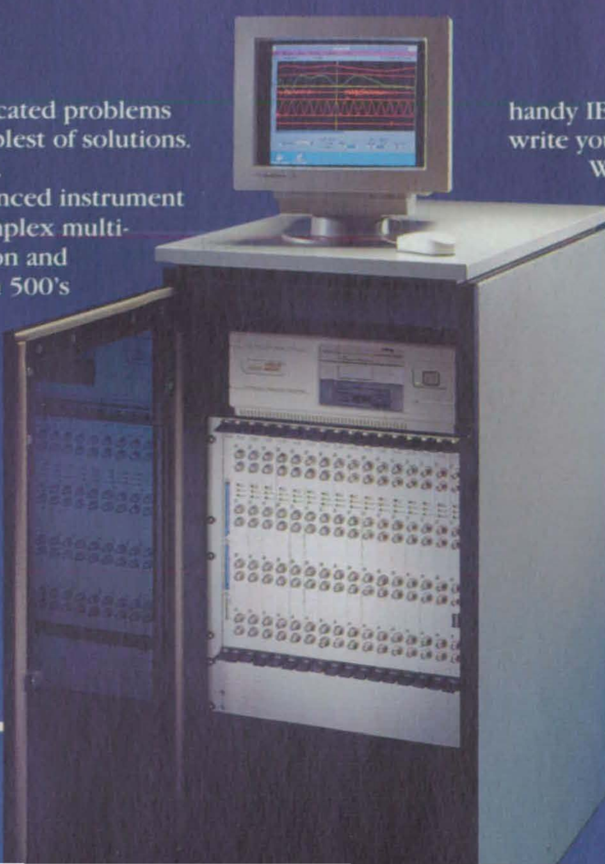

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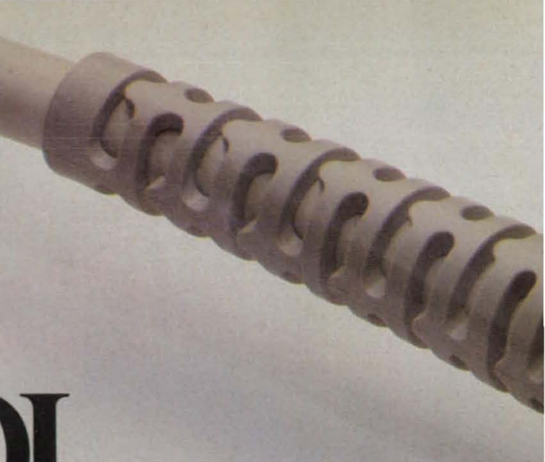

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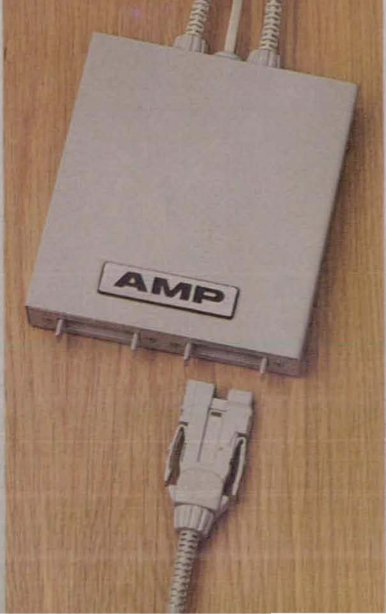

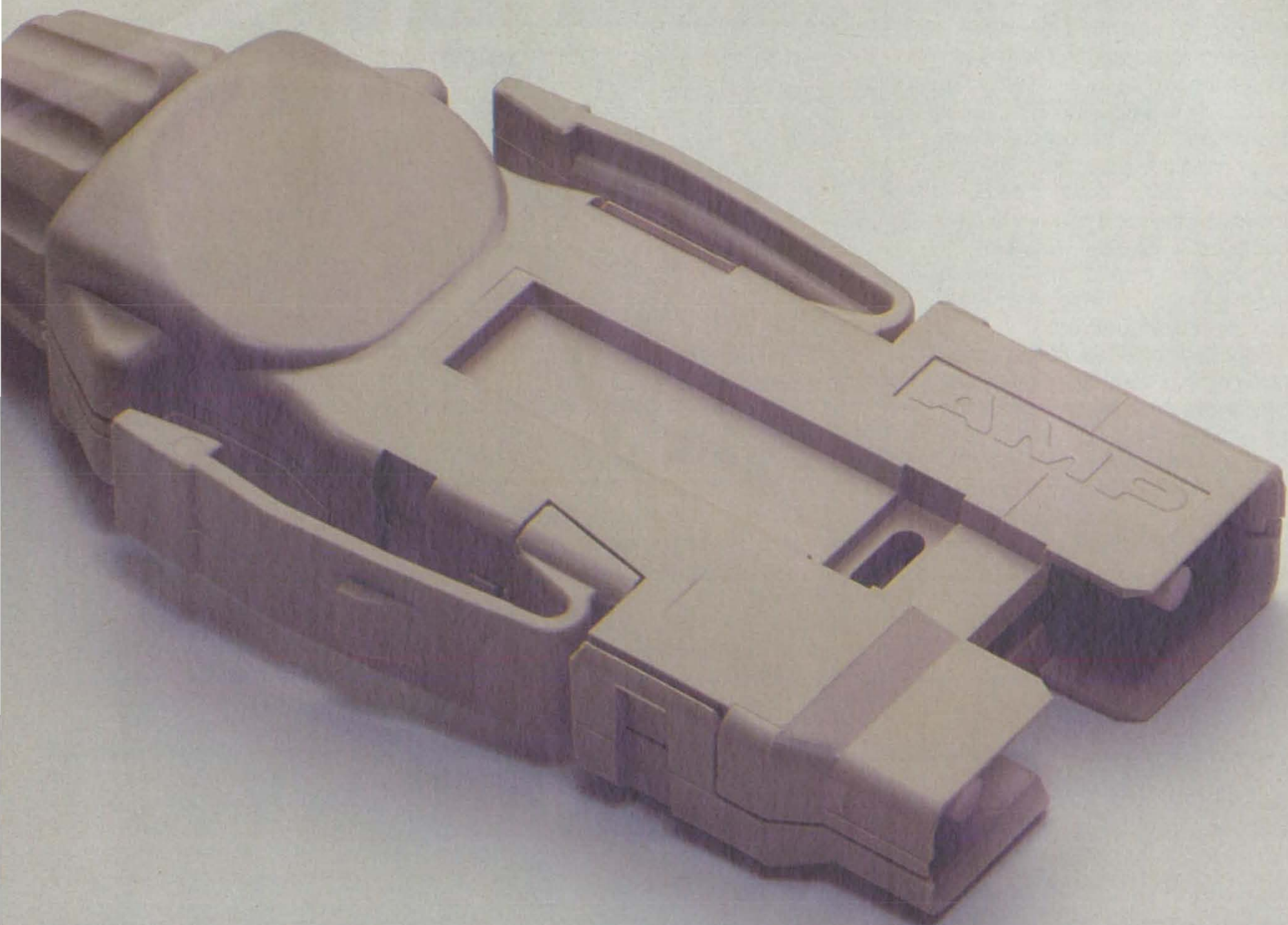

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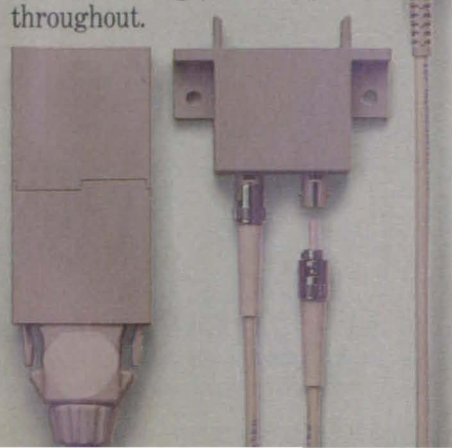

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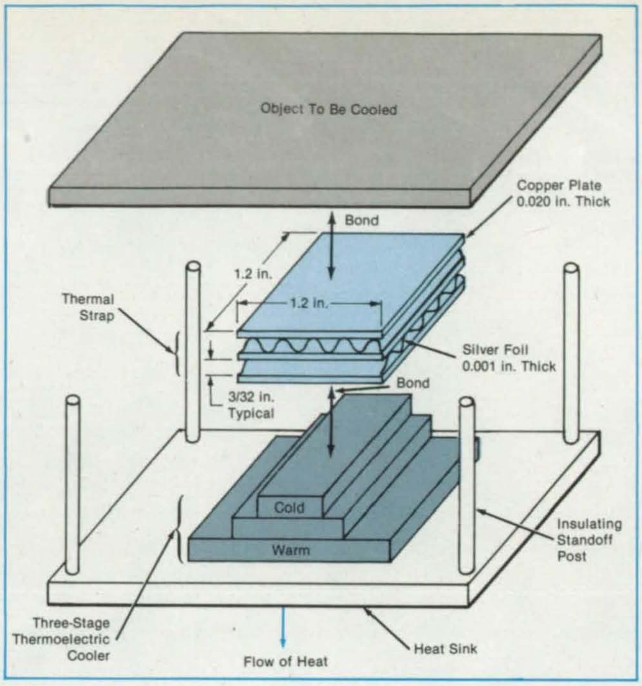
trast, would have a simple design and could be fabricated easily, with relatively inexpensive materials. It would have a thermal resistance of about 1 °C/W.

The new strap would include three thin copper plates between which two corrugated foils of a thermally conductive metal — copper, aluminum, or silver — would be sandwiched (see figure). The corrugations in the two layers of foil would lie perpendicularly to each other. The layers would be bonded to the copper plates with thermally conductive epoxy resin. The corrugations would be formed during the bonding process by inserting pins under and over the foils to create the wavy pattern. The pins could be coated with a release agent so that they could be removed easily after the strap is assembled.

Insulating standoff posts would support the device to be cooled. The top and bottom copper plates of the strap would be bonded to the object to be cooled and to the cold stage of the thermoelectric cooler, respectively. The corrugations would enable the top part of the sandwich to flex between right and left and the bottom part to flex between front and back. Both halves could flex up and down. (Flexing in torsion would be limited, however.) The unit strap could thus accommodate linear motion in all three directions. This feature would help to isolate the thermoelectric cooler from thermal stress and vibration. At the same time, it would be linked to the object to be cooled by many parallel thermal paths through the plates and foils.



The **Double-Deck Sandwich** of flexible thermal conductors would provide many parallel paths for flow of heat from a cooled device to a thermoelectric cooler, while protecting the cooler against stress and vibration.

This work was done by Jack A. Jones, S. Walter Petrick, and Steven Bard of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 95 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 14]. Refer to NPO-17806.

Microwave Oscillator Would Have Reduced Phase Noise

Performance would rival that of an oscillator stabilized by a quartz crystal.

NASA's Jet Propulsion Laboratory, Pasadena, California

Microwave oscillators of a proposed new type would incorporate a suppressed-carrier/negative-feedback feature to reduce phase noise near their carrier frequencies. Together with recent advances in the quality factors (Q's; that is, reciprocals of damping factors) of microwave resonators, the new oscillator concept could result in phase noise less than that achievable by cryogenically stabilized microwave components or by room-temperature oscillators stabilized by quartz crystals.

The new oscillator concept could be implemented in three different versions (see figure). The first version would be based partly on the established stabilized-local-oscillator concept. However, one way in which it would differ is that the signal from the resonator cavity would be returned from the input port of the cavity instead of from a second coupling port. A circulator would separate this signal from the forward driving signal. The returned signal would be fed to a phase detector in the form of a mixer. At critical coupling and on resonance, the returned signal would be identically zero. However, it would be the superposition of two nearly equal signals, one of which would emanate from the cavity and the other of which would be the reflection of the driving signal from the resonator port. At resonance, this reflected signal would not significantly affect the operation of the mixer because it would be in quadrature with the signal at the other mixer port. While the amplitude would go through zero on resonance, there would be a reversal of phase in which the in-phase signal on one side would become out of phase on the other, providing a linear dependence of the output voltage of the mixer on the frequency error, as required for effective feedback. Unlike in prior stabilized local oscillators, the returned signal would be amplified on its way to the mixer. Thus, the effective mixer phase noise would be reduced by the factor of amplifier gain. Degradation of the signal by phase fluctuations in the amplifier is prevented by carrier suppression due to the superimposed signals. Thus amplifier phase noise would also be reduced, with the amount of reduction given by the degree of carrier suppression.

The second version would resemble the first version somewhat, but the phase sensitivity would not be enhanced by amplification of the signal returned from the resonator. Instead, it would be enhanced by use of relatively high power in the high-Q resonator. The suppression of the carrier at the r port would make it possible to increase power supplied to the resonator without saturating the mixer.

The third version would be configured as a reflection oscillator with direct radio-frequency feedback. As in the first version, the signal returned from the resonator would consist of two superposed signals that would cancel at resonance if the coupling to the resonator were critical. However, here, the resonator would be slightly over-coupled, so that at resonance, the return signal would have a small, constant value. This condition can be shown theoretically to result in a reduction of the phase fluctuations by a factor that would increase with the gain of the amplifier. Because the path lengths of the circuit could give rise to large phase shifts that could cause oscillation at spurious frequencies, a band-pass filter would be incorporated to suppress such oscillations.

This work was done by G. John Dick and Jon Saunders of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 73 on the TSP Request*

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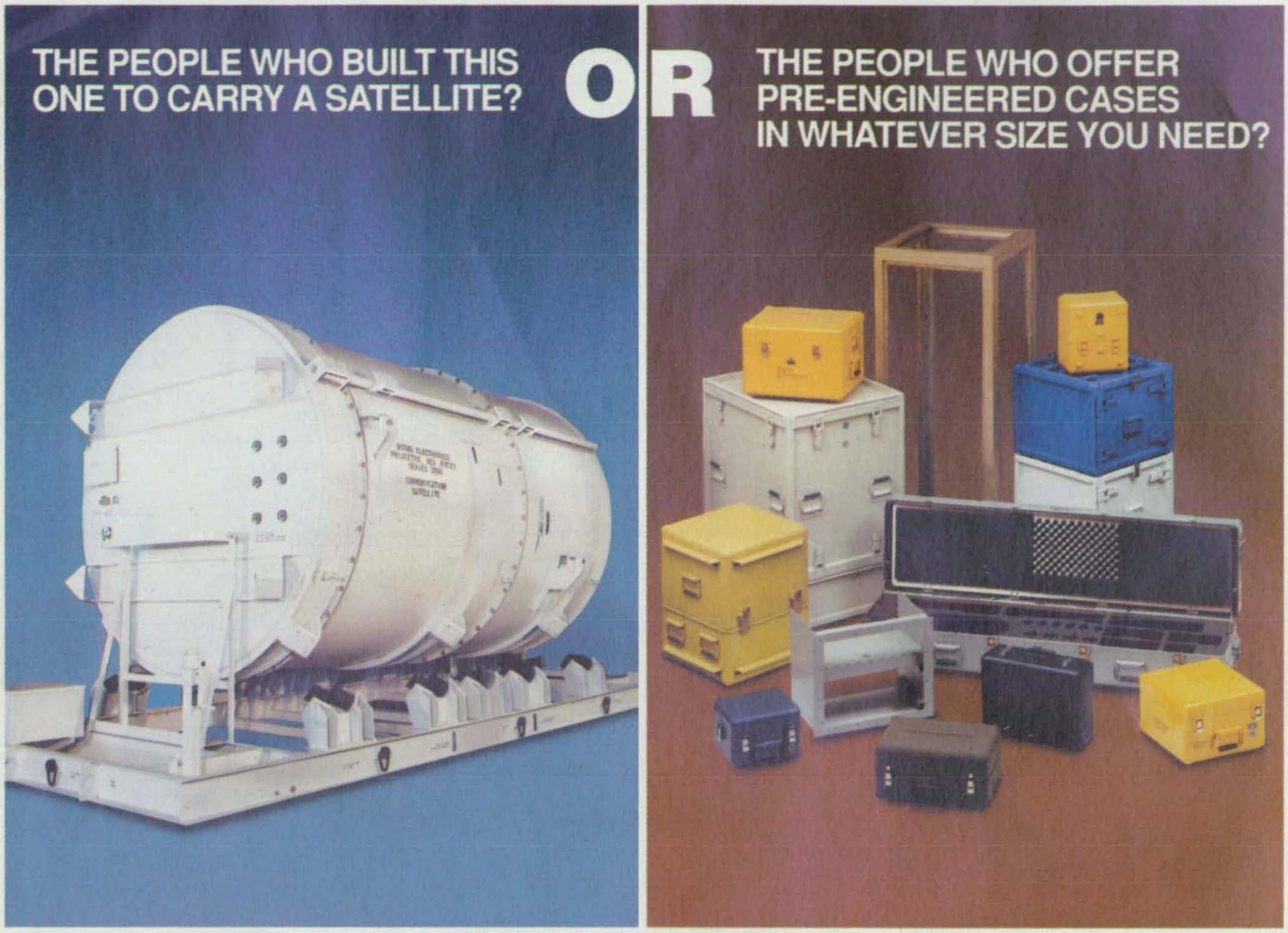

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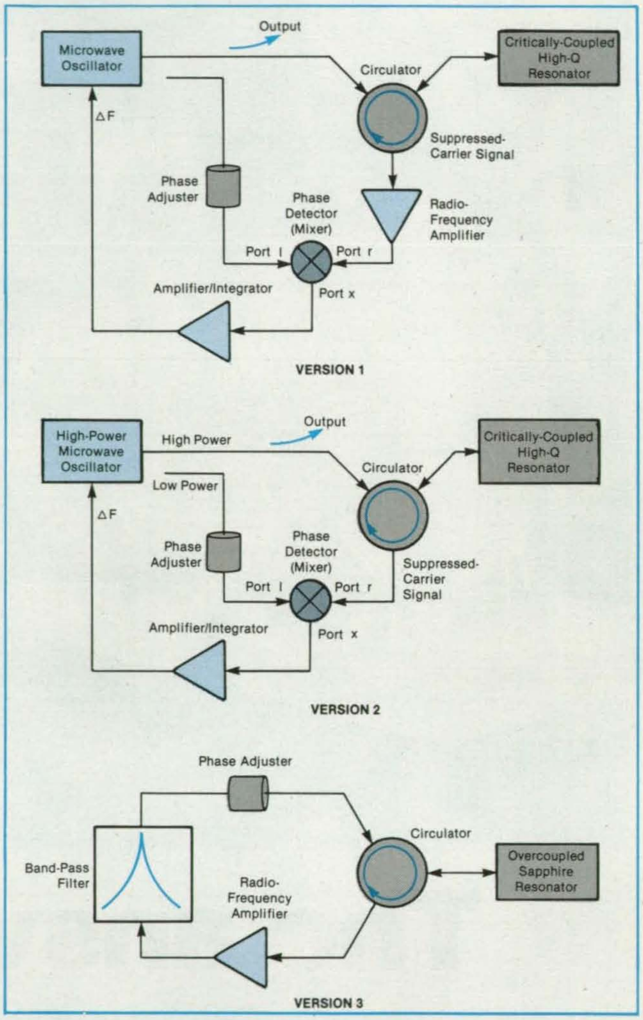
Refer to NPO-17945, volume and number of this NASA Tech Briefs *issue, and the page number.*



Three Versions of the Reduced-Phase-Noise Microwave Oscillator would reduce phase and frequency fluctuations via a suppressed-carrier/negative-feedback concept.

Megawatt Square Microwave Feed Horn

Experiments verify computed radiation patterns.

NASA's Jet Propulsion Laboratory, Pasadena, California

A prototype multiflare square horn antenna is designed to combine the phased 8.51-GHz outputs of four 250-kW amplifiers into a single 1-MW continuous-wave beam. This feed horn is intended to illuminate the subreflector of a 70-m-diameter radar antenna. Tests at low power confirm that, as expected from the design computations, it nearly duplicates

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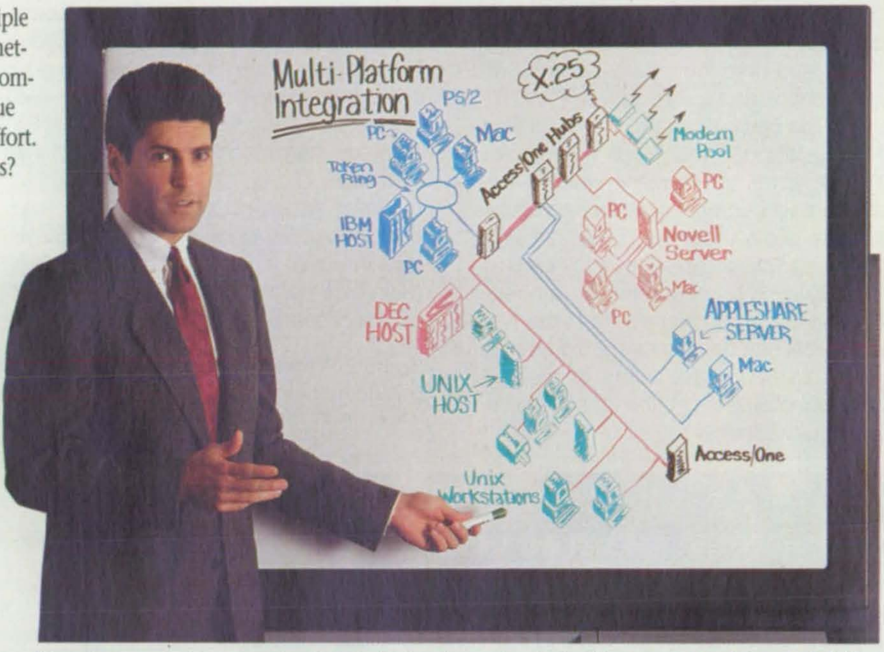

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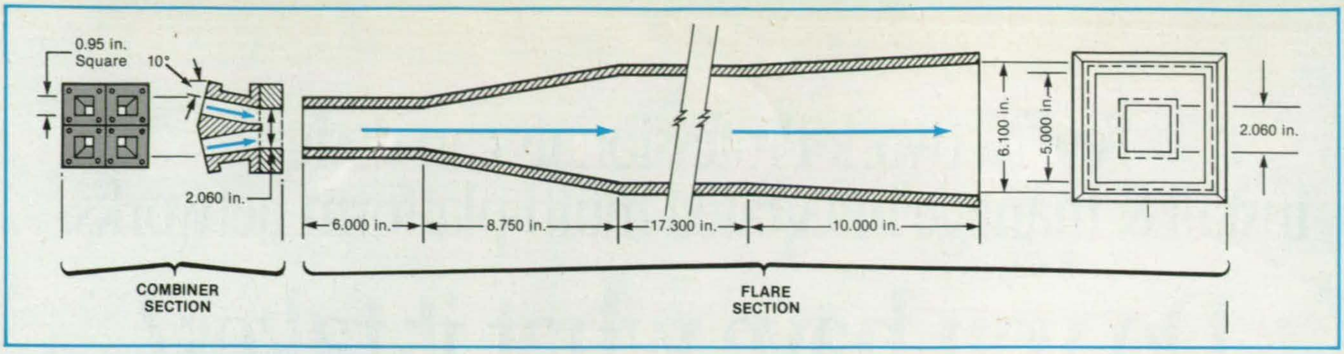


Figure 1. The **Prototype Multiflare Square Feed Horn** combines the outputs of four amplifiers into one beam, which radiates from the large aperture. In the production version, which will handle 1 MW, the walls will contain passages for cooling water.

the radiation pattern of a corrugated round feed horn now in use. (The round feed horn must be replaced because it is coupled to a waveguide that cannot reliably handle power in excess of 400 kW.)

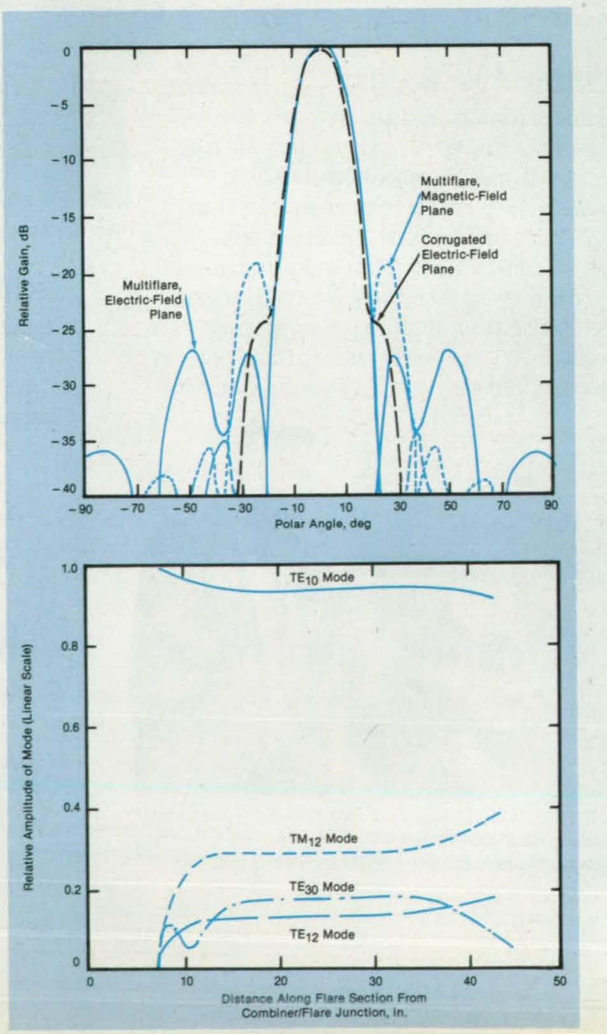
The feed horn includes a power combiner section and a flare section (see Figure 1). The power from the four amplifiers is fed in through four input waveguides 0.95 in. (24.1 mm) square, which allow electromagnetic energy to propagate only in the two orthogonally polarized TE_{10} modes at the design frequency of 8.51 GHz. By appropriately selecting the relative phases of the signals from the four amplifiers, one can cause the combined-power beam to have either of the two linear polarizations or either of the two circular polarizations.

The four input waveguides merge into an output waveguide 2.06 in. (52.3 mm) square, which is about 1 percent below the cutoff size for the TE_{30} and TE_{03} modes, which are strongly excited at the junction. The 2.06-in.-square section is extended to a length of 6 in. (152 mm) to cause the TE_{30} and TE_{03} modes to decay at least 30 dB before they reach the beginning of the first flare.

The radiation pattern of the new feed horn is required to have minimal spillover loss (minimal side lobes) and to have a main lobe as much as possible like that of the present corrugated circular feed horn (see Figure 2). The main lobe must illuminate the subreflector, which subtends the solid angle within a 16° half cone angle of the main antenna axis. The desired radiation pattern can be obtained by coupling some of the power from the TE_{10} mode to the TE_{30}, TE_{12}, and TM_{12} modes. In the design of the feed horn, the amount and location of each taper in the flare section are chosen to yield this coupling.

This work was done by Daniel J. Hoppe of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 56 on the TSP Request Card.*
NPO-18025

Figure 2. A **Main Lobe Like That of the Corrugated Horn** and side lobes reasonably below the main lobe are obtained by choosing the tapers of the multiflare horn to couple power from the TE_{10} mode into three other modes.



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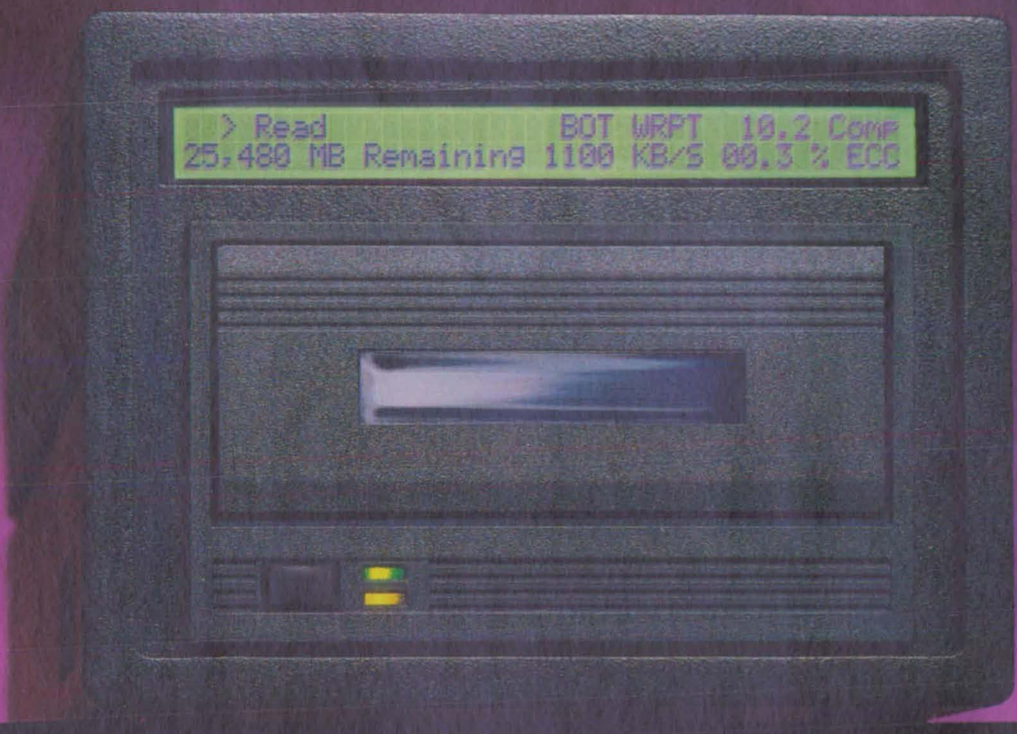

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An interface converts the signals at a standard printer port to those of a general-purpose bus.

Langley Research Center, Hampton, Virginia

An electronic circuit, called the printer-port interface circuit (PPI) has been developed to overcome certain disadvantages of previous methods for connecting the IBM PC or PC-compatible computer to other equipment. When used with appropriate software, the circuit converts the printer port on an IBM PC, XT, AT, or compatible personal computer to a general purpose, 8-bit-data, 16-bit address bus that can be connected to a multitude of devices.

The previous methods of connection included direct connection to the internal bus of the PC, use of an RS232 serial or other standard interface circuit, and modification of the printer port to provide the capability for bidirectional transmission of 8-bit data. Each of the these methods of connection has disadvantages. For example, a direct connection to the internal bus requires a special circuit card that occupies a card slot in the PC. With an RS232 serial interface, the rate of transfer of data is slow. Other methods are specialized, complex, and require additional cards or modification of equipment.

Because the printer port on the IBM PC was designed especially for the transmission of data to a printer, the PPI must be able to hold an address as well as to provide for the flow of data in both directions. To transmit to the external device, the PC printer port sends the address, data, and control values to the PPI one byte at a time. As the PPI receives this information, the PPI latches it on the proper output lines. Once the address and data are latched, the external device is signaled to accept the values. Before the PC reads from the external device, it first sends the address and control signals to the PPI. The external device then responds with eight bits of data on the input lines. Since the printer port has only five inputs, the PPI transfers the eight bits of data to the PC four bits at a time.

The PPI has both reading and writing modes of operation. The PPI is very simple, requiring only six integrated circuits. It provides for moderately fast rates of transfer of data and uses an existing unmodified circuit card in the IBM PC. The output of the PPI has the characteristics of a conventional bus, with address, data, and control signals. This "bus" can be easily connected to most peripheral integrated circuits.

This work was done by Jerry H. Tucker and Ann B. Yadlowsky of **Langley Research Center**. *For further information, Circle 112 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 14]. Refer to LAR-13950.

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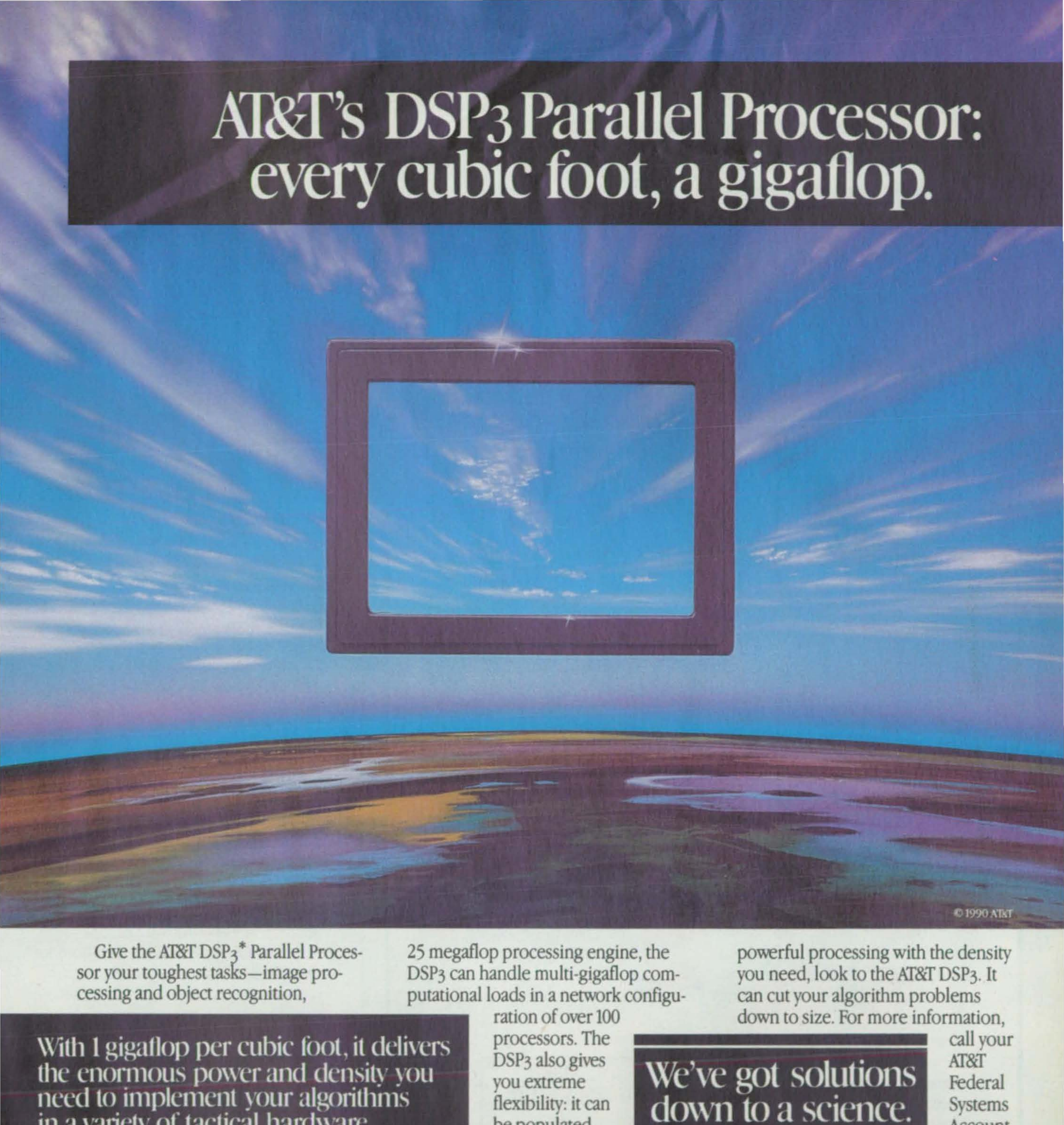

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Lithium Cells Accept Hundreds of Recharges

A new electrolyte prolongs the lives of cells.

NASA's Jet Propulsion Laboratory, Pasadena, California

A new mixed-solvent electrolyte increases the number of times a room-temperature lithium cell can be discharged and recharged. When subjected to more than 250 charge/discharge cycles, cells containing the new electrolyte lost only 20 percent of their initial capacities. The poor conductivity and the high reactivity of the electrolytes toward the lithium electrodes of previous cells greatly reduced the capacities of these cells after just a few cycles.

In the new electrolyte, 2-methyltetrahydrofuran (2-MeTHF) is the base solvent, and ethylene carbonate (EC) and ethylene propylene diene terpolymer (EDPM) are additives and cosolvents. These are mixed in the proportions 90 percent 2-MeTHF, 9.9 percent EC, and 0.1 percent EDPM. The electrolyte salt — $LiAsF_6$ — is added to the solvent mixture to a concentration of 1.5 molar. (The previous electrolyte consisted of 1.5 molar $LiAsF_6$ in 2-MeTHF alone.)

The new electrolyte was tested successfully in Li/TiS_2 cells. The conductivity of the new electrolyte is 70 percent higher than that of the previous electrolyte because of the high dielectric constant of EC and the low viscosity of 2-MeTHF. The low reactivity to lithium is believed to be due to the surface activity of EC and EPDM: These constituents probably form passivating films on lithium electrodes, thereby protecting them from attack by the other chemicals in the electrolyte. The new electrolyte may be useful in such other room-temperature rechargeable lithium cells as lithium/niobium triselenide and lithium molybdenum disulfide systems.

This work was done by David H. Shen, Subbarao Surampudi, Fotios Deligiannis, and Gerald Halpert of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 116 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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Mail Stop 305-6
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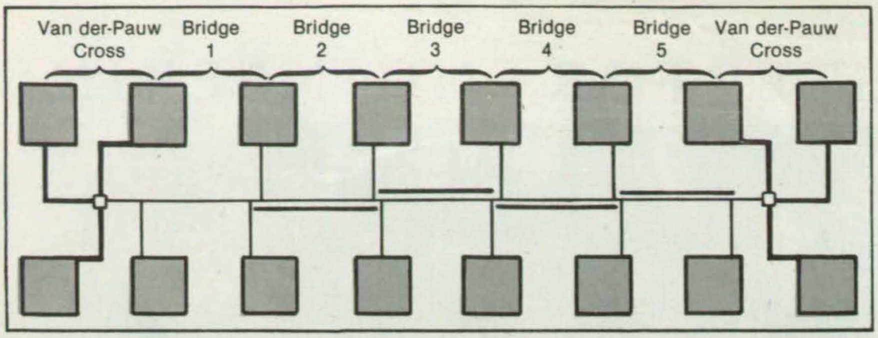
Refer to NPO-17676, volume and number of this NASA Tech Briefs *issue, and the page number.*

Cross-Quint-Bridge Resistor

Measurements of resistance yield data on widths of lines.

NASA's Jet Propulsion Laboratory, Pasadena, California

An integrated-circuit conductive test pattern is intended to provide data on the effects of design widths and design spacings upon the actual (as fabricated) widths of conductive lines. (The design and actual widths can be different.) The pattern provides for electrical measurements both on the lines of unknown width and on features that have known dimensions.



Five Bridges and two Van der-Pauw Crosses provide for electrical measurements from which one can compute the widths of the bridge resistors as a function of their design widths and their spacing from adjacent parallel bridges.

Then, from the known relationship between the dimensions and the electrical resistance of a line conductor, one computes the unknown widths.

The pattern (see figure), called a Cross-Quint-Bridge Resistor, includes five conductive line segments to be tested, connected as five bridge resistors in a row. Two Van der-Pauw crosses are connected at the ends of the row. One of the bridge resistors is a solitary conductive line, while alongside each of the other four bridge resistors is another conductive line, nominally of the same width and electrically isolated. To test the effects of design width and/or spacing, the bridge resistors can have equal or different design widths, and the distances to the isolated side lines can be equal or different.

Each Van der-Pauw cross provides for measurement of the sheet resistance, which is used along with the measured lengths and resistances of the bridge resistors to compute the widths of the lines. By placing Van der-Pauw crosses at both ends, one can obtain two values of the sheet resistance, which should be equal but which, if not equal, can be used to account for some of the spatial variation in the sheet resistances of the bridge resistors.

The data from the measurements on the five bridges can be used to determine the four parameters of a mathematical model that describes the system. In principle one can use this pattern to determine the effects of width and spacing and the interaction between them. The pattern is being fabricated by the Semiconductor Equipment and Materials International Standards organization for consideration as the standard pattern for electrical measurement of the widths of lines as narrow as 1 nm.

This work was done by David J. Hannaman, Udo Lieneweg, and Martin G. Buehler of Caltech and Linda Mantalas of Prometrix Corp. for **NASA's Jet Propulsion Laboratory.** *For further information, Circle 136 on the TSP Request Card. NPO-18106*

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.

Performance of Superconducting-Cavity Maser

Stability of frequency is high, and phase noise is low.

A two-page report describes experiments on the operation of a superconducting-cavity maser — an all-cryogenic oscillator. Like other oscillators stabilized by superconducting cavities, this one operates with a degree of stability, at short measuring times, superior to that achievable by any other means. The principal differences between this oscillator and the others of this type are that all of its components are designed for cryogenic operation and the stabilizing cavity is very rigid, consisting of a sapphire filling coated with lead. The cavity has a Q (ratio of electromagnetic energy stored to electromagnetic energy dissipated in one cycle, a measure of the sharpness of resonance) of about 10^9.

The oscillator assembly has been described in previous reports. It includes the stabilizing cavity, a coupling cavity, and an ultra-low-noise cryogenic ruby maser, which supplies the excitation. The ruby maser operates at a frequency of 13.1 GHz, creating an energy-level-population inversion that supports oscillation at 2.69 GHz. Splits of the energy levels are matched to changes in the resonant frequency of the stabilizing cavity by means of a bias magnetic field from a superconducting solenoid. The frequencies of the three modes of the coupled-cavity system are within about 5 percent of each other — close enough for effective coupling, but far enough apart to enable the selection of a mode by adjustment of the bias field.

A continuous-flow liquid-helium cryostat keeps the oscillator at a nearly constant low temperature. The frequency of oscillation varies with temperature and is maximum at about 1.57 K. Consequently, the oscillator can be operated at or near this temperature to obtain zero linear coefficient of variation of frequency with temperature. The measurements were performed at 1.58 K regulated to within $\pm 40\ \mu$K.

The performance of the oscillator was measured during times ranging from 1 to 10^4 s. The frequency was found to be stable to within a few parts in 10^{15}. The stability during a measuring time of 1 s was found to be 10 times as great as that of a hydrogen maser. The phase noise was found to be about $-80\ \mathrm{dB}/f^3$, where f denotes the deviation, in hertz, from the carrier frequency. This level is more than 20 dB below the phase noise of the best signals of comparable frequency derived from multiplication of the frequencies of quartz oscillators.

This work was done by G. John Dick and Rabi T. Wang of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Ultra-Stable Performance of the Superconducting Cavity Maser," Circle 148 on the TSP Request Card.*
NPO-18175

Electronic Systems

Hardware, Techniques, and Processes

Transmitting Reference Radio Signals on Two Optical Carriers

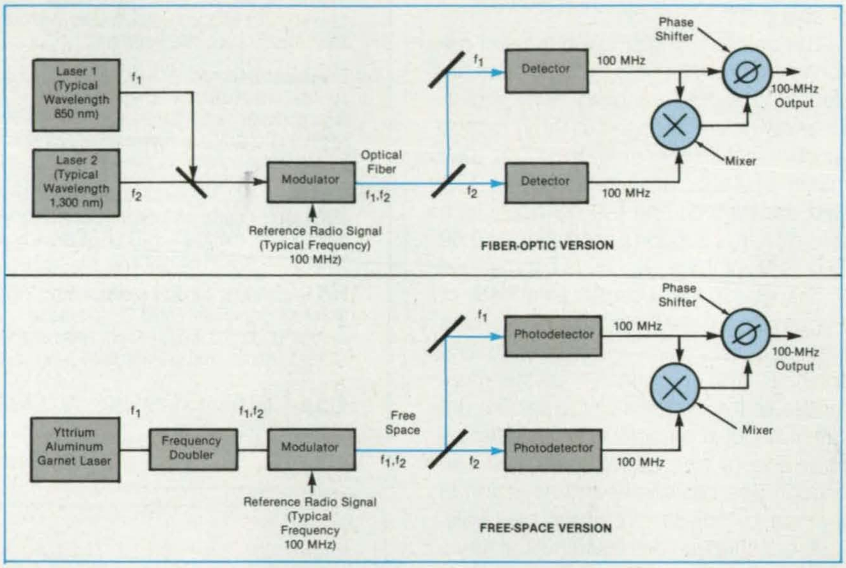
Corrections for delay and for changes in delay would be made at the receiver.

NASA's Jet Propulsion Laboratory, Pasadena, California

A reference radio signal would be transmitted as modulation on two optical carrier signals of different wavelengths, according to a proposal. The reference signal could be, for example, a frequency-standard signal for use in radio-science experiments, and the transmission medium would typically be air or an optical fiber that connects the reference-signal-generating station with a receiving station.

The proposed two-carrier transmission scheme would enable the receiving station to compensate for the propagation delay and for changes in the propagation delay (caused, for example, by fluctuations in temperature) in the transmission medium. Thus, a "cleaned-up" phase- and frequency-stabilized signal that represents the reference frequency and phase more accurately would be made available at the receiver. It is noteworthy that the proposed scheme would require only one-way transmission, whereas prior stabilization schemes have involved two-way transmission. The proposed scheme is, therefore, simpler in principle and is expected to be more energy- and cost-efficient. It should also enable the use of longer transmission paths.

The reference radio signal would be used to modulate the two optical carriers, which would be transmitted along the same optical fiber or path in free space (see figure). At the receiver, a dichroic beam splitter would separate the light into its two wavelength components. A photodetector would demodulate each component, producing two versions of the radio-frequency modulation corrupted by propagation along the optical-fiber or free-space transmission path.



The **Radio-Frequency Reference Signal** would be used to modulate two optical carriers at the transmitter. Dispersion in the optical-fiber or free-space transmission medium, usually regarded as a nuisance, would be used to advantage in the receiver to measure and compensate for phase and frequency fluctuations induced by fluctuations in propagation conditions.

The difference between the times of arrival of the radio-frequency modulation on the two optical carrier signals would depend on the optical-dispersion characteristics of the transmission medium and would be proportional to the length of the path. This difference would manifest itself as a difference between the phases of the two detected modulation signals and could, therefore, be measured by comparing the signals in a mixer. The output of the mixer would be used to control a phase shifter in the path of one of the detected modulation signals. The phase shifter would thus compensate for the propagation-induced phase and frequency fluctuations, yielding the desired phase- and frequency-stabilized output signal.

This work was done by Lutfollah Maleki of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 157 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 14]. Refer to NPO-18007.

Digital Signal Combiner for Receiving-Antenna Feed Array

Signals would be combined with estimated weights.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed digital system combines digitized baseband samples of signals received by an array of feeds in a large Cassegrainian paraboloidal-dish antenna. The system is intended to compensate in real time for degradation of the signal-to-noise ratio by vibrational, gravitational, and wind-induced deformations of the antenna structure. The signal-combining process makes use of parameters obtained from the received signals themselves.

The array of feeds is located in the focal plane of the antenna; each feed samples a portion of the distorted signal field (see Figure 1). A separate receiver front end

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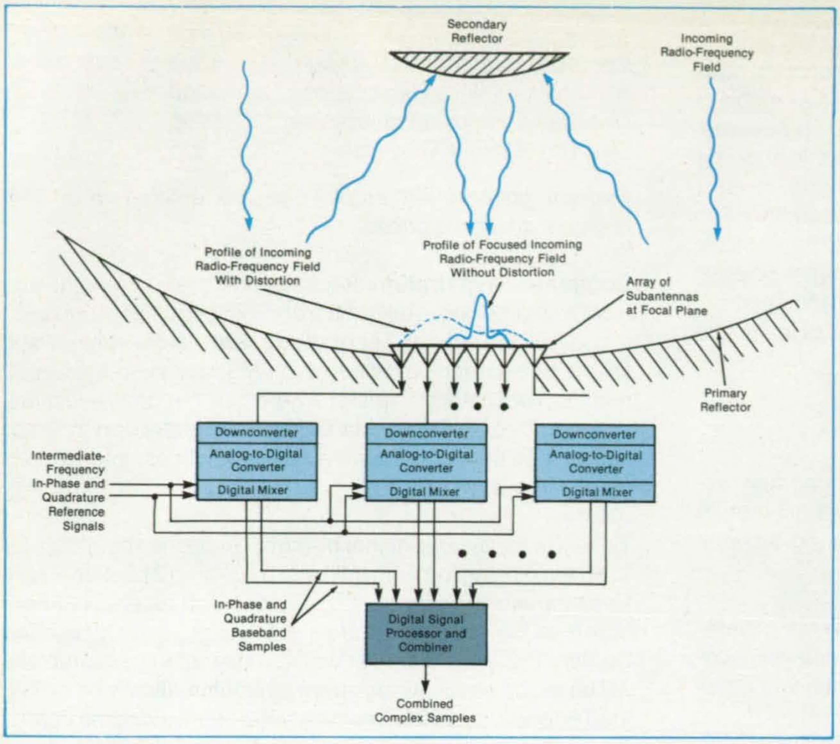


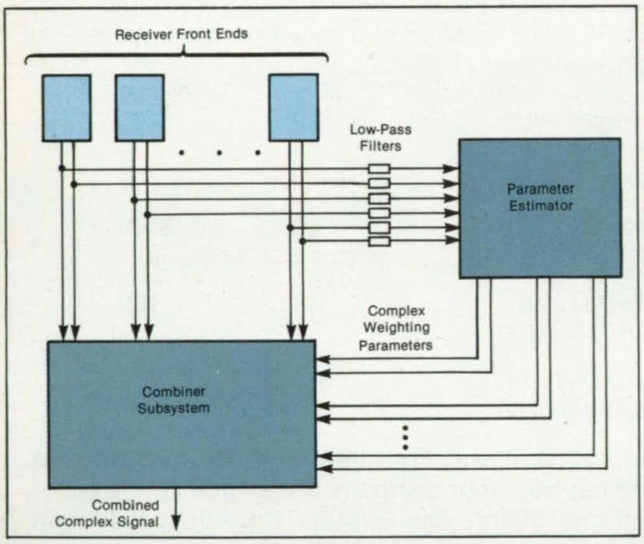


Figure 1. **Signals Received by Subantennas** in the focal-plane array of a large dish antenna would be combined by a system that would compensate in real time for distortions of wave fronts caused by mechanical distortions of the antenna.

Figure 2. The **Signal-Combining System** would combine the baseband output signals of the receiver front ends according to complex weighting parameters estimated from the signals themselves.

dedicated to each feed amplifies and downconverts the signal received by that antenna to an intermediate frequency (e.g., 10 MHz). The intermediate-frequency signal is digitized to 8 bits and sampled (typically, at a rate of 4 samples per intermediate-frequency cycle).

The proposed system is intended for use with an incoming signal that contains a residual carrier. The overall receiving system would lock in phase to the residual carrier and thereby generate an in-phase and a quadrature reference signal, which would be fed to all channels. Within each receiver front end, the digitized signal samples would be mixed with the reference signals and low-pass-filtered to remove higher-order mixer products. Further low-pass and narrow-band filtering separates these baseband outputs into slowly varying (nominally, dc) carrier-phase components and rapidly varying modulation components.

The signal-combining system consists of two main parts: the combiner subsystem and the parameter estimator (see Figure 2). The full baseband outputs of the receiver front ends are sent to the combiner subsystem, which multiplies them by complex-number optimum estimated weights and sums them to produce the combined output. The slowly varying carrier-phase components of the outputs of the receiver front ends are fed to the parameter estimator, which computes the optimum weights via an algorithm based on maximum-likelihood estimates of the underlying signals and noise. In this way, the signal-to-noise ratio of the combined samples is maximized.

This work was done by Victor A. Vilnrotter and Eugene R. Rodemich of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 121 on the TSP Request Card.*
NPO-18140

Processor Reformats Data for Transmission in Bursts

The source and sink of data can operate asynchronously.

Lyndon B. Johnson Space Center, Houston, Texas

A data-processor-and-buffer electronic system receives audio signals digitized in a first standard format at a relatively low data rate (1.554 Mb/s), rearranges these data for transmission in bursts in a second standard format at a relatively high rate (150 Mb/s), stores the second-format bursts, and releases the second-format bursts at the higher rate upon request. Although the system was conceived for the asynchronous, one-way transmission of digitized speech in outer-space communications, the concept of the system could be applied in other digital communication systems in which data are transmitted from low-rate sources to high-rate sinks that are not synchronized with the sources.

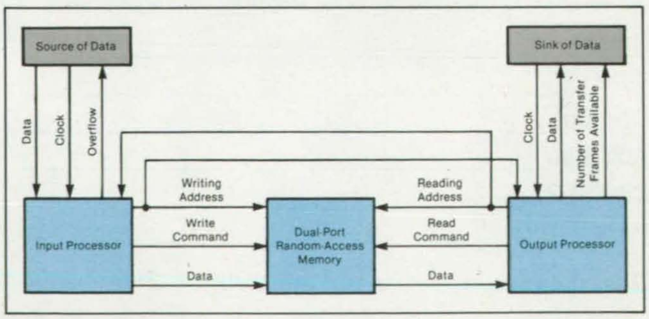


Figure 1. **Digitized Low-Rate Data** (e.g., audio) signals from the source are reformatted, buffered, and transferred to the sink in bursts called "transfer frames."

The system (see Figure 1) includes an input processor (which also acts as an "input-state machine"), a dual-port random-access memory, and an output processor ("output-state machine"). The random-access memory serves as the buffer memory. It is divided into eight parts,

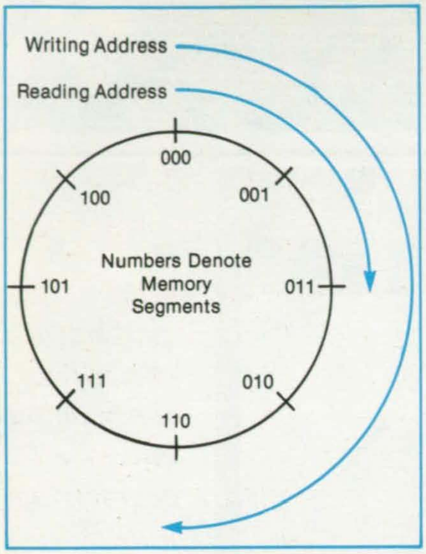


Figure 2. The **Addressing Scheme** for writing to and reading from the dual-port random-access memory is a repeating sequence. The addresses of the memory segments are put in gray code instead of normal binary sequence because this prevents the input and output processors from incorrectly perceiving asynchronous changes in the reading and writing addresses, respectively.

each of which can hold one of the second-format bursts, which are called "transfer frames."

Operation begins when the input processor detects an incoming (first-format) frame of data. The input processor so notifies the buffer memory by sending it a transfer-frame header. The input processor then repeatedly encapsulates the incoming first-format frames into packets of data of the second format and packs the second-format packets into the transfer frame that is being assembled in the buffer memory. When this transfer frame has been filled, the input processor notifies the output processor that this transfer frame is available. In turn, the output processor notifies the sink of data that this transfer frame is available. Meanwhile, the input processor begins to pack a new transfer frame into the buffer memory, and this processor continues as long as the first-format data continue to come in (provided that there is still room in the buffer memory).

When the sink signals a request for a transfer frame, the output processor responds by transferring that frame immediately from the buffer memory to the sink and indicating to the input processor that the portion of the buffer that stored that transfer frame is now available to hold a new transfer frame.

The input processor sends, to the output processor, the number (address) of the segment of random-access memory into which it is writing data. Similarly, the output processor tells the input processor the address of the segment from which it is reading data. Both processors step through the segments of the memory in the same prescribed, repeating sequence (see Figure 2). To prevent overflow, the writing address must not be allowed to get so far ahead of the reading address that it catches up with the reading address from behind in the repeating sequence. To prevent underflow, the reading address must not be allowed to catch up with the writing address. The output processor determines how many transfer frames are available for output by noting how far the writing address is ahead of the reading address.

This work was done by Glen F. Steele of **Johnson Space Center**. *For further information, Circle 165 on the TSP Request Card.*
MSC-21727

Multiple-Symbol Detection of Multiple-Trellis-Coded MDPSK

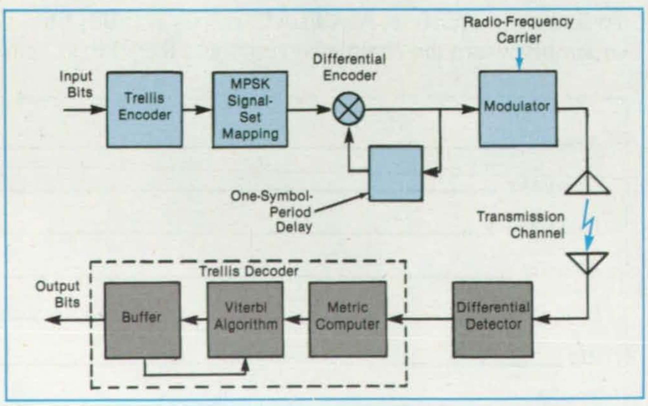
An increase in the observation time would reduce the probability of error.

NASA's Jet Propulsion Laboratory, Pasadena, California

In a proposed scheme for the detection and decoding of multiple-trellis-coded multilevel differential-phase-shift-keyed (MDPSK) radio signals, the observation time for differential detection would be extended from the conventional 2 to a larger number of symbol periods. This represents an extension of a previous scheme to decrease the rate of error in differential detection of uncoded MDPSK by increasing the number of symbol periods.

Figure 1 illustrates the roles of the various transmitting and receiving subsystems in the proposed scheme. Input bits occurring at a rate R_b would pass through a rate-$[nk/(n+1)k]$ multiple-trellis encoder (where k is the multiplicity of the code), producing an encoded bit stream at a rate

Figure 1. The **Multiple-Trellis-Encoding and -Decoding Subsystems** are similar to those described previously in *NASA Tech Briefs*, except that the observation time for detection is increased from 2 to 3 or more symbol periods.



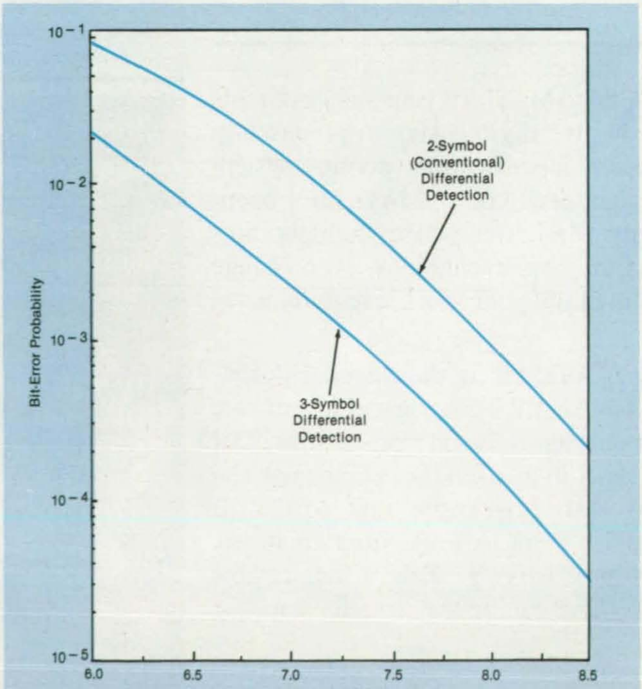


Figure 2. The **Performance of a System** like that of Figure 1 was determined by computer simulation. The simulated system used **8PSK** with a 16-state, rate-2/3 trellis-code that had an interleaving size of 512 symbols and an interleaving depth of 16 branches. It was assumed that the transmission channel was characterized by additive white gaussian noise and introduced no significant spurious phase modulation during the detection time of 2 or 3 symbol periods.

$R_s = [(n+1)k/nk]R_b$. Next, the encoded bits would be divided into k groups of $n+1$ bits each, and each group would be mapped into a symbol selected from an $M = 2^{n+1}$-level PSK signal set according to a set-partitioning method for multiple trellis codes analogous to that proposed for conventional ($k = 1$) codes. Inasmuch as the MDPSK symbol rate would be R_b/n, it is reasonable, from a perspective of equal bandwidths, to compare the expected performance of this system with that of an uncoded $M = 2^n$-level DPSK system that has the identical input bit rate.

At the receiver, the noise-corrupted signal would be differentially detected, and the resulting symbols would be fed to the trellis decoder, which would be implemented as a Viterbi algorithm. In the selection of a decoding metric, there is a tradeoff between simplicity of implementation and the optimality associated with the degree to which the metric matches the statistics of the output of the differential detector. For uncoded MDPSK, a metric based on minimization of the distance between the received and transmitted signal vectors is optimum in the sense of a minimum-probability-of-error test. For conventional trellis-coded MDPSK, the metric takes on the form of a minimum-squared-Euclidean-distance metric. For multiple-symbol detection of multiple-trellis-coded MDPSK, the form of the metric is quite different, but this metric can be converted once again into a minimum-squared-Euclidean-distance metric by a modification of the multiple trellis code. The so-called "equivalent" multiple trellis code that results from this modification then becomes the principal concept used in analyzing the performance of the overall system.

Figure 2 illustrates the computed performances of a representative system with 2- and 3-symbol detections. For the range of bit-error probabilities shown, the slight increase in the observation time from 2 to 3 symbol periods decreases the bit-error probability by an amount equivalent to a decrease of about 0.75 dB in the signal-to-noise ratio.

This work was done by Dariush Divsalar, Marvin K. Simon, and Mehrdad M. Shahshahani of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, Circle 110 on the TSP Request Card.* NPO-18043

Diplex Fiber-Optic Link for Frequency and Time Signals

Relatively inexpensive equipment delivers signals of high quality.

NASA's Jet Propulsion Laboratory, Pasadena, California

Reference frequency and time signals are transmitted simultaneously from a central signal-processing station along a 10-km fiber-optic link to a remote station. The diplex fiber-optic link is part of the Goldstone Deep Space Communications complex; similar links may be useful in television, communication, and electric-power-distribution networks and other applications in which signals at different locations must be synchronized precisely.

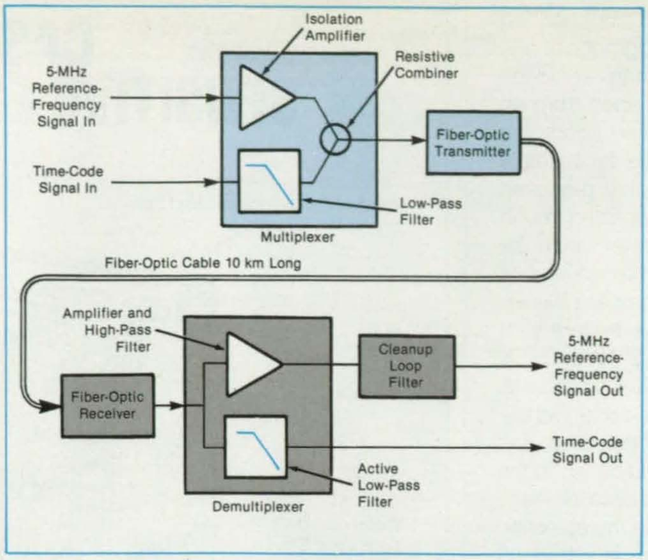
The fiber-optic link consists mostly of commercial equipment, some of which is modified slightly; because of this, its cost is relatively low. At the central station, a signal combiner adds the 5-MHz reference-frequency signal and the 36-bit time-code signal, forming a composite signal, which modulates the light transmitted along the optical fiber. At the remote station, the fiber-optic receiver detects the composite signal and provides the input to a diplexer, which separates the frequency reference signal from the time-code signal. The signals are then amplified to the desired levels. Despite the relatively low cost of the fiber-optic equipment, the stability of its output reference-frequency signal is greater than that of a prior cesium frequency standard.

The figure illustrates the operation of the system in more detail. The 5-MHz reference-frequency signal is fed to the combiner through an isolation amplifier: this prevents the time-code signals from feeding back into the reference-frequency source, where they would give rise to cross modulation between the two signals. The time code signal is fed to the combiner through a low-pass filter with a cutoff frequency of 10 kHz. The signal combiner is of the resistive type to minimize intermodulation distortion (the amount of intermodulation distortion produced by a transformer-type combiner would be excessive in this application).

In the fiber-optic transmitter, the optical carrier emitted by a laser diode is amplitude-modulated with pulses at a subcarrier frequency of 24 MHz. The output of the signal combiner is used to frequency-modulate the subcarrier. The optical signal modulated by the frequency-modulated subcarrier is transmitted along the optical fiber. In the receiver at the remote station, a photodiode detector recovers the frequency-modulated subcarrier from the optical signal, and a frequency discriminator recovers the modulation.

To recover the separate time-code and reference-frequency signals, the output of the receiver is fed to a two-branch demultiplexer. In one branch, a low-pass active filter extracts the time-code signal. In the other branch, the signal is amplified and passed through a high-pass filter with a cutoff frequency of 100 kHz to obtain a "dirty" version of the 5-MHz signal that is partially contaminated with the time code. The time-code contamination is removed, and the noise bandwidth is reduced by a cleanup loop filter, which consists of a quartz frequency-standard oscillator locked in phase to the "dirty" 5-MHz signal.

This work was done by George F. Lutes and Malcolm D. Calhoun of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 79 on the TSP Request Card.* NPO-18180



Time-Code and Reference-Frequency Signals are transmitted in diplex along an optical fiber and recovered at the remote end.

Burst-Compression and -Expansion for TDMA Communication

Variable-data-rate users are interconnected via a satellite-switched network.

Lewis Research Center, Cleveland, Ohio

A burst-compression and -expansion technique enables the interconnection of users transmitting and receiving data at rates asynchronous with respect to clocks within the ground terminals of a satellite-switched, time-division-multiple-access (TDMA) communication network. In such a network, a matrix switch aboard the satellite routes bursts of data from source users received on uplink antennas to downlink antennas that illuminate ground areas containing destination users. Each burst is timed so that while it lasts, only one pair of source and destination users is communicating; and during the burst, the full receiving, switching, and transmitting resources of the satellite are allocated to that pair. These resources are divided or time-division-multiplexed among all active users in the network. Greater flexibility in interconnecting widely dispersed users is achieved by use of hopping beams. Multiple uplink and downlink antenna beams are electronically switched to cover specific source and destination locations simultaneously in a periodic sequence. Source and destination users in covered locations communicate with each other through TDMA ground terminals (see Figure 1).

At each source terminal, lower-rate, continuous digital data streams from multiple users are compressed into high-rate bursts for modulation and transmission in the assigned time slots within the TDMA frame (see Figure 2). Serial data from each source user are temporarily converted to a parallel format and stored in one of several compression buffers. At the assigned time, parallel data are read out of the compression buffer onto the multiplexed-data bus, scrambled, converted to a high-rate, serial data format, modulated, and transmitted as a burst. Bursts received by the destination terminal are demodulated, converted back to a parallel format, descrambled, and expanded back into continuous data streams at the original lower data rates and delivered to the destination users.

To support multiple users with a wide range of asynchronous data rates, the number of bits of user data transmitted by the source terminal from frame to frame must vary. At the destination terminal, the regenerated bit clock delivered to the user must replicate the frequency and stability of the source user. The key feature of the technique is to group the number of lower-rate user data bits received by the source terminal over roughly one frame period into an equivalent number of higher-bit-rate valid data words each frame and thereby "quantize" the frame-to-frame variation in the number of valid data bits per frame into one-word increments. This grouping of user data into words is performed by the compression buffer; continuous user data are written into the first-in, first-out (FIFO) memory at the user's clock rate and are read out at the burst modulator clock rate. Each transmitted burst is an integer number of words in duration. On a frame-to-frame basis, the number of valid words in the burst may increase or decrease by one from some nominal number that represents the approximate data throughput.

In the destination terminal, a control loop subroutine executing in the user interface controller varies the frequency of a voltage-controlled oscillator (VCO). The VCO is used to generate both the read clock for the expansion buffer and the data synchronized bit clock delivered to the destination user. The control loop adjusts the regenerated clock frequency based on the fill level of the expansion buffer observed at the end of each frame.

Through the use of nominal and valid data-word counts, FIFO memories, adjustments to the duration of transmit and receive frames, and microprocessor-controlled regeneration of clock signals, the variable-rate-compression-and-expansion-buffer technique preserves bit integrity and minimizes overhead and latency for low-to-medium-data-rate users who are not traditionally served by TDMA networks. The technique enables the use of inexpensive clock sources by both the users and the ground terminals and obviates the need for elaborate user-clock-synchronization processes. The technique accommodates a continuous range of data rates from kilobits per second to that approaching the modulator burst rate (hundreds of megabits per second).

This technique was developed for use in NASA Lewis Research Center's satellite network simulation facility. Some key features of the technique have also been implemented in the ground terminals developed at NASA Lewis for use in on-orbit evaluation of the Advanced Communications Technology Satellite high-burst-rate system.

This work was done by James M. Budinger of **Lewis Research Center**. *Further information may be found in NASA TM-102414 [N90-15983], "A Burst Compression and Expansion Technique for*

Variable-Rate Users in Satellite-Switched TDMA Networks."

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703)487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.
LEW-15102

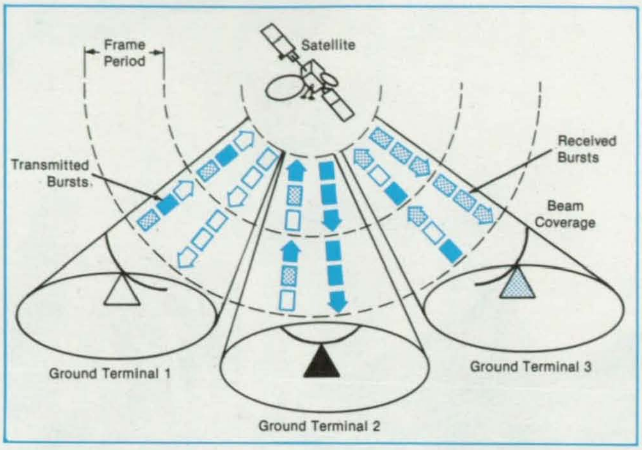


Figure 1. In a **Multiple-Beam, Satellite-Switched TDMA Network**, multiple pairs of source and destination users take turns communicating via a satellite and ground terminals.

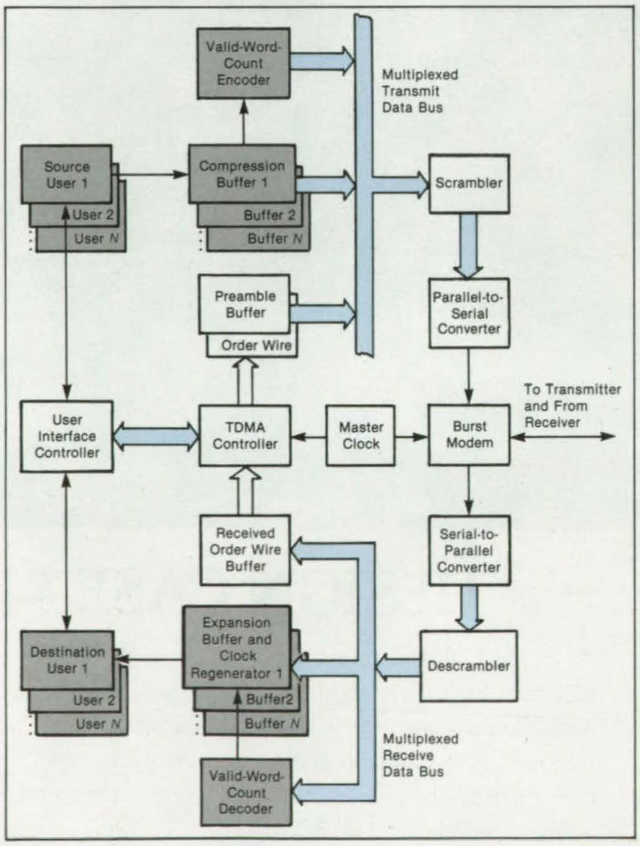


Figure 2. A **TDMA Ground Terminal** compresses streams of data from source users into rapid bursts for transmission and reexpands bursts of received data into slower streams of data for delivery to destination users.

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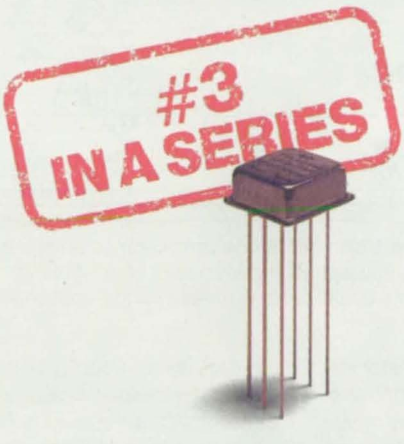

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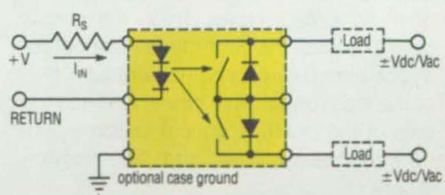
- Adjustable turn-on times
- Low profile 6-pin mini-DIP
- Cost efficiency

Review the electrical characteristics below and call us for immediate application assistance.*

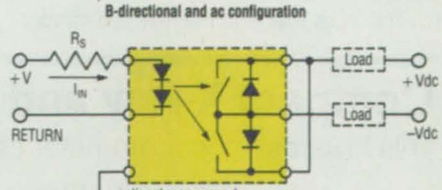
INPUT ELECTRICAL CHARACTERISTICS (–55° to +105° unless otherwise noted)			
	Min	Max	Units
Continuous Input Current (I_{IN})	10	50	mA_{DC}
Input Current (Guaranteed On)	10		mA_{DC}
Input Current (Guaranteed Off)		100	μA_{DC}
Input Voltage Drop at (I_{IN}) = 25mA		3.25	V_{DC}

OUTPUT ELECTRICAL CHARACTERISTICS (–55° to +105° unless otherwise noted)				
Part Number	FB00CD	FB00FC	FB00KB	Units
Bidirectional Load Current (I_{LOAD})	±1.0	±0.50	±0.25	A_{DC}/A_{PK}
DC Load Current (I_{LOAD})	2.0	1.0	0.5	A_{DC}
Bidirectional Load Voltage (V_{LOAD})	±80	±180	±350	V_{DC}/V_{PK}
DC Load Voltage (V_{LOAD})	80	180	350	V_{DC}
ON-Resistance (R_{ON}) at (I_{LOAD}) max.	0.72	1.8	12.9	Ohms
Turn-On Time (T_{ON})	800	800	500	µs
Turn-Off Time (T_{OFF})	300	600	500	µs

Notes:
1. A series resistor is required to limit continuous input current to 50mA (peak current can be higher).
2. Rated input current is 25mA for all tests.
3. Loads may be connected to any output terminal.
4. ON resistance shown is for the bidirectional configuration. The DC ON resistance is ¼ of these values.



B-directional and ac configuration



DC configuration

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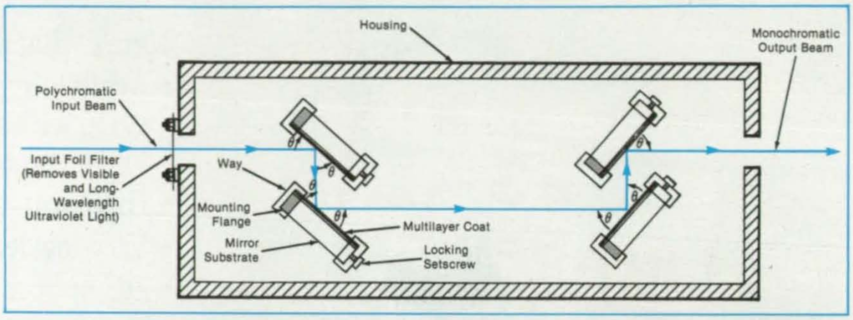
Four-Mirror X-Ray and Extreme-Ultraviolet Monochromator

More mirrors provide additional wavelength selectivity.

Marshall Space Flight Center, Alabama

The four-mirror x-ray and extreme-ultraviolet monochromator provides a narrower wavelength passband than do the devices described in the two preceding articles, "Compact X-Ray and Extreme Ultraviolet Monochromator" (MFS-28499) and "Scanning X-Ray or Extreme Ultraviolet Monochromator" (MFS-28492). Like the foregoing devices, the four-mirror monochromator relies on Bragg reflection from two identical parallel multilayer mirrors to extract a narrow-spectrum x-ray or extreme-ultraviolet beam from a broad-spectrum input beam.

The four-mirror monochromator resembles the compact monochromator, except that the interior of its housing contains two pairs of mirrors instead of one pair. The second pair of mirrors is positioned and oriented symmetrically with respect to the first pair. The particular symmetry is such that the reflections from the second pair of mirrors cancel the lateral displacement caused by the reflections from the first pair of mirrors (see figure). Thus, the output beam leaves the four-mirror monochromator along an axis coincident with that of the input beam. This preservation of the axis of the beam is critical in some synchrotron beam lines and free-electron lasers.



The **Four-Mirror X-Ray and Extreme-Ultraviolet Monochromator** contains two identical pairs of mirrors like the pair in the compact x-ray and extreme-ultraviolet monochromator. The two pairs are placed "back-to-back" to return the output beam to the path of the input beam and to obtain additional spectral selectivity.

The input filter and the first two mirrors constitute a compact monochromator like the one described previously, and, therefore, the laterally displaced intermediate beam has a narrow spectrum. This spectrum is narrowed further by the reflections from the mirrors of the second pair. Thus, one of the principal advantages of the four-mirror monochromator is additional spectral selectivity, achieved at a modest increase in cost and complexity and with some loss of throughput.

As in the compact monochromator, one can change the wavelength of peak transmission by putting other mirror substrates that have different Bragg-reflecting multilayer coats in the mirror mounts. Ordinarily, the multilayer coats on all four mirrors are identical. However, one could obtain even better spectral resolution (at the cost of significant loss of throughput) by use of multilayers that have Bragg-reflection band-pass spectra slightly offset from each other.

This work was done by Richard B. Hoover of **Marshall Space Flight Center.** *For further information, Circle 151 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 14]. Refer to MFS-28498.

Compact X-Ray and Extreme-Ultraviolet Monochromator

This low-cost monochromator can operate at selected wavelengths in a wide spectral range.

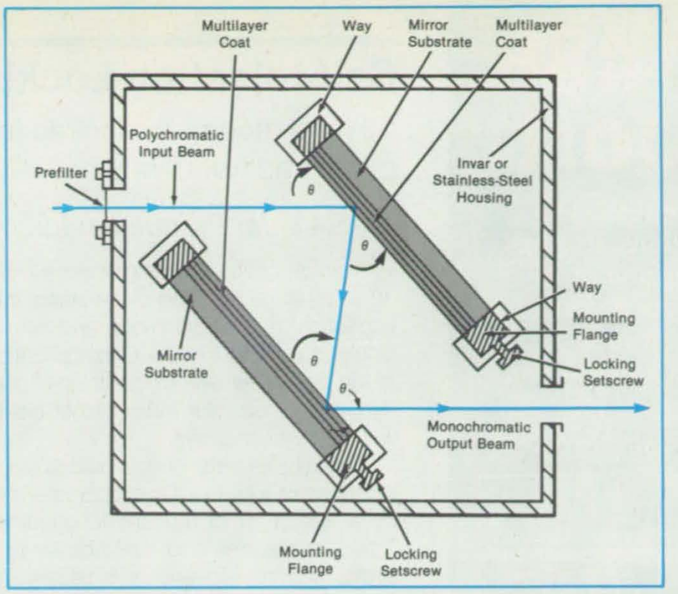
Marshall Space Flight Center, Alabama

A monochromator for x-ray and extreme-ultraviolet radiation provides higher spectral resolution than can be achieved with thin-metal-foil broad-band-pass filters. It operates over a much broader x-ray and extreme-ultraviolet spectrum than devices based upon natural crystals do, and in comparison with a typical grating monochromator, it is smaller and less expensive. The new monochromator is intended to filter the continuum radiation from sources like synchrotrons, laser plasma sources, free-electron lasers, and wigglers to produce monochromatic beams for testing and analysis of x-ray and extreme-ultraviolet telescopes and microscopes, for calibration of photographic films and detectors, for biological and biomedical research, for x-ray lithography, for processing of materials, and for research in the properties of materials.

As shown schematically in the figure, the monochromator includes a pair of mirror substrates with identical reflecting multilayer coats. These mirrors are mounted in a housing of stainless steel or low-thermal-expansion alloy on surfaces machined and lapped precisely to keep the mirrors parallel to each other. The radiation enters the monochromator housing through a prefilter that filters out visible and longer-wavelength ultraviolet light.

The mirror substrates — made of sapphire or low-thermal-expansion glass/ceramic composite — must be superpolished to a roughness of less than 3 Å root mean square. The reflecting coat on each substrate consists of many alternating layers of high-atomic-number x-ray-diffracting material separated by layers of low-atomic-number spacing material. All layers are uniform and of accurately repeatable thicknesses throughout the multilayer stack.

Each multilayer coat constitutes a synthetic Bragg crystal, which reflects x rays by Bragg diffraction. The wavelength at which the peak of the reflected flux occurs is given by the Bragg relation $N\lambda = 2D \sin \theta$, where N is the order of the diffraction (usually 1); D is the effective thickness of a high-atomic-number/low-atomic-number pair of layers, corrected for the effect of refraction; and θ is the angle between the incident beam of radiation and the surface of the mirror. The reflection from both mirrors occurs at angle θ, and the reflection from the second mirror narrows the spectrum that remains after the reflection from the first mirror.



The **Compact Multilayer X-Ray and Extreme-Ultraviolet Monochromator** uses Bragg reflection to band-pass-filter the radiation from a high-intensity, broad-spectrum source.

By the choice of D, θ, and the materials in the layers of the multilayer coats, the monochromator can be made to operate at a desired wavelength in the soft-x-ray or extreme-ultraviolet portion of the electromagnetic spectrum. An additional pair of multilayer reflectors (not shown) could be used to enhance the spectral resolution of the monochromator and to cancel the lateral displacement of the beam; such displacement would be unacceptable in some synchrotron-beam-line or free-electron-laser applications.

The mirrors are nominally tilted at an angle of 45° with respect to the incident beam, but different angles can be chosen for selected wavelengths. The operating wavelength is changed by replacing the pair of mirrors with another pair. Because the mirrors can be quite small (nominally rectangular, 1 cm wide by 2 cm long by 0.5 cm thick), the cost of fabricating the pairs of mirrors can be very low. A collection of pairs of coated mirrors could be made available to enable operation at selectable and precalibrated wavelengths from 20 Å to over 400 Å. Adjustable slits could be mounted in the exit aperture to facilitate control of the spatial extent and intensity of the emerging beam.

This work was done by Richard B. Hoover of **Marshall Space Flight Center**. *For further information, Circle 36 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 14]. Refer to MFS-28499.

Self-Injection Locking of Diode Lasers

Several modes are locked to a single spatial mode and frequency.

NASA's Jet Propulsion Laboratory, Pasadena, California

A simple optical coupling scheme locks an array of gain-guided diode lasers into oscillation in a single mode and with a single-lobed output beam. One application of the new scheme is for pumping of neodymium: yttrium aluminum garnet lasers with diode-laser arrays.

Typically, an array of gain-guided diode lasers emits a beam of light characterized by a spectrum of multiple longitudinal-mode frequencies and dual-lobe far-field spatial pattern. However, it is usually desirable to concentrate the energy of the output beam into a single longitudinal mode and a single spatial lobe in the far field. In the simplified coupling scheme, selective feedback from a thin etalon self-injection-locks the array into the desired mode.

The concept was tested in experiments with arrays of 10 and 20 diode laser stripes in the configuration shown in Figure 1. The temperatures of the arrays were maintained within ±0.1 °C of a preset value. Figure 2 shows the results of one of the experiments: Once the etalon was carefully aligned, four of the five wavelength modes were suppressed, and the two lobes of the main beam were combined into a single lobe.

This work was done by H. Hemmati of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 75 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 14]. Refer to NPO-17665.

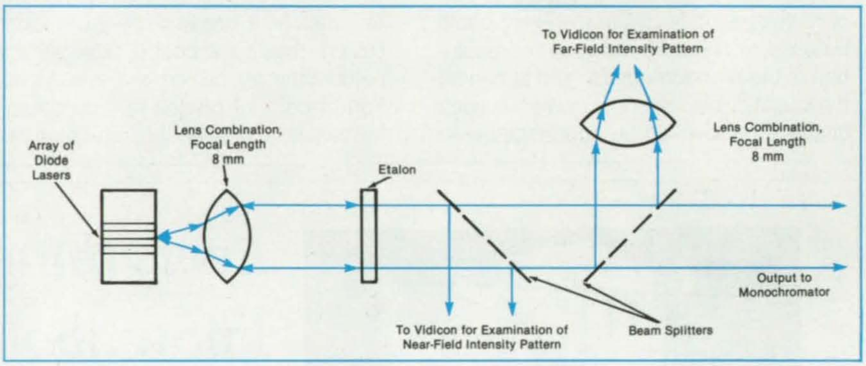


Figure 1. An **Array of Diode Lasers** is self-injection-locked to a single mode by feedback from a thin etalon.

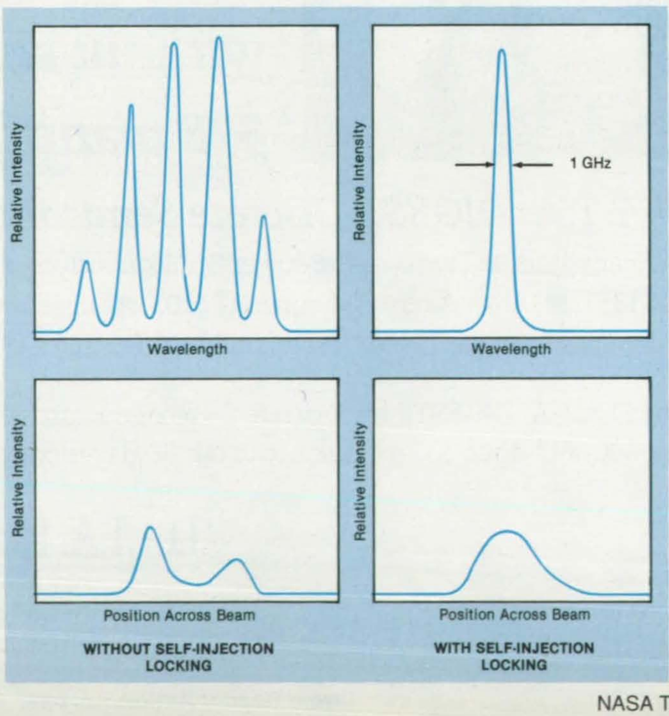


Figure 2. The **Spectrum and Spatial Modes** of the array are shown with and without self-injection locking of the type illustrated in Figure 1.

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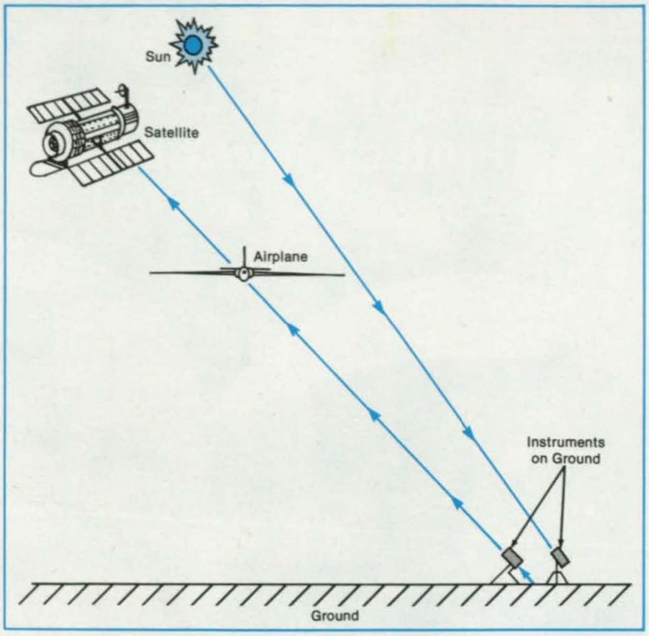
Airborne Calibration of an Orbiting Radiometer

Measurements enable compensation for degradation of optics and changes in detector circuitry.

Ames Research Center, Moffett Field, California

An experiment has demonstrated the feasibility of using a recently calibrated airborne radiometer to calibrate a satelliteborne radiometer that monitors the Earth and that has not been calibrated since before launch. The calibration technique helps to assure Earth scientists of the accuracy of satellite radiometric measurements taken during a long time. The optical train of the orbiting radiometer is degraded slowly and the sensitivities of detectors and gains of amplifiers are changed slowly in the outer-space environment, but frequent calibrations by the airborne-radiometer technique make it possible to compensate for these changes.



The **Same Area of the Earth** is viewed along the same direction by a spaceborne and an airborne radiometer.

In concept (though not in implementation) the calibration technique is simple. The airborne and spaceborne radiometers simultaneously monitor the same target area on the Earth during clear weather. The target is preferably bright and relatively uniform. The aircraft measurements are made from as high an altitude as possible along the same viewing vector as that of the satellite (see figure), so that the airborne and spaceborne radiometers measure nearly identical spectra, including the effects of the atmosphere. The radiances measured by the airborne radiometer are corrected for what little part of the atmosphere lies above the aircraft. The spaceborne radiometer is then calibrated by comparing its measurements with the corrected measurements taken by the presumably-accurate airborne radiometer.

In the experiment, a radiometer was flown aboard a U-2 airplane at an altitude of 19.8 km to calibrate the visible and near-infrared spectral band of the Visible-Infrared Spin-Scan Radiometer (VISSR) aboard the Geostationary Orbiting Environmental Satellite 6 (GOES-6), which produces images of an entire hemisphere once each hour in three spectral bands to provide nearly global observations of clouds, water vapor, and temperatures. White Sands, New Mexico, was selected as the target area for several reasons: It has the required brightness and near uniformity; the probability of a clear sky there is great; the characteristics of the atmosphere there have been well documented for years; the reflectance of the surface is diffuse and nearly Lambertian, and, consequently, any errors that arise from slight differences between the fields of view of the airborne and spaceborne radiometers are minimal; and the radiance of this area lies in the higher dynamic range of the spaceborne radiometer. The airborne and spaceborne radiometric measurements were supplemented with surface meteorological data, including horizontal visibility and soil moisture, and with other meteorological data.

The satellite and aircraft measurements were processed and compared to obtain calibration coefficients. The results showed that the radiances measured by the airborne radiometer were of the order of 14 percent greater than those measured with the spaceborne radiometer, using its original calibration. Assuming that the spaceborne radiometer was calibrated correctly before launch, this means that it had lost some sensitivity in orbit, as one might expect.

This work was done by Gilbert R. Smith, Robert H. Levin, Robert S. Koyanagi, and Robert C. Wrigley of **Ames Research Center**. *Further information may be found in NASA TM-101064 [N89-25494], "Visible and Near-Infrared Channel Calibration of the GOES-6 VISSR Using High-Altitude Aircraft Measurements."*

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-12617

Monatomic-Oxygen Reactors for Materials Testing and Surface Chemistry

Specimens receive even doses.

Lyndon B. Johnson Space Center, Houston, Texas

Two kinds of gas-flow reaction chambers expose specimens of materials to spatially even fluxes of monatomic oxygen. In radio-frequency plasma ashers and other reaction chambers used previously to test reactions of materials with monatomic oxygen, experiments have been complicated by uneven fluxes of monatomic oxygen and by undesired fluxes of electrons, ions, and ultraviolet radiation.

The first type of chamber is part of a flowing-afterglow apparatus. A gas that contains oxygen flows through a radio-frequency discharge, in which monatomic oxygen is produced. The gas cools to near room temperature as it flows from the discharge. Specimens are mounted at the outer ends of side-arm tubes attached to the flowing-afterglow apparatus at a suitable location downstream of the discharge (see Figure 1).

The oxygen atoms enter the side-arm tubes and diffuse to the specimens at the outer ends. The dimensions of the side-arm tubes and the total pressure in the flowing-afterglow gas are selected so that the characteristic time for the diffusion of monatomic oxygen across a side-arm tube is much less than the characteristic time for recombination of monatomic oxygen into diatomic oxygen. This selection assures that the flux of monatomic oxygen is distributed evenly across each side arm and across the specimen at the end of each side arm.

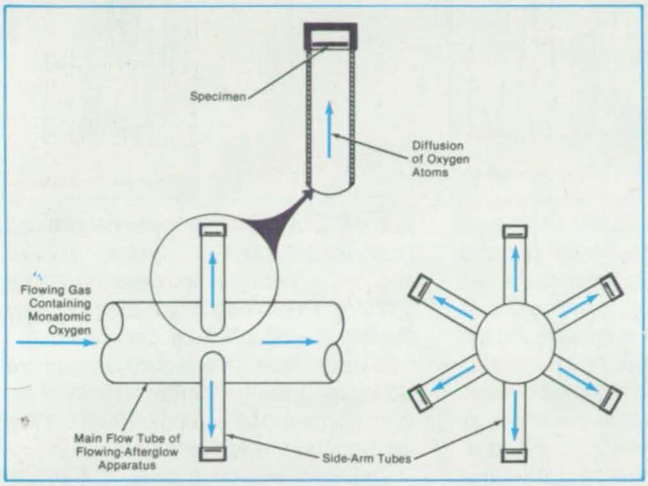
In the second kind of chamber, monatomic oxygen is generated by laser-pulse photolysis. In the version illustrated in Figure 2, the ultraviolet (or, in some cases, infrared) output of an excimer laser is focused into a beam of rectangular cross section. Specimen sheets are placed near and parallel to (but not touching) the beam. The gas (which could contain O_2, O_3, NO_2, N_2O, or other suitable precursor molecules) flows through the chamber.

As in the side-arm approach, the oxygen atoms reach the surfaces of the specimens only by diffusion. In this case, the dose received by each specimen is proportional to the number of oxygen atoms generated in the photolysis volume between the specimens. The flux of atomic oxygen is distributed evenly across each specimen as long as the monatomic oxygen is distributed evenly in the photolysis volume.

This work was done by Steve Koontz of **Johnson Space Center**. *For further information, Circle 16 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center [see page 14]. Refer to MSC-21505.

Figure 1. **Monatomic Oxygen Diffuses Along Side-Arm Tubes** attached to a flowing-after-glow apparatus. If the rate of diffusion is high enough, the specimens at the ends of these tubes receive uniform doses.



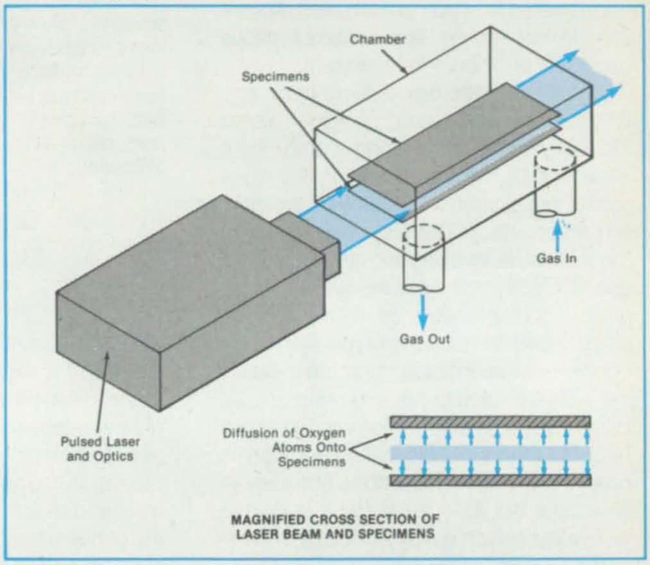


Figure 2. **Monatomic Oxygen Generated by Photolysis** in the pulsed laser beam diffuses sideways out of the laser beam and onto the nearby surfaces of the specimens.

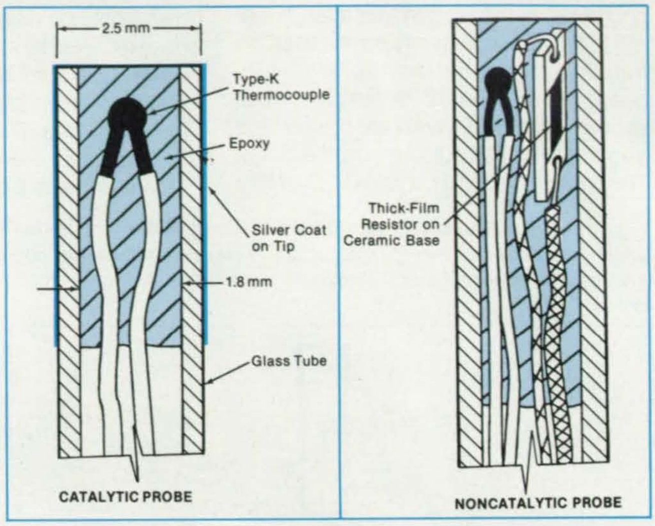
Measuring Flux Density of Monatomic Oxygen

Two probes measure heat of recombination on a catalytic surface.

Marshall Space Flight Center, Alabama

An improved version of the catalytic-probe technique yields more accurate measurements of the flux density of neutral, monatomic oxygen. The principal application of this technique will likely be in experiments in which oxygen plasmas are used to examine the degradation of various materials by monatomic oxygen.

In the catalytic-probe technique, one measures the flux density of oxygen atoms indirectly by measuring some of the heat generated by the recombination of oxygen atoms into oxygen molecules on a catalytic probe surface. The improved version of the technique involves two similar probes, one of which is catalytic, the other of which is not. Both probes (see figure) include glass tubes that contain type-K thermocouples sealed in epoxy near the measuring tips. A thick-film heating resistor on a ceramic base is also sealed into the epoxy near the thermocouple in the noncatalytic probe. The other probe does not contain a resistor, but its outer surface is coated with silver, which quickly oxidizes and becomes a catalyst for the recombination of monatomic oxygen. The emissivity of the silver oxide is 0.85 — the same as that of the glass.



The **Catalytic Probe and the Noncatalytic Probe** measure the rate of heating caused by the recombination of monatomic oxygen on the catalytic surface. The flux density of monatomic oxygen is proportional to this rate of heating.

The probes are mounted near each other in the plasma chamber and operated simultaneously so that both sample nearly the identical atmosphere and its atomic-oxygen content. (One of the weaknesses of prior versions of the technique is that they involved single probes and sequential measurements in which identical conditions could not be assured.) The temperature measured by the thermocouple in the catalytic probe includes the effect of heat released by recombination of oxygen. The electrical power delivered to the resistor in the noncatalytic probe is measured and automatically adjusted by control circuitry that attempts to keep the temperature in the noncatalytic probe the same as that in the catalytic probe. Under this condition, the electrical heating power is nearly proportional to the rate of recombination and, therefore, to the flux density of monatomic oxygen. The noncatalytic probe can also be operated without heating to measure the temperature of the probed atmosphere.

The total flux of oxygen atoms that strike the probe is computed from the known energy released in each recombination (5.2 eV) and the empirically determined proportionality between the heating power and the increase in temperature above ambient. The flux density is then found by dividing the total flux by the area of the catalytic surface. If the probed atmosphere is thermal, then the number density of oxygen atoms can be computed from the flux density and the temperature.

This work was done by M. R. Carruth, Jr., R. F. DeHaye, J. K. Norwood, and A. F. Whitaker of **Marshall Space Flight Center**. *For further information, Circle 48 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 18]. Refer to MFS-28446.

GC/MS Gas Separator Operates at Lower Temperatures

Less power is consumed, and the catalytic hydrogenation of compounds being analyzed should be diminished.

NASA's Jet Propulsion Laboratory, Pasadena, California

Experiments have shown that a palladium/silver tube used to separate the hydrogen carrier gas from the gases being analyzed in a gas-chromatography/mass-spectrometry (GC/MS) system functions satisfactorily at temperatures as low as 70 to 100 °C. Heretofore, it was believed necessary to maintain operating temperatures between 200 and 250 °C to obtain adequate separation.

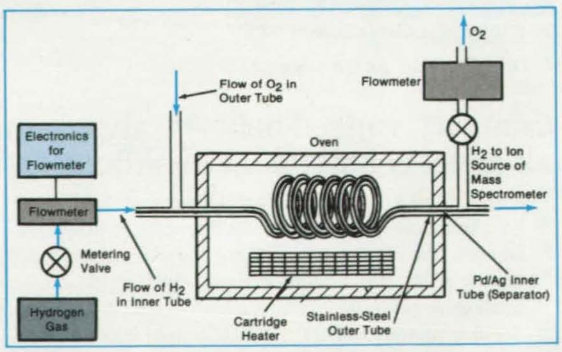


Figure 1. This **Experimental Apparatus** was used to determine the separation efficiency of the **Pd/Ag** tube as a function of temperature.

Figure 1 illustrates the experimental apparatus and the principle of operation. The 75-percent palladium/25-percent silver separator tube is sealed inside a stainless-steel outer tube. The hydrogen carrier gas (and any entrained gas to be analyzed) flows along the Pd/Ag tube toward the ion source of a mass spectrometer. The hydrogen diffuses through the wall of the Pd/Ag tube to the annulus between the inner and outer tubes. Oxygen flowing in the annulus combines with and sweeps away the hydrogen. Thus, the gas emerging from the output end of the tube contains a much lower concentration of hydrogen and, consequently, a much higher concentration of the gases to be analyzed. The experimental data indicate that the separation efficiency — that is, the fraction of entering hydrogen removed through the wall of the Pd/Ag tube — increases with temperature, as expected. The data also indicate that nearly complete separation is achieved at

temperatures below 100 °C (see Figure 2).

At the conventional higher operating temperatures, the Pd/Ag alloy undesirably catalyzes the modification and hydrogenation of some of the gases being analyzed — particularly dienes and nitriles. At the proposed lower operating temperatures of 70 to 100 °C, it is expected that these catalytic effects will be suppressed. Operation at lower temperatures would also require less heater power. Furthermore, because the separation efficiency is still high even at the lower temperatures, the gas load on the vacuum pump of the mass spectrometer can be kept low, permitting the use of a smaller pump. These features are expected to facilitate the development of a relatively small, lightweight, portable GC/MS system for such uses as measuring the concentrations of pollutants in the field.

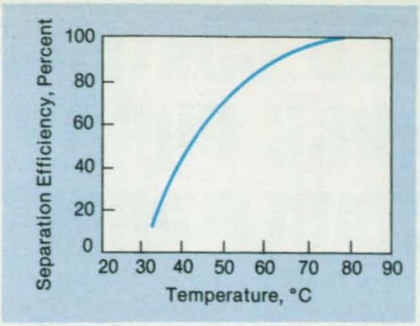


Figure 2. The **Separation Efficiency** approaches 100 percent at temperatures well below the conventional minimum operating temperature of 200 °C. Beyond the precision of this plot, the data indicate a separation efficiency of 99.98 percent at 78 °C.

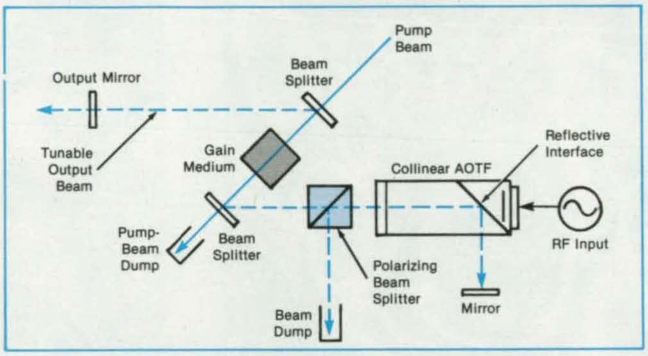
This work was done by Mahadeva P. Sinha of Caltech and George Gutnikov of California State Polytechnic University, Pomona for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 101 on the TSP Request Card.* *NPO-17930*

Acousto-optical Filter Can Rapidly Tune Solid-State Lasers

Output wavelength can be randomly selected in microseconds.

NASA's Jet Propulsion Laboratory, Pasadena, California

The incorporation of an acousto-optical tunable filter (AOTF) in the cavity of a solid-state laser, such as a Ti:Sapphire laser, would provide a means of adjusting the wavelength of the laser output electronically, according to a recent proposal. The table shows the tuning range of several solid-state lasers with particularly broad tuning ranges. Incorporation of this technique with up/down conversion could be used to extend this range even further.



The **Intercavity Acousto-optical Tunable Filter** provides a method of rapidly tuning a solid-state laser to any wavelength within its gain profile.

Laser	Tuning Range
Ti:Al_2O_3	690-1,050 nm
NaCl:OH	1,420-1,850 nm
Co:MgFl	1,750-2,500 nm

Tuning Ranges for wide band solid-state lasers.

Typically, the AOTF is placed inside the laser cavity and is driven with a sinusoidal RF signal (see figure). The frequency of the RF signal determines the center of the spectral bandpass of the AOTF and hence the wavelength of the laser output. The laser can be programmed to produce multiple output wavelengths simultaneously by driving the AOTF with several RF frequencies. Pulsing an intercavity AOTF periodically could provide a means for wavelength-selectable mode-locking.

Since the AOTF can be tuned in as little as 1 μs with a resolution as small as 1 Å, this technique could be useful in remote-sensing applications, such as in a differential-absorption lidar (DIAL) and in communications for wavelength-division multiplexing.

This work was done by James L. Lambert of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 113 on the TSP Request Card.* *NPO-17891*

Low-Speed Optical Speedometer

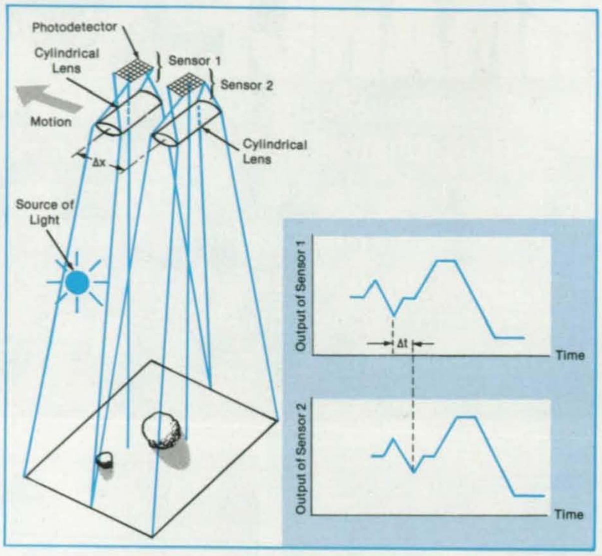
The delay between terrain-reflectance signals from two optical sensors indicates speed.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed speedometer would measure the speed of a vehicle along the ground by comparing the signals from two inexpensive sensors focused on the surface passing beneath the vehicle (see figure). Unlike such sensors as Doppler radar, the proposed speedometer could be used to measure speeds as low as 10 cm/s.

Each of the two sensors would include a cylindrical lens and a single-element photodetector. Each lens would focus light from a small rectangular area of the passing ground-surface scene onto the plane that contains its detector. The sensors would be positioned so that the axes of the cylindrical lenses would be parallel to each other and perpendicular to the direction of motion.

As the vehicle moved, the sensors would follow the same path over the surface, one after the other. Thus, the two photodetectors would generate similar signals as they pass one after the other over the same surface features, but one signal would be delayed with respect to the other by an interval inversely proportional to the speed. A processor would compute a correlation between the two signals to determine the delay between them. The distance between the sensors would then be divided by this delay to determine the speed. The distance between the sensors and the focal length of the cylindrical lenses could be chosen to optimize performance for the anticipated speed range.



The **Optical Correlation Speedometer** would compare signals from two sensors to find the delay Δt between the passage of the first and second sensors over the same points on the ground. The two signals would be correlated to determine the value of Δt that provides the best match between them. The speed of the vehicle would be computed as $\Delta x/\Delta t$, where Δx is the distance between the sensors.

The source of light used to illuminate the area viewed by the sensors could be continuous or pulsed. With appropriate processing of the signals from the photodetectors, a pulsed or modulated source could facilitate discrimination from ambient light. An infrared source may be preferable if operation during both day and night is desired. The light source could be made to illuminate the surface obliquely to enhance ground features.

In the case of a vehicle free to move in any direction, such as a hovercraft or a vehicle equipped with pivoting wheels, there are two perpendicular components of velocity to measure. In that case, two sets of sensors mounted with their axes perpendicular to each other could measure both components.

This work was done by Katsunori Shimada of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 126 on the TSP Request Card. NPO-17702*

Organometallic Salts Generate Optical Second Harmonics

Molecular structures are selected to obtain large hyperpolarizabilities.

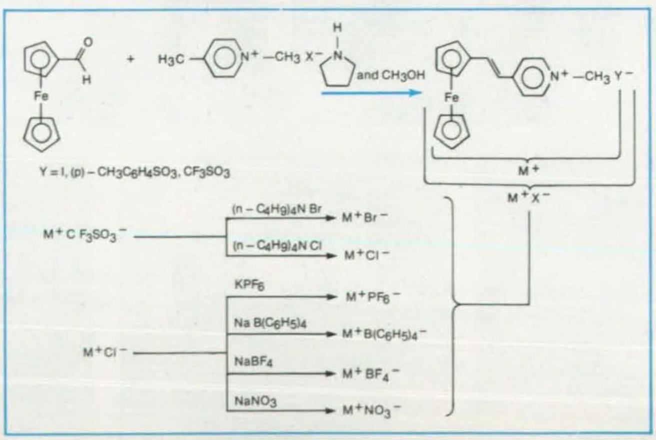
NASA's Jet Propulsion Laboratory, Pasadena, California

A series of organometallic salts have been found to exhibit large second-order dielectric susceptibilities, as evidenced by the generation of second harmonics when they are illuminated at visible and near-infrared wavelengths. Investigations of these and related compounds continue with a view toward the development of materials for use as optical second-harmonic generators, electro-optical modulators, optical switches, piezoelectric sensors, and parametric crystals.

The organometallic salts in question are ferrocenyl compounds of the form

$(E)\text{-}(\eta-C_5H_5)Fe(\eta-C_5H_4)\text{-}CH=$
$CH\text{-}(p)\text{-}(C_5H_4N\text{-}CH_3)^+X^-$, where
$X^- = I^-, Br^-, Cl^-, CF_3SO_3^-, BF_4^-, PF_6^-, NO_3^-, (p)\text{-}CH_3\text{-}C_6H_4SO_3^-$, or $B(C_6H_5)_4^-$.

In experiments, these compounds were synthesized in processes that began with the reaction of $CH_3\text{-}(p)\text{-}C_6H_4N\text{-}CH_3{}^+Y^-$ ($Y = I^-$, $CF_3SO_3^-$, and $(p)\text{-}CH_3\text{-}C_6H_4SO_3^-$ with $(\eta-C_5H_5)Fe(\eta-C_5H_4)CHO$ (See figure). By virtue of the excellent electron-donor properties of the ferrocenyl moiety and the excellent electron-acceptor properties of the N-methyl-pyridinium moiety, these compounds were expected to exhibit very large molecular hyperpolarizabilities, which could, in principle, lead to very large macroscopic second-order nonlinearities. In addition, by selection of the X^- counterions,



Organometallic Salts are synthesized: some by the reaction shown above (only) and some by the reactions shown above followed by the reactions shown below. The selection of the appropriate counterion X^- causes the salts to exhibit large second-order susceptibilities.

it has been possible to affect the packing of the molecules in the crystal and to find salts in which the packing arrangements are conducive to the generation of second harmonics.

The experimental compounds were prepared in powder form and illuminated with 1.907-μm light that had been H_2-Raman shifted from the light of a neodymium:yttrium aluminum garnet laser operating at 1.064 μm. The effect of the selection of the counterions was seen clearly: the second-harmonic-generating efficiencies of some of these compounds was many times that of a urea reference standard. The best results were obtained with counterions of I^-, Br^-, and NO_3^-, which exhibited efficiencies 220, 150, and 120 times that of urea, respectively.

This work was done by Seth R. Marder and Joseph W. Perry of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 137 on the TSP Request Card.* *NPO-17730*

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.

Trapped-Mercury-Ion Frequency Standard

The principle of operation and initial results are described.

A report describes the principle of operation, the design, and the results of initial measurements on a trapped-mercury-ion frequency-standard apparatus at NASA's Jet Propulsion Laboratory. The particular apparatus is one of four that were being developed when the report was presented in May 1987, and other, commercial units may be available shortly.

The use of trapped Hg^+ ions as a frequency standard was first proposed more than 20 years ago. The standard frequency — in this case, about 40,507,347,997 Hz — is defined in terms of the photon energy of the hyperfine transition between two atomic ground states of the $^{199}Hg^+$ ion. The ions are confined in a radio-frequency electric quadrupole trap, in which they are subjected to very small perturbations of their atomic energy levels and to weak forces that equalize the populations of the ground-state hyperfine energy levels. Potentially, the largest source of fluctuations in the frequency is the second-order Doppler effect of the motions of the ions in the trap. To minimize this effect, heavy ions like Hg^+, which move more slowly than do other ions at the same temperature, are preferred for trapped-ion frequency standards.

The hyperfine transition of interest is $^2S_{1/2}$ $(F = 0, m_F = 0) \rightarrow {}^2S_{1/2}$ $(F = 1, m_F = 0)$. The $^{199}Hg^+$ ions are first created in the trap by bombarding a neutral ^{199}Hg vapor with a pulse of electrons that lasts 1/2 second. During this bombardment and for about 1/4 second afterward, the ions are irradiated with photons of wavelength 194.2 nm from a ^{202}Hg discharge lamp to excite the transition $^2S_{1/2}$ $(F = 1, m_F) \rightarrow {}^2P_{1/2}$. The $^2P_{1/2}$ state decays rapidly (with a lifetime of 2 ns) to either the $^2S_{1/2}$ $(F = 0, m_F = 0)$ state or the $^2S_{1/2}$ $(F = 1, m_F)$ state, thereby scattering a 194-nm photon. Since the transition $^2S_{1/2}$ $(F = 0, m_F = 0) \rightarrow {}^2P_{1/2}$ is not resonant with the light from the ^{202}Hg lamp, the ions are pumped out of the $^2S_{1/2}$ $(F = 1, m_F)$ states into the $^2S_{1/2}$ $(F = 0, m_F = 0)$ state, and when they have all been thus pumped, they stop scattering ultraviolet light.

When the lamp is turned off, the ions are then exposed for 1/2 second to a magnetic field of amplitude 10^{-10} T oscillating at or near the standard frequency to be determined. This field makes the ions undergo the desired hyperfine transition from the $^2S_{1/2}$ $(F = 0, m_F = 0)$ state to the $^2S_{1/2}$ $(F = 1, m_F = 0)$ state. The ions then scatter ultraviolet light until the lamp pumps them back into the nonscattering $^2S_{1/2}$ $(F = 0, m_F = 0)$ state.

The intensity of the fluorescence (scattering) is measured while the frequency of the applied magnetic field is varied about a fixed nominal value in increments of 0.2 Hz. This yields a resonance peak that, in the initial measurements, was found to be about 1.6 Hz wide. The short-term frequency stability of the apparatus was found to be better than twice that of the best commercial cesium frequency standards.

Currently, a new frequency standard is being developed. It is based on the linear ion trap described in *NASA Tech Briefs* 14, No. 9, page 44, (NPO-17758). The new standard is expected to show much better short-term frequency stability because of its increased ion-storage capacity. This work will be described in a future issue of Tech Briefs.

This work was done by John D. Prestage, G. John Dick, and Lutfollah Maleki of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "The JPL Trapped Mercury Ion Frequency Standard," Circle 134 on the TSP Request Card.*
NPO-17456

Optimum Platinum Loading in Pt/SnO_2 CO-Oxidizing Catalysts

Catalytic activity peaks at about 17 weight percent Pt.

Langley Research Center, Hampton, Virginia

Platinum on tin oxide (Pt/SnO_2) is a good catalyst for the oxidation of carbon monoxide at or near room temperature. Tests at NASA Langley Research Center have shown that the activity of this catalyst can be maximized by optimizing the platinum loading of the catalyst. Pt/SnO_2 is available commercially at loadings of about 0.5 to 2.0 percent platinum (per total weight of catalyst), whereas catalysts with platinum loadings as high as 46 percent have been fabricated by a technique developed at Langley Research Center. Work was conducted to determine optimum platinum loading for this type of catalyst.

A Pt/SnO_2 catalyst that contained 17 percent platinum converted a stoichiometric mixture of 1.00 percent CO and 0.50 percent O_2 to CO_2 with a yield 3.7 times as great as that of a commercial catalyst that contained 2 percent platinum. Tests of Pt/SnO_2 catalysts with various Pt loadings revealed the following (see figure): (1) The activity of the catalyst increased with Pt loading until a peak was reached at 17 percent Pt. (2) The activity of the catalyst exhibited a trough at 24 percent Pt. (3) The activity of the catalyst then increased with further Pt loading until a second, lower peak was reached at 39 percent Pt. (4) The activity of the catalyst then declined with higher Pt loading, becoming very low at 100 percent Pt.

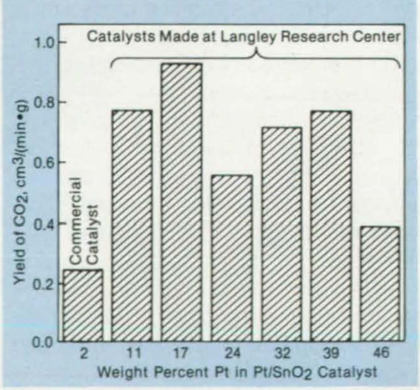
The observed behavior may represent two similar but somewhat different mechanisms. The common feature of both mechanisms is the oxidation of CO chemisorbed on Pt by OH groups on SnO_2. This postulate requires significant concentrations of both Pt and SnO_2 for maximum efficiency, and, therefore, both very low and very high Pt loadings exhibit low activity.

At Pt loadings below 24 percent, the major source of the oxidant species, OH, is H_2O, which is contained predominantly in the SnO_2 phase. This is shown by the fact that high-temperature pretreatment of Pt/SnO_2 catalysts with Pt loadings below 24 percent invariably causes an initial dip in activity, which dip can be readily eliminated simply by exposure of the catalysts to H_2O. However, catalysts with Pt loadings above 24 percent do not exhibit an initial dip in activity when heated and, therefore, do not appear to be as sensitive to dehydration as those with lower Pt loadings are. This indicates that they may have an alternative source of OH.

With high Pt loadings, sufficient hydrogen may be stored in the Pt phase to furnish OH by reaction with oxygen from the SnO_2 phase. Therefore, the presence of H_2O is not essential at such loadings. Thus, above about 24 percent Pt, the major source of OH is believed to be hydrogen stored in the Pt phase combined with oxygen from the SnO_2.

In some applications, a 39-percent Pt loading (which gives the lower peak in activity) may be preferable because this higher Pt loading should not require humidification, as does the 17-percent loading (which gives the higher peak in activity). Generally, the optimum platinum loading for the oxidation of CO, as derived from this study, is believed to be about 15 to 20 percent. A major application would be the removal of unwanted CO and O_2 in CO_2 lasers.

This work was done by David R. Schryer, Billy T. Upchurch, and Patricia P. Davis of **Langley Research Center** *and Kenneth G. Brown and Jacqueline Schryer of Old Dominion University. No further documentation is available.* LAR-14183



The **Effect of Platinum Loading** on activity of Pt/SnO_2 catalysts is clearly demonstrated in this comparison of several catalysts fabricated at Langley Research Center and one commercial catalyst.

Computer Programs

COSMIC: Transferring NASA Software

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

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

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

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Computer Programs

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

Physical Sciences

Displaying Images of Planets

Magnifications, contrasts, and/or subsampling can be selected for whole or partial images.

The Interactive Image Display Program (IMDISP) is an interactive image-displaying utility program for the IBM personal computer (PC, XT, and AT models) and compatibles. Until recently, efforts to utilize small computer systems for display and analysis of scientific data have been hampered by the lack of sufficient data-storage capacity to accommodate large arrays of image data. Most images of planets, for example, require nearly a megabyte of storage per image. The recent development of the "CD-ROM" (Compact Disk Read-Only Memory) storage technology makes possible the storage of up to 680 megabytes of data on a single 4.72-in. (12.0-cm) disk.

IMDISP was developed for use with the CD-ROM storage system that is being evaluated by the Planetary Data System. The latest disks to be produced by the Planetary Data System are a set of 8 disks containing 16,000 images of Jupiter, Saturn, and Uranus acquired by the Voyager spacecraft. The images are in both compressed and uncompressed formats. IMDISP can read the uncompressed images directly, but special software is provided to decompress the compressed images, which cannot be processed directly. IMDISP can also display images stored on floppy or hard disks.

A digital image is a picture converted to numerical form so that it can be stored and used in a computer. The image is divided into a matrix of small regions called picture elements, or pixels. The rows and columns of pixels are called "lines" and "samples," respectively. Each pixel has a numerical value, or DN (data number) value, that quantifies the darkness or brightness of the image at that spot. In total, each pixel has an address (line number, sample number) and a DN value, which are all that the computer needs for processing.

DISPLAY commands enable the IMDISP user to display all or part of an image at various positions on the display screen. The user can also zoom in and out from a point on the image defined by the cursor and can pan around the image. To enable more or all of the original image to be displayed on the screen at once, the image can be "subsampled." For example, if the image were subsampled by a factor of 2, every other pixel from every other line would be displayed, starting from the upper left corner of the image. Any positive integer can be used for subsampling.

The user can produce, from an image file, a histogram that shows the number of pixels per DN value, or per range of DN values, for the entire image. IMDISP can also plot the DN value versus the number of pixels along a line between two points on the image. The user can "stretch" or increase the contrast of an image by specifying low and high DN values; all pixels that have DN values lower than the specified "low" then become black, and all pixels that have DN values higher than the specified "high" value become white. Pixels between the low and high values are evenly shaded between black and white.

IMDISP is written in a modular form to make it easy to change it to work with different display devices or on other computers. The code can also be adapted for use in other application programs. There are device-dependent image-display modules, general image-display subroutines, image input/output routines, and image-label and command-line-parsing routines.

The IMDISP software system is written in C language (94 percent) and Assembler (6 percent). It was implemented on an IBM PC with the MS DOS 3.21 operating system. IMDISP has a memory requirement of about 142K bytes. The program was developed in 1989 and is copyrighted. Additional images of planets can be obtained from the National Space Science Data Center at (301) 286-6695.

This program was written by Michael D. Martin, Frank Evans, and Daniel I. Nakamura of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 21 on the TSP Request Card.*
NPO-17977

Mathematics and Information Sciences

Systematic Identification of Discrepant Hardware

The material-review process is automated for greater speed and efficiency.

The basic function of a manufacturer's production-support-engineering unit is to identify, document, and dispose of hardware that does not conform to drawing requirements. CAMRAD, a program designed for rapid input and retrieval of all data used in engineering-to-manufacturing support operations, aids the engineer by automating the material-review-disposition process. Before CAMRAD, material-review record searches were manual. The time spent searching through old documents precluded the timely disposition of new material reviews. CAMRAD facilitates the research of material-review histories and provides for the efficient processing of material-review documents.

Three SmartWare project files control the operation of CAMRAD. The project file CAMRAD initializes variables for the other project files and specifies the paths of the CAMRAD program, data-base files, and document files. The project file DATARAD controls all data-management functions. The data base consists of individual files that contain all records of specific hardware discrepancies for a part designated by a given number.

There are four basic avenues for a search of records: the serial number of a part, a feature of the part, the Material Review (MR) number, and nonconformance. WORDRAD is the project file that controls the management of document files created when processing a material-review disposition. Given a material-review report that identifies a defective item of hardware, the production-support engineer can use CAMRAD to search the data base quickly for any history of the same problem, find out how well the problem has been documented, and create appropriate documentation for this latest occurrence.

CAMRAD is written in the Smart programming language and is designed to run on IBM PC compatibles with the SmartWare version 3.1 software package available from Informix Software. CAMRAD was developed in 1987.

SmartWare is a registered trademark of Informix Software, Inc. IBM PC is a registered trademark of International Business Machines Corporation.

This Program was written by Timothy L. Hanna and William R. Stinson of **Marshall Space Flight Center**. *For further information, Circle 45 on the TSP Request Card.*
MFS-29525

Generating Three-Dimensional Grids About Anything

A Poisson's-equation scheme can fit a grid to a body of arbitrary shape.

The ability to treat boundaries that have arbitrary shapes is one of the most desirable characteristics of a method for generating grids. The Three-Dimensional Grids About Anything by Poisson's Equation (3DGRAPE) computer program is designed to make computational grids in or about almost any shape. These grids are generated by the solution of Poisson's differential equations in three dimensions. The program automatically finds its own values for inhomogeneous terms that give near-orthogonality and controlled grid-cell height at boundaries. Grids generated by 3DGRAPE have been applied to both viscous and inviscid aerodynamic problems, and to problems in other areas of fluid dynamics.

3DGRAPE uses zones to solve the problem of warping one cube into the physical domain in problems of computational fluid dynamics. In a zonal approach, a physical domain is divided into regions, each of which maps into its own computational cube. It is believed that even the most complicated physical region can be divided into zones, and since it is possible to warp a cube into each zone, a grid generator that is oriented to zones and provides communication across zonal boundaries (where appropriate) solves the problem of topological complexity.

3DGRAPE accepts input in the form of already-distributed x, y, z coordinates on the bodies of interest — coordinates that remain fixed during the entire grid-generation process. The 3DGRAPE code makes no attempt to fit given body shapes and redistribute points thereon. Body fitting is a formidable problem in itself. The user must either be working with a body of some simple analytical shape, upon which a simple analytical distribution can be easily effected, or must have available some sophisticated stand-alone body-fitting software.

3DGRAPE does not require the user to supply the block-to-block boundary surfaces or the distribution of points on them. 3DGRAPE typically supplies those block-to-block boundaries simply as surfaces in the elliptic grid. Thus, at block-to-block boundaries the following conditions are obtained: (1) grid lines match up as they approach the block-to-block boundary from either side, (2) grid lines cross the boundary with no discontinuity in slope, (3) the spacing of points along a line piercing the boundary is continuous, (4) the shape of the boundary is consistent with the surrounding grid, and (5) the distribution of points on the boundary is reasonable in view of the surrounding grid.

3DGRAPE offers a powerful building-block approach to the generation of complicated three-dimensional grids, but it is a low-level software tool. Users can build each face of each block as they wish, from a wide variety of resources. 3DGRAPE uses point-successive-over-relaxation (point-SOR) to solve the Poisson equations. This method requires a large number of iterations, but it vectorizes nicely. Any number of sophisticated graphics programs can be used on the stored output file of 3DGRAPE even though it lacks interactive graphics. Versatility was a prominent consideration in developing the code. The block structure allows a great latitude in the problems it can treat. As the full title of 3DGRAPE implies, this program should be able to handle just about any physical region into which a computational cube or cubes can be warped.

3DGRAPE was written in 100 percent FORTRAN 77 and should be machine-independent. It was originally developed on a Cray computer under COS and tested on an IRIS 2500T workstation under UNIX.

This program was written by Reese L. Sorenson of **Ames Research Center**. *For further information, Circle 44 on the TSP Request Card.*
ARC-12620

Mechanics

Hardware, Techniques, and Processes

Holographic Interferometry To Measure Three-Dimensional Flow

Double-exposure holography is used in studies of transonic flow near rotating blades.

Ames Research Center, Moffett Field, California

A double-exposure holographic interferometry technique is used for studies of the density distribution in transonic airflow in the vicinity of a rotating helicopter blade. The interference fringes in the holographic interferograms are contours of a two-dimensional projection of the flow-field density integrated along the light path. A detailed three-dimensional density distribution should be obtainable by tomographic analysis of a series of such interferograms taken with the blade at different angles with respect to the object beam in the interferometer.

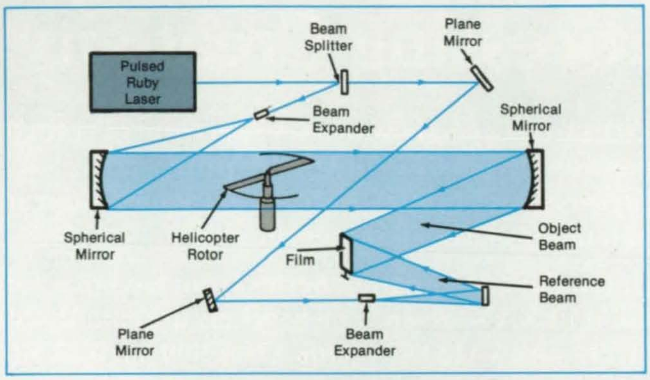
Three-dimensional flow-field density data should prove helpful in altering blade geometry to reduce the loud impulsive noise generated by transonic flow. The high-speed impulsive noise generated on the advancing-blade side of the rotor (where transonic flow is inevitable) is believed to radiate significantly more energy than the impulsive noise generated when the rotor blades interact with previously generated tip vortexes. In both cases, good data are essential for the theoretical prediction of the acoustic signature and for the verification of aerodynamic-transonic-flow numerical codes.

Holographic interferometry is nonintrusive. Furthermore, it is economical and suitable for large-scale experiments; there are no stringent optical requirements because the two object beams that produce the interference pattern use the same object-beam optics at different times, thus avoiding the generation of spurious fringe shifts that would otherwise be caused by differing path lengths.

A holographic interferometry test setup is shown in the figure. Interferograms were produced using a pulsed ruby laser to "freeze" the rotor blade during the exposures. The object beam passed through a beam expander and was collimated into a beam 2 ft (0.6 m) in diameter by a spherical mirror. After passing the rotor, the object beam was directed to the film by a second mirror. The reference beam followed a separate path of similar length. After the two exposures were made (blade stationary and blade rotating), the film was developed. The interference pattern was reconstructed by illuminating the film with a continuous-wave He/Ne laser.

A variant of the technique can be used to provide a qualitative visualization of the three-dimensional flow field. A diffuser is inserted in the object beam just ahead of the rotor blade, and a two-exposure interferogram is recorded as before. The distribution of density change can be visualized by noting where the fringes are located in the three-dimensional real image created upon reconstruction.

This work was done by Yung H. Yu of **Ames Research Center**. *For further information, Circle 82 on the TSP Request Card. ARC-11474*



In the **Holographic Interferometry System**, two exposures are superimposed on the film to produce an interferogram. During the first exposure, the helicopter rotor blade is stationary. The second exposure is made with the blade rotating, at the instant the blade passes through the same position it occupied during the stationary exposure.

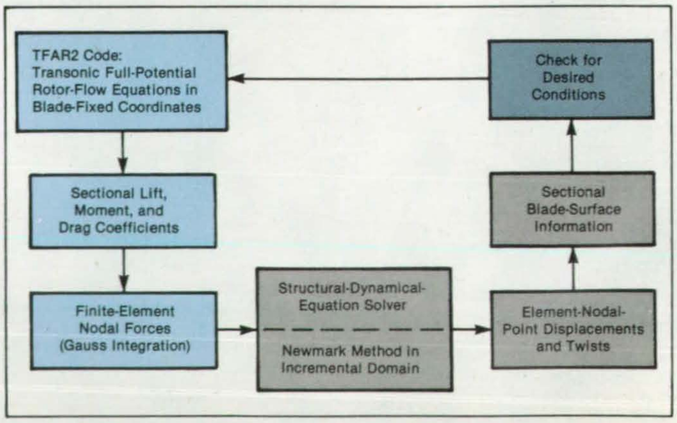
Transonic Aeroelasticity Analysis for Helicopter Rotor Blade

Two established techniques are combined.

Ames Research Center, Moffett Field, California

A numerical-simulation method for the aeroelasticity analysis of a helicopter rotor blade combines established techniques for the analysis of aerodynamics and the vibrations of the blade. The application of the method clearly shows that the elasticity of the blade modifies the flow and, consequently, the aerodynamic loads on the blade.

The flow is assumed to be compressible, irrotational, inviscid, and isentropic, and to obey an ideal-gas law with a con-



Aerodynamical and Structural Computer Codes are coupled to complete the analysis of aeroelasticity of a helicopter rotor blade.

stant specific-heat ratio (1.4 for air). These assumptions permit the use of Bernoulli's equation of unsteady motion in a nonlinear, potential-flow form. This equation is transformed to a reference frame attached to the blade. The boundary conditions include zero perpendicular velocity on the surface of the blade. The wake is represented by a vortex sheet shed by the trailing edge of the blade. Bernoulli's equation is solved by a transonic-rotor-flow code, TFAR-2.

For the dynamical analysis of the blade structure, Hamilton's principle is applied to derive finite-element equations, using potential-energy equations from the theory of elasticity of beams. Shape functions are introduced to describe the deflections as functions of position within each element in flapping, lagging, axial-extension, and twisting modes. Mass, stiffness, and damping matrices are derived from the equations for the kinetic energy, equations for potential energy, and semiempirical modal damping equations, respectively. A global/local coordinate-transformation matrix reduces the inaccuracies caused by large deformations of the blade.

The structural and aerodynamical portions of the analysis are combined in the following procedure (see figure):

1. The full-potential transonic-rotor-flow equations are solved by the TFAR2 code, and the lift, drag, and moment on each section of the blade are calculated.
2. The aerodynamic forces are converted to the corresponding forces at the end nodes of the elements by applying the shape functions and using Gauss integration.
3. The equation of the structural dynamics is rotated from the local to the global coordinate system and integrated in the time domain by Newmark's method (an extension of the linear-acceleration method) to obtain the displacements of the end nodes of the elements.
4. The deformation of the blade is read into TFAR2, and a new grid system with new surface boundary conditions is generated for the next step in the aerodynamical calculations.

Steps 1 through 4 are repeated until the desired conditions are reached.

The aeroelasticity analysis was performed on an experimental helicopter rotor. The structural portion was evaluated by comparing the computed natural vibrational frequencies of the blade with experimental data. In general, the correlation was found to be good for most of the four types of modes. The coupled aerodynamical and structural codes were used to study the aeroelastic effect in the transonic regime in both hover and forward flight. According to the numerical results, the effect of elasticity in hover is not as important as it is in forward flight. But in forward flight, even at a low advance ratio, the blade elastic response due to unsteady aerodynamic forces is significant, and it is necessary to take elasticity into account to obtain accurate predictions of flow.

This work was done by I-Chung Chang of **Ames Research Center** *and Lie-Mine Gea and Chuen-Yen Chow of the University of Colorado. For further information, Circle 80 on the TSP Request Card.*
ARC-12550

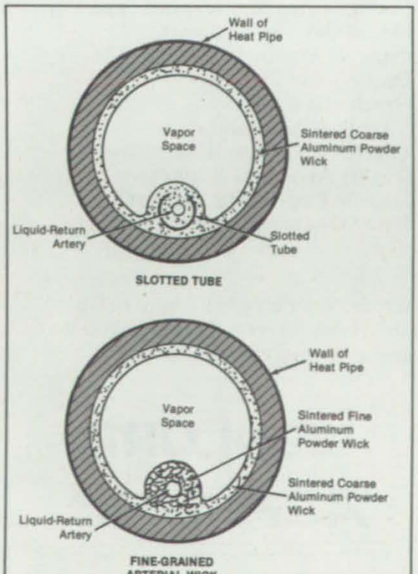
Vapor-Resistant Heat-Pipe Artery

New features of the wick improve the return of liquid in a heat pipe.

Lyndon B. Johnson Space Center, Houston, Texas

Vapor lock in a heat pipe can be delayed or prevented by modification of the liquid-return artery. In vapor lock, vapor generated in the wick penetrates the artery. Vapor lock prevents liquid from moving along the artery and thus stops the transfer of heat along the heat pipe.

Two anti-vapor-lock modifications have been developed and tested (see figure). In one, a fine-grained aluminum powder is sintered to form the portion of the wick that surrounds the artery; a coarse-grained sintered aluminium powder constitutes the rest of the wick, which lines the wall of the heat pipe. The fine-grained portion of the wick allows condensed liquid, but not much vapor, to pass through to the artery.



Modifications of the Wick prevent the flow of vapor into, or the formation of vapor in, the liquid-return artery. The small pores of the fine-grained sintered wick help to prevent the formation of large bubbles. The slotted tube offers few nucleation sites for bubbles.

In the other modification, a slotted tube is placed around the artery within the wick. Condensed liquid can pass through the slot to the artery. The smooth inside surface of the tube, unlike the rough, porous interior of the wick, offers few sites for the nucleation of bubbles. Thus, a larger temperature drop is required before nucleate boiling — and, hence, the formation of appreciable amounts of vapor — can begin.

This work was done by Peter M. Dussinger, Robert M. Shaubach, and Matt Buchko of Thermacore, Inc., for **Johnson Space Center**. *No further documentation is available.*

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

Peter M. Dusinger
Thermacore, Inc.
780 Eden Road
Lancaster, PA 17601

Refer to MSC-21492, volume and number of this NASA Tech Briefs *issue, and the page number.*

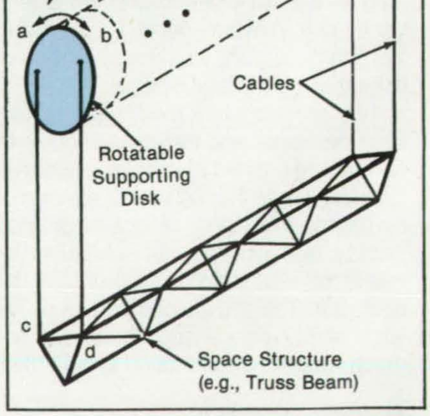
Low-Frequency Suspension System for Large Space Structures

A simple system enables vibration testing of space structures on the ground.

Langley Research Center, Hampton, Virginia

Large, lightweight space structures are designed for operation in a weightless environment, yet must be tested in facilities on the ground under the influence of gravitation. Such structures are generally too frail to support their own weights on Earth. Therefore, to determine experimentally the shapes, frequencies, and damping parameters of the vibrational modes of a structure in a test facility on the ground, it is necessary to suspend the structure in a manner that not only allows freedom of motion similar to that found in outer space but that also relieves those stresses within the structure that are due to the weight of the structure itself.

The suspension system must support the structure and allow freedom of motion without distorting the natural vibrational modes of the structure. Therefore, the vibrational modes of the suspension system must be uncoupled from those of the structure. Large truss-type structures typically have extremely low natural frequencies — often below 0.5 Hz. For adequate



Disk and Cable Adjustments would lower the frequency of oscillatory motion of the suspension system to enable accurate measurements of frequencies of vibration of the space structure.

uncoupling of the vibrational modes of the suspension system from the fundamental vibrational modes attributable to the flexibility of the structure, the modes of the suspension system should have frequencies substantially lower than that of the first fundamental mode of the structure.

The suspension of a structure from long cables in pendulum fashion allows the structure to move in one plane. However, to obtain the required extremely low frequencies, one must make a simple pendulum suspension prohibitively long. In addition, suspension from fixed cables can significantly affect the torsional vibrational modes of the structure. To allow torsional freedom of motion for a space structure undergoing ground testing, a low-frequency torsional suspension system has been designed. This concept involves a plurality of suspension stations attached to the space structure along its length to suspend it from an overhead support.

The suspension system (see figure) would include a number of suspension stations attached by cables to a space structure (such as a truss beam) along its length. The suspension stations would be fixed to a ceiling or other rigid support. Although only the end stations are illustrated in the figure, a sufficient number of additional suspension stations would be placed between the end stations. The exact number of stations would depend on the length and strength of the space structure to be tested.

The system is designed to alleviate the coupling between the suspension system and the torsional vibrational modes of the structure. To accomplish this, each station would include two cables of the same length and a rotatable supporting disk. The cables and disk would act together to lower the frequency of the torsional vibrational or rotational mode of the suspension system. It is desirable to keep the fundamental natural frequency of the system significantly lower than the lowest structural frequency, which, for one 60-m test mast beam, was found to be 0.18 Hz.

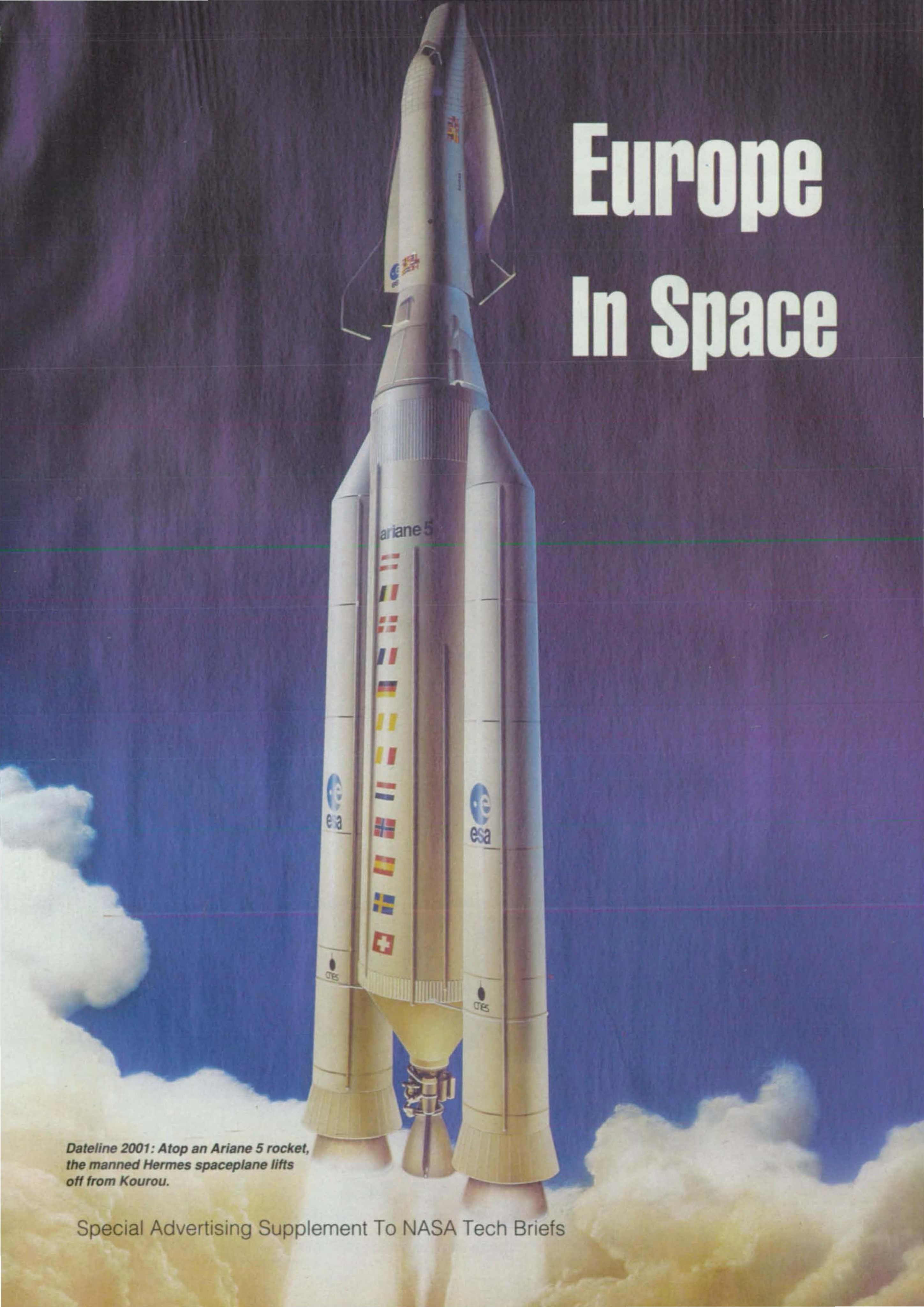
The disk would be free to rotate about a horizontal axis. The cables would be arranged to form a parallelogram, *abcd*, such that at rest, the center of gravity of the beam would hang directly below the axis of rotation of the disk. The system would have two uncoupled natural pendulum modes: one would be the simple pendulum mode; the other would be the torsion or compound pendulum mode involving rotation of the suspended body about its own center of gravity. The vertical distance between the points of attachment of the cables to the disk and the axis of rotation of the disk is adjusted to lower the frequency of the suspension system to a level at which the motions of the suspension system do not interfere with the motions of the space structure, thereby enabling accurate measurements.

The torsion suspension system could be combined with suspension systems designed according to other concepts to provide lateral and vertical translation of the test structure. In addition, the dynamic characteristics of such systems could be improved further through the use of active-feedback-control techniques. The torsion suspension system could be combined with a lateral pendulum suspension system that included an active feedback control system. This arrangement would lower the frequency of the pendulum by controlling lateral motion of the suspension point, increasing the effective length of the cables. Active feedback control in the vertical degree of freedom would also augment the dynamic characteristics of the vertical mode.

This work was done by Wilmer H. Reed III and Ronald R. Gold of Dynamic Engineering, Inc., for **Langley Research Center**. *For further information, Circle 77 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 14]. Refer to LAR-14149.

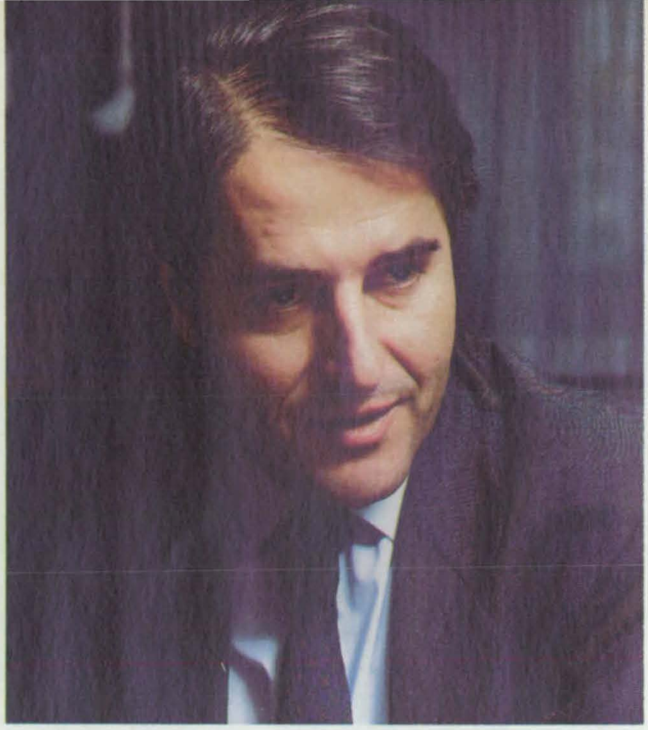
Europe In Space



Dateline 2001: Atop an Ariane 5 rocket, the manned Hermes spaceplane lifts off from Kourou.

Special Advertising Supplement To NASA Tech Briefs

Foreword



Jean-Marie Luton, ESA director general

I am very pleased to have this opportunity to address the readers of *NASA Tech Briefs* as a result of the editors' initiative in publishing a special section on European space activities.

If today Europe is able to participate with equal status on the international stage in space exploration, it is thanks to many people working together in government, industry, universities, and space organizations. Many of Europe's successes in the exploration and exploitation of space have been the result of collaborative ventures, some of which have been undertaken with the United States. These include scientific projects such as COS-B, Exosat, Giotto, Hipparcos, the Hubble Space Telescope, and the recently launched Ulysses sun probe. Such joint programs as Ariane, Spacelab, Meteosat, and the European communication satellites are important symbols of Europe's technical capacity and political will. The all-weather satellite ERS-1, scheduled for launch this spring, and the follow-on mission ERS-2, will provide a new perspective for better understanding and monitoring the Earth and its environment.

This is an important year for the European space effort. The European Space Agency's member states are faced with the decision of whether or not to move from the preparatory stage to the development phase of two of the agency's key programs: the Hermes spaceplane and Columbus, Europe's contribution to space station Freedom. With the exception of the Ariane program, the ESA has never before been confronted with projects of this dimension.

There is no doubt that the future of Europe—its industrial performance and its political standing—is closely linked with technological innovation. The challenge of developing a vigorous and strong European space program will take considerable political will and a firm belief by our governments that long-term benefits can accrue from such a commitment.

But the success of our efforts in space research and technology also depends on many other factors, in particular the close cooperation between the scientific and industrial communities participating in these joint undertakings of common European interest.

I believe Europe's future in space will be measured by our ability to cooperate. The challenge ahead of us can only be met with a common European effort, and cooperation on a worldwide basis. I am convinced Europe possesses all the resources and talent necessary to move forward in the exciting adventure of space.

NASA Tech Briefs performs a valuable service in demonstrating the impact of space technology on our daily lives. I hope that this special section will give its readers a new view of the magnificent ventures in which the ESA and its member states are involved.

Jean-Marie Luton
director general
European Space Agency

Ulysses, a joint ESA-NASA project, will explore the sun's polar regions beginning in 1995.

Europe, A Major And Independent Space Power

Europe is ranked third among leading space powers, following the USA and USSR. Initiated a quarter century ago at a rather modest pace by its four major industrialized countries, the European space effort has worked towards more ambitious space ventures since 1975, when its resources were pooled to form a single cooperative body, the European Space Agency (ESA).

The ESA currently has 13 member states: Austria, Belgium, Denmark, France, Germany, Ireland, Italy, the Netherlands, Norway, Spain, Sweden, Switzerland, and the United Kingdom. Finland is an associate member, and the agency has a cooperative agreement with Canada. The ESA's three largest shareholders, by the magnitude of their contribution, are: France (25%), Germany (20%), and Italy (15%). Together they provide nearly two-thirds of the agency's resources.

The ESA's 1991 budget is more than 2.4 billion Accounting Units (AU) or ECU, or nearly $3 billion. Europe's space spending is thus one-tenth of the combined expenditures of the US Department of Defense and NASA. It must be remembered, however, that Europe has no defense space program as yet, except for limited military and government systems such as the Syracuse and Helios communication and observation satellites in France and the Skynet communication satellites in the UK. Italy is still contemplating building its own Sicral communication satellite system.

The Europeans are still able to rival major-power efforts with varied and less expensive systems in the fields of science, microgravity, technology, communications, meteorology, and remote sensing. Over the last two decades, Europe has successfully launched dozens of satellites and achieved important cooperative ventures with the USA and USSR.

Photo courtesy ESA

Artist's conception of a test launch of the Hermes spaceplane from Kourou in the year 2000.

Through the ESA, Europe has been especially successful in developing scientific and application satellites. The latter are operated by European user organizations. ECS and MARECS communication satellites, for example, have been handed over to Eutelsat and Inmarsat, and the Meteosat weather spacecraft are now operated by Eumetsat.

The most well-known achievement in this field, however, is the Ariane family of European launchers developed by the ESA. Ariane is marketed and operated by Arianespace, the first private space transportation company, which has captured more than half of the worldwide commercial launch market.

Europe is now engaged in more ambitious and costly ventures such as developing the Columbus space station, the Hermes reusable spaceplane, and the Ariane 5 heavy-lift launcher. This triad is the centerpiece of Europe's effort to achieve an independent and autonomous capability in manned space flight by the turn of the century.

Also Read NASA Tech Briefs' *July 1990 Report*

As most European space organizations mentioned in this report have already been spotlighted in a special section published last July (NTB vol. 14, No. 7), we will not provide background on them now, except for those appearing here for the first time. This report instead will concentrate on current and planned activities by European firms and agencies. For more information on the organizations mentioned in these pages, please read the special report on European space activities in the July 1990 issue of NASA Tech Briefs.

2001: Europe's Manned Space Odyssey

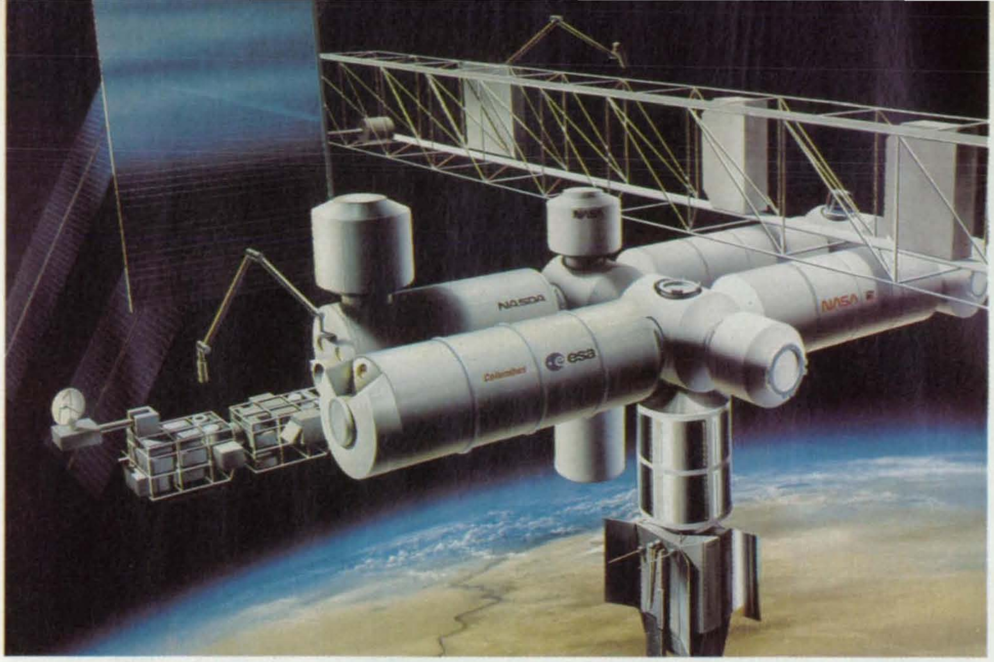


Photo courtesy ESA

Europe's Columbus laboratory will be permanently attached to space station Freedom.

This fall, European ministers will make a crucial decision concerning the ESA's involvement in manned space activities. Ministers from the 13 member states participating in the manned spaceplane and space station programs will have to give the go-ahead for the full development of Hermes and Columbus, and the associated data-relay satellite (DRS) systems.

The heavy-lift rocket Ariane 5 is the only major new element of Europe's long-term space plan engaged since the last ministerial council of ESA was held at the Hague in November 1987. The next meeting is scheduled for Germany in October or November. The objective is to begin full development (phase two) of both Columbus and Hermes in early 1992, if it has been demonstrated to the ministers' satisfaction that both programs are technically feasible within the budget defined in 1987.

The ESA is committed to building a man-tended free-flying laboratory and pressurized module (similar to Spacelab) which will be permanently attached to space station Freedom. Both facilities are primarily dedicated to materials and life sciences research under microgravity conditions.

The Hermes reusable spaceplane, similar to but smaller than the space shuttle, is designed to carry up to three astronauts and 3 tons of payload in low-Earth orbit for autonomous missions or for servicing manned stations flying at 450 km. Hermes will be launched by the manned version of Ariane 5. As the successor of Ariane 4, the heavy-lift rocket is mainly designed for launching commercial satellites in geostationary or polar orbits. The schedule for the heavy-lift vehicle remains unchanged, with two qualification flights planned for 1995.

Earlier this year, the ESA suggested a slowdown in the development of Columbus and Hermes in order to ease budgetary constraints.

ESA's new strategy for manned space programs was unveiled last February at a special council meeting held in Santa Margherita, Italy. A revised version of the European long-term space plan was submitted to member states by Jean-Marie Luton, ESA's new director general. The updated scenario addresses annual funding problems by extending by two or three years the development phases of Columbus and Hermes.

The Attached Pressurized Module, fully dependent on Freedom, is now planned for launch in 1998, while the man-tended free-flyer (MTFF) has been postponed until 2001. Hermes' first unmanned flight is now planned for 2000, and the manned flight for 2001. Delaying Hermes and the MTFF until the turn of the century will save 10.4% or 3.2 billion ECU, thus reducing the overall funding request for the long-term plan to nearly $36 billion (1986 dollars) or 30 billion ECU. But this postpones Europe's manned space odyssey until 2001.

The first flight of the European Polar Platform is still scheduled for 1997. Called Poem-1, the mission will cover meteorology and climatology. A second polar bird with the same instrumentation will follow in 2002. Each huge platform, derived from the Spot satellite system, will weigh 8 tons and carry up to 2.4 tons of payload. A third model will be equipped with a high-resolution (5 meter) optical camera and an advanced synthetic aperture radar (SAR), and will observe and monitor the Earth continuously starting in 2000.

It will succeed the first European radar-observation satellites, ERS 1 and 2, slated for launch by Ariane in 1991 and 1994. Each 2.5-ton satellite will have the same set of five microwave sensors, allowing unprecedented measurements over land, sea, and ice to better understand interactions between the Earth's atmosphere and oceans. Their equipment will include a wind scatterometer, a radar-altimeter, and a high-resolution (30 m) SAR working at 5.3 GHz. Costing $1.4 billion, the ERS spacecraft will be the first civil radar satellites launched in the west since Seasat in 1978.

Eureca, the largest autonomous

Photo courtesy ESA

ESA's Huygens probe will be launched towards Titan by the NASA-built Cassini spacecraft.

satellite ever built in Europe, is planned for launch aboard the shuttle in 1992. It weighs 4.5 tons, including the payload for life and material sciences in zero gravity. Further experiments in microgravity will be conducted on Spacelab by European astronauts. ESA invested $1 billion developing the laboratory, which was subsequently given to NASA.

In a cooperative venture with NASA, a solid-Earth research satellite called Aristoteles is planned for launch in 1997 by a Delta 2 rocket. It will carry a high-resolution gradiometer for measuring the fine structure of the Earth's gravity fields and a magnetometer to map its magnetic field.

Previous successful ESA scientific missions include the Hipparcos astronomy satellite and the fly-by of comet Halley by Giotto, which is now on a path to encounter comet Grigg-Skjellerup in July 1992. The next milestone will be the Jupiter gravity-assist designed to bounce the Ulysses probe out of the ecliptic plane and swing it into an orbit over the sun's poles in 1995.

Other missions include Cluster and Huygens. Four Clusters will be launched by Ariane 5 in 1995. The European probe Huygens will be dropped on Titan by the Cassini Saturn orbiter. ESA is also preparing a new set of astrophysical observatories, including the ISO infrared telescope scheduled for launch in 1993, the XMM x-ray mission of 1998, and a far-infrared facility called FIRST.

As a follow-on to the Olympus 1 communication satellite launched two years ago, the ESA is developing Artemis, an experimental satellite for testing land mobile and optical intersatellite links. The $600 million spacecraft is slated for launch in 1995, and will be the forerunner of the DRS, now scheduled for operation in 1998-99.

All of these satellites and space vehicles incorporate advanced technologies mastered in Europe. The ESA is spending $140 million annually to develop high-tech computers and software systems, lightweight and deployable structures, robotic mechanisms, optical systems, thermal and attitude controls, orbital propulsion and energy storage systems, and other advanced technologies. The agency is also preparing a unique catalog containing over 50 transferable European space technologies.

CNES Develops And Markets French High Technology For Space

Photo courtesy ESA
The Ariane 5 rocket will be able to loft 21 tons of payload into low-Earth orbit.

CNES, the Centre National d'Etudes Spatiales, is the government agency charged with developing and managing the French space program, including participation in the ESA and cooperative agreements, mainly with the USA and USSR.

The French space agency is nearly 30 years old. Late last year, it celebrated the 25th anniversary of the launch of the first French satellite, Asterix, from Hammaguir (Algerian Sahara) by the first French rocket, Diamant A. Since then, France has launched several domestic satellites and the Diamant program provided the technological know-how for developing the Ariane rocket.

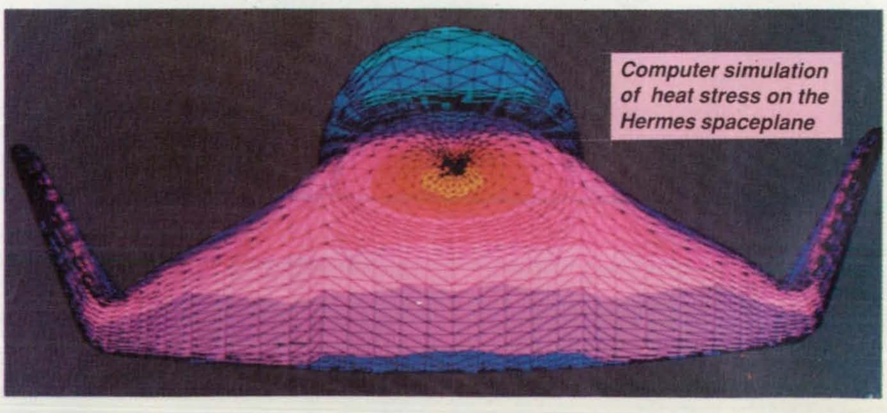
Over the past three decades, France has been the most prominent force in promoting and building the European space program. It is responsible, for example, for the Meteosat weather satellite system, the Ariane family of launchers, and the Hermes spaceplane.

Nearly half of France's space budget is invested in the European program. Besides managing the development of Ariane 5 and Hermes, France is participating in European application and scientific satellite projects such as Soho and Cluster. It is also building the ISO infrared astronomy observatory for the ESA. For the United States, it provided the data collection equipment carried on NOAA polar satellites and the radar-altimeter for the Topex oceanographic satellite planned for launch by Ariane in mid-1992.

In addition, France is participating in several scientific projects with the Soviet Union, including Interball and Mars 94. For the latter project, CNES is providing balloons to be deployed on the Red Planet in 1994. It is also building scientific instruments such as Scarab and Alissa which will fly this year on Soviet satellites and the Mir space station. A ten-year agreement has been signed with the Soviet Union to conduct manned space operations on board Mir. French astronaut Jean-Loup Chretien participated in missions in 1982 and 1988. The next flight of a French astronaut on Mir is planned for the summer of 1992.

CNES was among the original promoters of the Sarsat-Cospas international search and rescue system developed and operated in cooperation with the USA and USSR. Since 1985, the satellite system has saved more than 1500 lives.

Communication and observation satellites make up the lion's share of France's national space program. CNES is responsible for the Spot remote sensing satellites and communication satellites such as Telecom 1



Computer simulation of heat stress on the Hermes spaceplane

Photo courtesy Dassault Aviation

and 2 and TDF 1 and 2 operated, respectively, by France Telecom and Telediffusion de France (TDF). Presently, the French space agency is developing Locstar, the first European radiodetermination system.

CNES has established a series of industrial and trade subsidiaries to promote and manage commercial developments of space. Over the last decade, CNES has established 15 subsidiaries, including Arianespace, Novespace, Prospace, Intespace, Locstar, Spot Image, Sat Control, Scot Conseil, Satel Conseil, CLS, and GDTA. Together, they employ more than 700 workers. Last year, they achieved an overall turnover of more than $675 million.

Two of these subsidiaries are among the world's most successful commercial space ventures. Arianespace, the first space transportation company, has captured more than half of the global launch market for commercial satellites and 80 percent of operators worldwide, while Spot Image has achieved an outstanding record in selling remote sensing data throughout the world, including the United States through its subsidiary Spot Image Corp. (SICorp). Based in Washington, DC, SICorp has become a regular source of data for a growing number of private and government customers in the USA. Globally, Spot Image has captured half the market for optical remote sensing satellite data, with the other half being held by Eosat Corp. of the United States.

Novespace, one of the newest subsidiaries, managed by Jean-Pierre Fouquet, is involved in both technology transfer and the microgravity business. The company has successfully introduced and commercialized parabolic flights using the Caravelle "Zero G." Its customer list includes industrial and scientific users thoughout Europe and Japan.

In 1991, CNES has received more than $1.7 billion to conduct domestic and cooperative ventures. This is approximately 0.2 percent of France's gross national product. Nearly 15,000 skilled people are working for the French space program, mainly in national or multinational aerospace companies such as Aerospatiale, Alcatel Espace, Arianespace, Dassault, Matra Marconi Space, Novespace, Sextant Avionics, Spot Image, SNPE, and SEP.

CNES has a highly-skilled 2400-member team headed by Jacques-Louis Lions as chairman and Jean-Daniel Levi as director general. Headquartered in Paris, CNES has several sites throughout France. The directorate for space transportation is based in Evry, on the outskirts of the capital, while its technical center is in Toulouse, the French "aerospace valley." A balloon launch facility is located at Aire/Adour in the southwest. CNES also operates the Centre Spatial Guyanais, the launch base for Arianes. Located only five degrees from the Equator, the European spaceport is the best-situated rocket launching facility in the world.

Aerospatiale: Creating Advanced Technology For Satellites And Rockets

Aerospatiale, one of Europe's major aerospace manufacturers, offers a diverse range of products for the international market, including civil aircraft, civil and military helicopters, tactical and ballistic missiles, space launchers, and satellites. Its Strategic and Space Division employs nearly 6000 people and last year achieved sales of $1.4 billion, a growth of 12.5 percent. Aerospatiale represents an even larger work force when its association with Alcatel Espace of France, Alenia of Italy, and Loral Space Systems of the USA is taken into account. Earlier this year, Aerospatiale and Alcatel Espace won a contract to build and launch two Turkish communication satellites, the first of which is scheduled for a 1993 launch. Part of the $300 million contract calls for the construction of a control center, including a tracking station. The same team—along with Marconi Space Systems, Aeritalia, and other aerospace firms —previously won a $395 million contract to manufacture six Eutelsat 2 satellites. Two are in orbit and a third is planned for launch in August by an Atlas rocket from Cape Canaveral, Florida. Aerospatiale and Alcatel Espace are now competing for the Europesat series of European direct broadcasting satellites.

Photo courtesy Aerospatiale

Three-dimensional manufacturing of Hermes' carbon-carbon fiber nose at Aerospatiale

Over the past quarter century, Aerospatiale has built more than 60 scientific and application satellites for French, European, and foreign customers. Forty percent of Europe's civil satellites have been developed under its prime contractorship. The company is presently building the Meteosat series of European geostationary weather satellites and is participating in design studies of the second generation Meteosats for ESA. The fifth operational Meteosat was launched in March and the sixth and final one will be orbited in September 1993. The same year, Helios, the first French military observation satellite, will be launched. Its high-resolution camera was designed and built by Aerospatiale.

Another current program is the Infrared Space Observatory (ISO), slated for launch by an Ariane in 1993. The 2.4-ton observatory will be equipped with a 60-centimeter aperture telescope installed inside a large cryostat cooled by liquid helium. Aerospatiale is manufacturing the ISO telescope and one of its cameras as part of a $260 million contract.

The company has also received a research contract from the Eureka organization to develop a large lightweight metallic mirror for the LAMA optical observatory, and will build the Huygens probe which will study Titan.

As Europe's leader in the space transportation field, Aerospatiale is the industrial architect for all versions of the Ariane launcher, from the original Ariane 1 to the new Ariane 4. To date, 99 Ariane 4 rockets have been ordered by Arianespace for missions into the late 1990s.

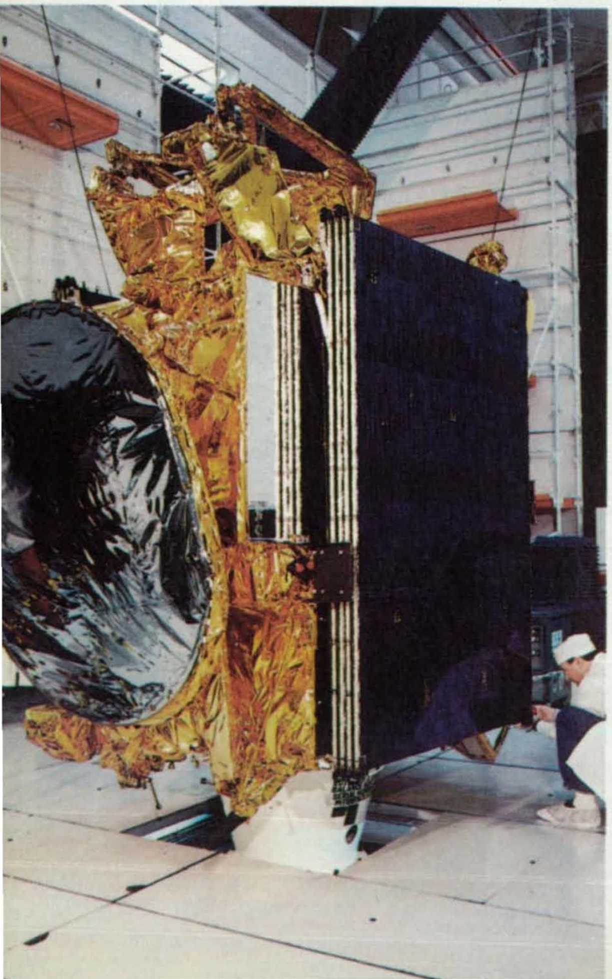
Aerospatiale's three main responsibilities are technical management of the program, system engineering, and integration of Ariane's elements. The company develops the three stages, boosters, and fairings in cooperation with leading European companies such as British Aerospace, Matra Marconi Space, Contraves, SEP, BPD, and ETCA. It also manufactures carbon-fiber payload adapters and other components.

Aerospatiale is playing the same role of industrial architect and stage contractor for Ariane 5, the largest rocket ever built in Europe. The company is conducting design studies, program management and planning, and system testing and checkout. It is also in charge of the two main stages: the solid boosters and the main cryogenic stage.

The tank has impressive dimensions: 100 feet tall and nearly 18 feet in diameter. It weighs 12.5 tons and contains 155 tons of liquid cryogenic propellant. It is composed of aluminum alloy panels which are welded by two giant machines and then pressure-tested in a 98-foot-deep well.

This facility is part of the Ariane 5 integration building recently erected at Les Mureaux. It stands alongside the Seine river, allowing the stages to be loaded on barges and taken to Le Havre, then transferred onto the SS Ariana to cross the Atlantic to Cayenne (French Guiana). Built at a cost of $60 million, the 65,500 square foot integration facility will produce eight cryogenic stages per year starting in 1996, when Ariane 5 becomes operational.

Photo courtesy Aerospatiale



Aerospatiale is prime contractor for the Eutelsat 2 satellites.

The fifth-generation rocket is based upon an entirely new design. It features a main stage fitted with one cryogenic engine flanked by two large strap-on boosters filled with 250 tons of solid propellant. Planned for use until 2015, Ariane 5 will be able to launch one or more satellites representing a total mass of 6.9 tons into geostationary transfer orbit; a Columbus space station module of 18 tons; or the Hermes spaceplane at 23 tons.

More powerful versions of Ariane with recoverable elements are anticipated for the future. On the drawing board are an Ariane 6 with four solid boosters and an Ariane 7 featuring several Vulcain cryogenic engines on its first stage. Changes may also be made to the upper section, according to Aerospatiale officials, with storable propellant propulsion replaced by cryogenics. The company also envisions reusable rocket stages and boosters equipped with air-breathing engines.

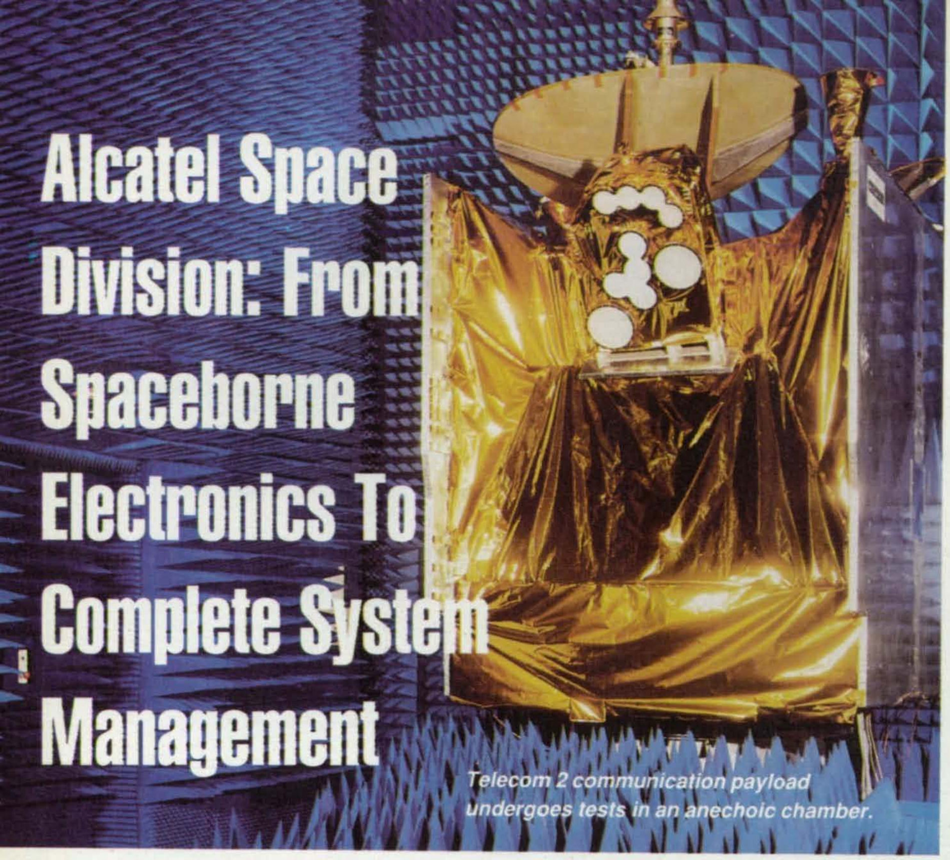
Regarding Hermes, significant changes have been made in the program structure to increase the efficiency and coherence of the management before entering the development phase early next year. Four leading European aerospace companies—Aerospatiale and Dassault Aviation of France, Deutsche Aerospace of Germany, and Alenia of Italy—have formed a fully-integrated prime contractor team called Euro-Hermespace. The same has been done at the agency level by forming an ESA-CNES program team.

The program report was delivered to managing agencies last March. The document describes the technical definition of the chosen configuration, called Hermes Stage 1. It is the reference configuration for the industrial proposal and the development program. The spaceplane layout has been optimized by moving the center of gravity forward to balance the craft for atmospheric reentry, and by improving the aerodynamic shape through computational fluid dynamics (CFD). "We now have a sound basis on which to proceed with the project," says Jorg Feustel-Buechl, director of space transportation systems for the ESA.

Hermes is being designed for launch by an Ariane 5 from Kourou and will join the Columbus space station in low-Earth orbit at an altitude of about 450 km with an inclination of 28.5°. The spaceplane will be manned by a crew of three astronauts including two pilots, and will carry a payload of about 3 tons. The European shuttle will be able to remain docked to the man-tended free-flyer for one week. It will then reenter the atmosphere at hypersonic speed and land on a runway in Korou. Two flights a year are planned after 2001 to service the MTFF.

Aerospatiale also has a $240,000 contract to study an automated logistics vehicle for carrying payloads to a future European space station. Called LoVe, the vehicle is to be launched by an Ariane 5. The study is being performed by a team consisting of Aerospatiale, British Aerospace, and Space Applications Services of Belgium.

Alcatel Space Division: From Spaceborne Electronics To Complete System Management



Telecom 2 communication payload undergoes tests in an anechoic chamber.

Photo courtesy Alcatel Espace

The Alcatel Space Division (ASD), part of the Alcatel Radio Space and Defense Group, began operation this year. It is the most diverse multinational space group in Europe, incorporating seven companies in six European countries, with a total work force of 2000. The division controls space subsidiaries in France, Belgium, Denmark, Germany, Norway, and Spain. Chairman Jean-Claude Husson is assisted by Alain Roger, vice president of international business development, and Pierre de Bayser, executive director. Mr. Husson also serves as director general of the division's largest body, Alcatel Espace of France. Its deputy, Bernard Deloffre, was recently recruited from Aerospatiale.

Deloffre's transfer illustrates the close relationship between Alcatel's Space Division and Aerospatiale. Together they have won important contracts for communication satellite systems. The duo recently received a $375 million contract to deliver into orbit the first two Turksats and to build a Turkish scientific spacecraft.

They also won a $1 billion contract to build six Eutelsat 2s—the largest contract ever awarded in Europe. ASD provides antennas, telemetry and command, and transponder elements for the Eutelsat 2s, while Aerospatiale is responsible for the Spacebus platform.

ASD, Aerospatiale, and Alenia of Italy have taken a 49 percent interest in Space Systems/Loral (formerly Ford Aerospace). The four-member team will be challenging Hughes Aircraft, the world leader in satellite manufacturing. ASD is part of the management team set up by Space Systems/Loral to manufacture seven Intelsat communication satellites. With Alenia, it is building the ESA's Artemis experimental communication satellite.

Alcatel Espace, the division's largest member, has a staff of 1300 and sales approaching 250 MECU. It works exclusively on space projects, enabling it to achieve a high level of technology expertise and competitiveness in spaceborne systems and payloads for communication, observation, and scientific missions. The French firm is mastering antenna techniques in the 2 to 90 GHz range. Its "savoir-faire" extends from corrugated horns to multi-source antennas for shaped beam coverage and dual-grid reflectors for frequency reuse in the Ku-band. It supplies all the antennas for Telecom 2 satellites, including an X-band steerable spot-beam antenna dedicated to military communications.

Alcatel Espace has 20 years experience in supplying spaceborne microwave receivers in frequency bands ranging from L through Ku. It has delivered 200 receivers for European and foreign satellites, including NASA's Tracking and Data Relay Satellite System, and has produced microwave filters and solid-state power amplifiers from 6 to 20 w, as well as broadband high-gain amplifiers featuring bare-chip microwave hybrid-circuit technology at 12 GHz.

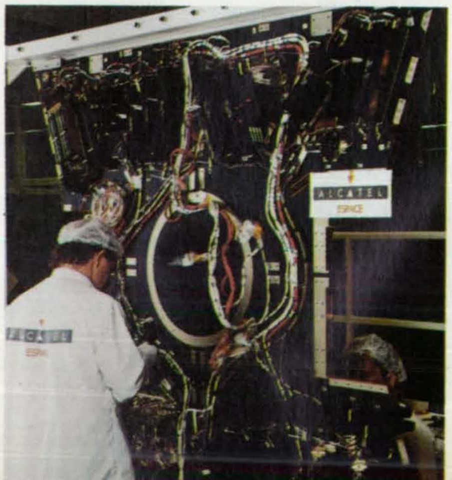
The company also specializes in telemetry, command, and ranging subsystems, including S-band transponders, 1.4 GHz receivers, and 4-12 GHz transmitters. It has equipped several deep space probes, including Giotto and Ulysses, as well as communication spacecraft such as Telecom 2, TDF, and TV-SAT. Moreover, it has developed high-rate image telemetry systems for the Spot and Helios observation satellites.

Expert in fast signal processing, Alcatel Espace designed and manufactured the intermediate frequency stages of ERS' synthetic aperture radar. And it recently delivered the complete microwave instrumentation for the Poseidon radar-altimeter to be carried on the Topex satellite built by Fairchild Space. The company is now developing an experimental communication payload for the interorbital radio-link to be tested with the European Eureca platform planned for launch by the space shuttle in 1992.

Alcatel Espace can design, develop, manufacture, and manage complete communication satellite systems—including space and ground segments—for either civil or military applications, as demonstrated by its success in building the Syracuse system for the French Ministry of Defense in the 1980s. This system will be upgraded starting with the first Telecom 2 satellite, planned for launch by an Ariane this November. Alcatel Espace is also investing in studies of potential satellite systems for observing and monitoring the disarmament in Europe.

Alcatel Espace technicians integrate the communication payload of a Telecom 2 satellite in Toulouse.

Photo courtesy Alcatel Espace



Over 80 Percent Of World's Commercial Satellite Operators Are Flying Arianespace

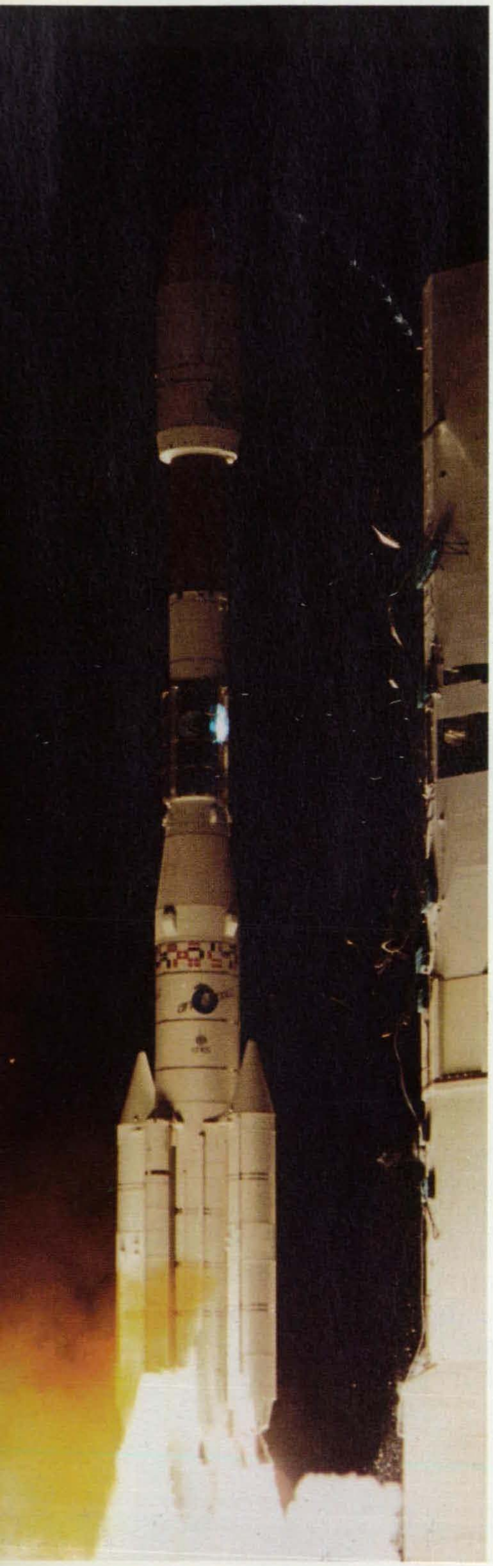


Photo courtesy Arianespace

Night launch of Ariane V42 carrying the Astra 1B and Meteosat MOP 2

The fiftieth Ariane rocket will be launched early next year according to the current launch manifest issued by Arianespace, the world's leading commercial space transportation company. This year and next, the European rocket company plans nine launches of its Ariane 4 liquid-propellant rocket. Three rockets have been launched since the beginning of the year. The next flight will carry the first European radar-observation satellite, ERS-1, and the following flight will transport an Intelsat 6 communication satellite built by Hughes Aircraft. It will be launched by the Ariane 44L, the most powerful version of the European rocket, which is fitted with four liquid strap-on boosters.

Arianespace has orbited 44 satellites in the last 44 months. "It's a world record," says Charles Bigot, the new company chairman. He succeeded Frederic d'Allest, founder and first chairman of the European launch consortium, in 1990 shortly after Arianespace celebrated its tenth anniversary.

Since its inception in March 1980, the company has booked 92 satellite launch contracts. Arianespace has 34 satellites contracted for launch in coming years, collectively worth more than $2.6 billion. Today, over 80 percent of the world's commercial satellite operators fly Arianespace and its European workhorse, Ariane 4.

Industry has ordered a total of 99 Ariane rockets, including a single batch of 50 Ariane 4s worth about $3.4 billion —the single largest order of commercial rockets ever placed in Europe. Last year, the company's net sales amounted to $660 million and its net profit after taxes was $22 million. Although Arianespace's in-house staff numbers only 275, there are 12,000 people working on the Ariane program throughout Europe.

For the coming decade, Arianespace forecasts limited market growth averaging 20 satellites per year worldwide, excluding the USSR. Patrice Larcher, Arianespace marketing manager, expects the launch rate to increase in coming years to re-equip American networks and replace communication satellites for international organizations such as Intelsat, Inmarsat, Eutelsat, and Panamsat. Larcher believes that "the market will be very steady until 1993-94." After 1994, he expects launch rates to dip as the size and weight of satellites grow significantly.

Future communication satellites will be different from today's spacecraft, Larcher explains. They will feature operational lifetimes of 14-16 years, instead of the current norm of 10-12 years, as well as a four-fold increase in circuit capacity, to over 100,000 circuits.

Tomorrow's communication satellites will also be heavier. Within five years, the average mass of world communication satellites will increase two-fold, from 1.2 to 2.4 tons. But the heaviest satellites—such as Telstar 4 and Intelsat 6, 7, and 8—will represent only five percent of the market.

Arianespace is anticipating further increases in the annual accumulated launch weight of commercial satellites, from 40 tons in 1991 to 50 tons in 1993. They predict that within the next decade the total launch mass will rise to nearly 60 tons per year.

In order to maintain its market share and leadership, Arianespace is aggressively pursuing new customers abroad, particularly in the Americas, the Middle East, and Asia. The firm's objective is to keep at least 50 percent of the world commercial launch market, despite its evolution.

Arianespace officials are confident that Ariane 4 will be able to handle the growing mass of commercial satellites for the next five years. The company will then shift to the more powerful Ariane 5 heavy-lift rocket, which is expected to be operational in 1996. Ariane 5 will allow dual launches from Kourou of satellites weighing 2.6 tons each, or single launches of payloads up to 6.8 tons into geostationary transfer orbit. The rocket also will be able to launch recoverable capsules, space station elements such as Columbus, and the Hermes spaceplane.

Austria's Space Program Waltzes To A High-Tech Tune

Austria is developing life support equipment for the Hermes spaceplane. Photo courtesy ESA

Austria has produced some of the world's greatest composers, including Mozart, Strauss, Haydn, and Schubert. But music is not the country's only quality product.

Today, Austria's industry is engaged in research and development of space technologies in the framework of the ESA. Twenty highly-specialized firms are competing for services and product development contracts within the ESA's scientific, communication, Earth observation, Ariane 5, and Hermes programs. Together they have formed the Association of Austrian Aerospace Companies, known as Austrospace.

For more than a decade, Austrian companies and research institutes have participated in the ESA telecommunication program, including the construction of Olympus, the largest communication satellite ever built in Europe. Austria specializes in the development of flight hardware, ground terminals, and software. Austrian universities and institutes have simulated the distance between the Earth and a communication satellite, and the influence of the atmosphere and weather on communication quality in the high-frequency area, thereby providing basic research necessary to develop future commercial systems.

Austria's space industry is active in the development of European scientific spacecraft, including the ISO infrared telescope. The Austrian company ORS has produced and delivered a large mechanical sun shield designed to protect the delicate infrared sensor and its helium tank. The shield's support structure was developed by ORS and manufactured by Advanced Composites Technologies (ACT).

ORS is providing the thermal insulation system, mechanical ground support equipment, and structural elements for the Soho and Cluster scientific satellites. A significant part of the electrical ground support equipment is being produced by Schrack Aerospace. Schrack and the Vienna Technical University are fabricating a laser intersatellite link for future communication satellites.

In Graz, the Joanneum Research Institute has developed a videoconference system which links up to four groups in different countries via satellite. And Schrack has developed terminals for "satellite telephone" systems similar to those demonstrated so impressively during the Gulf war by Peter Arnett of CNN.

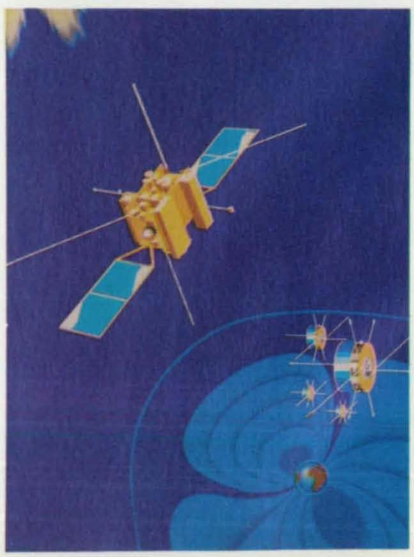
Earth observation has also attracted many Austrian aerospace firms, including ORS and Schrack, which provided ground support equipment for the ESA's first radar-observation satellite—ERS-1. For the ERS-2 program, the firms are building a microwave radiometer to measure water vapor content in the Earth's atmosphere. Geospace Company, another Austrian firm, is processing and marketing remote-sensing data from Eosat, Eurimage, and Spot Image.

For the Ariane 5 project, ORS is developing a major part of the ground support equipment; Steyr-Daimler-Puch AG is providing the cryogenic fuel system and various components for the solid rocket boosters; and Maschinenfabrik Andritz AG is producing the DAAR-rings connecting the rocket's boosters and core stage.

ORS is working on food storage and waste removal techniques for the Hermes program, while the Technical University in Graz is studying temperature-resistant connection elements for the heat shield produced by the Austrian company Plansee.

Austria is a relatively new player in the space business, according to Dr. Georg Serentschy, chairman of Austrospace. Although Austria has participated in various space programs since the mid-1970s, it wasn't until 1987 that the Austrian government signed a full membership contract with the ESA. Currently, the Austrian Space Agency is paying about $30 million annually as its financial contribution to ESA programs. In return, the ESA is providing nearly the same amount in contracts to the Austrian space industry.

ORS is developing thermal insulation for the ESA's Soho and Cluster scientific satellites. Photo courtesy ESA



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British Aerospace Is Meeting The Challenges Of Space Commercialization

Artist's concept shows the Interim Hotol spaceplane launched from atop the Soviet Union's Antonov An225 heavy-lift aircraft. Photo courtesy British Aerospace

British Aerospace Space Systems is one of Europe's most experienced space contractors. Over the last 30 years it has built or helped to build 100 spacecraft and has played a leading role in achieving many of the milestones in the relatively short history of space exploration and commercialization.

British Aerospace (BAe) produced the first scientific satellite launched by the ESA and its first communication satellite. It was prime contractor for Europe's first geostationary scientific spacecraft and the highly successful Halley's Comet interceptor, Giotto. The company has been building the Skylark sounding rocket since 1957. With over 400 successful launches, Skylark is one of the world's longest-running space programs.

BAe is one of the world's largest and most experienced suppliers of communication satellites, having participated in the development of more than 70 communication spacecraft, a third of these as prime contractor.

Today, the company is preparing for the challenges of increasing commercialization in the space business. It is developing the technologies to play a leading role not only in the supply of space hardware for new ventures, but also in the specialized services that will be available over the next decade and into the 21st century.

One of the keys to the successful exploitation of space is cheap and reliable access to orbit. Seven years ago, BAe unveiled its Hotol concept, a reusable spaceship capable of taking off like a conventional aircraft and flying directly into low-Earth orbit. The spaceship would employ a revolutionary hydrogen and atmospheric oxygen propulsion system for the initial stages, then convert at altitude to pure rocket power using on-board liquid oxygen. The concept is being pursued jointly with the Soviet Union through a study for an "Interim Hotol" which omits the air-breathing stage of propulsion by launching from an Antonov An-225 heavy-lift transport aircraft at an altitude of 9 km.

Looking to the future, British Aerospace Space Systems has formed a number of separate but wholly-owned companies to specialize in a range of satellite-based and related services in the communication and Earth resources sectors.

In the rapidly-expanding arena of private and business communication networks, BAe was one of the first European companies to secure licenses to act as a Specialized Satellite Services Operator, and is currently licensed to provide services in the UK and Germany. The company is pioneering the use of satellites to narrowcast a variety of sports events to clubs and other sites throughout the UK. Further afield, business communication between North America and Europe will be greatly enhanced when the powerful BAe-built Orion satellite system becomes operational.

Recognizing the rapid spread of cellular telephony, BAe is pioneering the development of mass-market radio-based communication networks as a means of enhancing—and in some instances competing with—existing fixed and mobile telephone systems. BAe set up and led a powerful consortium of communication companies which bid successfully for one of the world's first licenses to provide a national digital cellular telephone service. Known as PCN (Personal Communication Network), the system will be operational in the UK in 1992 and is expected to supersede "hard-wired" telephone systems. Satellites can be used to supplement these terrestrial networks, providing an economical method of covering rural and remote areas anywhere in the world. A 2000-subscriber digital-radio-based telephone system which can be interconnected to a national telephone network via satellite is available at a moderate cost.

As the UK's largest exporter of engineering products, BAe has extensive experience with the technical, financial, and organizational problems facing overseas communications operators and administrators. A complete package has been developed to define and meet their needs.

As the world places greater emphasis on the wise husbandry of the Earth's environment and resources, analysis of data gathered from space-borne instruments becomes more important. BAe is very active in this area. It is also experienced in designing and manufacturing a wide range of sensors, and will lead a European consortium to build the Earth observation polar platform that the ESA plans to launch by 2000.

The British government contracted BAe to establish the National Remote Sensing Center (NRSC), a commercial organization for the collection, archiving, and analysis of Earth observation data. When combined with existing national facilities, the NRSC will be one of the world's leading centers for the analysis of remotely-sensed information.

Without the backing of large military space programs, the European space industry has found it difficult to remain profitable in an increasingly competitive marketplace. Long established in space science, Europe has emerged over the last decade as a capable commercial space power. British Aerospace Space Systems has played a pivotal role in this success, just as it intends to do in developing the new products and services the space industry has long promised and is finally capable of delivering.

Dassault: From High-Performance Aircraft To Spaceplanes

Dassault is developing man-machine interfaces for extravehicular activity.

Photo courtesy Dassault Aviation

Dassault Aviation, the world-reknowned manufacturer of high-performance civil and military aircraft such as the Falcon, Mirage, and Rafale, also is involved in the development of the Hermes spaceplane.

Following the recent restructuring of the Hermes program for the development phase, Dassault is sharing the industrial prime-contractorship with three other partners—Aerospatiale, Alenia, and Dasa—within the new integrated structure of Euro-Hermespace.

Since 1985, Dassault has been helping to refine the spaceplane's basic configuration, including its shape, thermal protection system, hot structures, and rescue subsystems. These tasks have been performed under the aegis of the ESA and CNES.

As a member of Euro-Hermespace, the company chaired by Serge Dassault has full responsibility for the following tasks: aerodynamic design and shape definition, reentry trajectories and aerothermodynamics, thermomechanical architecture design and supply of the thermal protection and hot structures, reentry software, navigation guidance and control, flight controls, crew escape devices, subsonic test flights, and assistance for orbital flights.

Dassault is performing aerodynamic simulations and wind tunnel tests to shape the spaceplane, which will have an extended flight envelope ranging from 200 to 16,000 knots. The craft will require an optimized trajectory to dissipate the tremendous kinetic energy generated during atmospheric reentry, which will increase Hermes' skin temperature from - 150°F to 3300°F. The objective is to limit the stress on the hot structure made of carbon-fiber-reinforced composites and ceramic materials such as carbon-carbon or carbon-silicon carbide.

In cooperation with its European partners, Dassault has initiated an extensive research and development effort in such areas as ceramic matrix composites, refractive materials, internal multiscreen insulation, and tribology. It also has developed highly-sophisticated mathematical simulation and computer-aided design tools to handle the challenge of hypersonic aerothermodynamics up to Mach 29, a domain never before explored by European aerospace designers.

Controlled Configured-Vehicle (CCV) concepts and techniques developed by Dassault for the Rafale advanced combat aircraft are now being applied to Hermes. Dassault plans to conduct atmospheric flight tests at subsonic speeds with one of the two spaceplanes. Hermes will be dropped from a carrier aircraft to investigate its flight characteristics and to qualify approach and landing procedures before proceeding with orbital flights.

Dassault is participating in studies of the Hermes Carrier Aircraft and Hermes Trainer Aircraft, for which airplanes such as Airbus and Falcon have been proposed. The company also is in charge of providing Hermes' crew ejection seats. It is evaluating two competitive concepts, one featuring a new seat to be developed by Martin Baker and the other a derivative of an existing seat used by Soviet Mig-29 pilots. The main requirement is to be able to eject the crew from zero-zero (altitude and speed) to Mach 3 at 30 km.

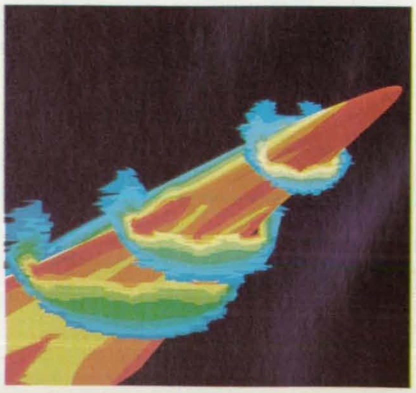
Dassault's space activities are a spinoff of the company's experience in several high-tech domains, including aerothermodynamics, manned systems design, man-machine interfaces, human factors and crew safety, environmental control and life support, thermal protection, in-flight tests, and procedures for manned vehicles. The French firm also has expertise in computer-aided design and manufacturing, expert systems, and artificial intelligence—including applications to man-machine systems such as advanced piloted aircraft and manned spaceplanes.

Under contract to CNES, Dassault is conducting advanced studies of reusable space shuttles through its Star-H concept of a two-stage-to-orbit vehicle. The goal is to create a database for studying future hypersonic shuttles or transatmospheric aircraft. Dassault also is involved with Aerospatiale and Hyperspace in a French research program focused on hypersonic propulsion, and is part of the team designing and manufacturing the first European space suit for extravehicular activity.

The space division created last year to manage the company's participation in Hermes and other space programs now employs about 150 highly-skilled people, most housed in Toulouse in a newly-built space center. The group's goal, according to Jean-Jacques Roussel, director general of the division, is to increase space business from the present 4.4 percent to 10 percent of Dassault's revenues by the mid-90s.

Three-dimensional Euler CFD analysis for the Star-H project

Photo courtesy Dassault Aviation



Matra Marconi Space, The First Integrated Space Team In Europe

Matra Marconi Space manufactured the platform for the ESA's first radar-observation satellite, ERS-1. Photo courtesy ESA

Last year, two of Europe's foremost space companies, Matra Espace of France and Marconi Space Systems of the UK, formed the first true international space company by joining forces to create Matra Marconi Space (MMS). The new company achieved consolidated sales of approximately $780 million and an order book of more than $1.3 billion with a work force of 3000 in 1990. This year, it anticipates a turnover of nearly $820 million.

Marconi Space Systems teamed with GE Astro Space of the United States in a winning bid to build Inmarsat's third generation of maritime communication satellites. The $320 million contract calls for four Inmarsat 3s, with an option for five additional satellites, all based on GE's Satcom 4000 platform. Marconi will receive half of this award for providing the communication payload, including transponders and antennas. It is the largest space contract ever received by the British arm of MMS.

The UK and French firms complement each other well. Matra specializes in communication satellite platforms and optical sensors for observation satellites, while Marconi is experienced with communication payloads and microwave instruments for remote-sensing spacecraft. An excellent example of this synergy is the ERS radar-observation satellites. Matra Espace manufactured the platform, derived from the Spot bus, and integrated it with the observation payload in Toulouse. Marconi Space Systems developed and built in Portsmouth ERS' primary sensor, a C-band radar which can be used as either a wind scatterometer or a synthetic aperture radar. The team also is involved in building the European polar platform, a derivative of the Spot Mk2 bus developed for Helios and Spot 4.

British Aerospace, the prime contractor for the polar platform, has a history of collaboration with both Matra Espace and Marconi Space Systems. Platforms BAe developed for British Skynet satellites were equipped with Marconi's payloads. It is currently working with Matra Espace in Satcom International to develop the Eurostar platform, which has been selected for 13 communication satellites, including Telecom 2, Inmarsat 2, Locstar, and Hispasat.

The first French Telecom 2 satellite, planned for launch in November, was developed in 44 months. Hispasat and Locstar will be manufactured in only 34 and 35 months, respectively. "It will be a European record," says Claude Goumy, MMS chairman. Mr. Goumy has offered to provide an interim satellite to Eutelsat within 26 months. It would be the forerunner of Europesat, a series of pan-European direct broadcasting satellites that would succeed present TDFs and TV-SATs.

Key space technologies developed by the MMS team include the Silex experimental optical inter-satellite link, built under ESA contract. In 1995, the Artemis geostationary communication satellite and a Spot 4 observation spacecraft in polar orbit will each be equipped with a small Silex telescope to test the laser link.

The ESA also awarded Matra Espace a contract to demonstrate the feasibility of an advanced radiometer designed for Meteosat 2 weather satellites. The new instrument, an infrared vertical sounder, would scan the atmosphere to measure its contents and temperature profile in three dimensions. A previous Meteosat radiometer set a world record by capturing 400,000 visible and infrared images of the Earth in seven years.

In Portsmouth, Marconi is working on high-tech subsystems for satellites, including new antennas for Inmarsat 3, advanced multi-frequency synthetic aperture radars, ion-propulsion thruster engines, and nickel-hydrogen batteries. The UK10 ion engine has a 10 mN thrust with a specific impulse of 3000 s. It is to be flight-tested for the first time on ESA's Artemis satellite.

Photo courtesy Matra

MMS performs satellite integration in a Toulouse facility.

Novespace: Promoting Microgravity And Transferring High Technology

Novespace, a private company owned by CNES and eight banks, does much of its business through cooperative agreements. Last year, when the company earned an unprecedented seven percent profit, it owed a large part of its success to joint ventures with European partners.

In the promotion of microgravity, alliances were cemented with English, German, and Italian companies for joint research in weightlessness and experiments on parabolic flights using the dedicated Caravelle nicknamed "Zero-G."

Novespace has been designated the exclusive operator of "Zero-G," according to company chairman Jean-Pierre Fouquet. Novespace has already organized several parabolic flight campaigns for industrial and scientific customers. Although the first clients were the ESA and CNES, the company has also attracted major foreign companies and organizations, especially from Germany and Japan, including

Photo courtesy Novespace

Earlier this year, Novespace organized parabolic flights of Japanese experiments on the "Zero-G" Caravelle.

Mitsubishi and the Nippon Ministry for Trade and Industry.

"Zero-G" has a natural appeal in Europe. An important flight campaign was organized last year in Bremen, Germany, by the local space company OHB, which Novespace agreed to represent. This activity of airborne microgravity experiments is expanding rapidly, with eight to ten flight projects already scheduled in 1991. To accommodate the increased business, Novespace is looking to replace the Caravelle with a younger and larger jumbo jet, possibly an Airbus. The decision should be made later this year.

Novespace recently signed its first agreement with the Soviet space agency Glavcosmos. It calls for flying a Matra/BioEurope life sciences experiment on a recoverable Photon spacecraft this September. Concurrently, Novespace and CNES are conducting market studies to determine if the opportunity exists to develop a European recoverable capsule for microgravity experiments. The craft would be able to carry a payload of about 1 ton and would be launched by either an Ariane 4 or 5.

Novespace's technology transfer business has also taken on a European dimension. European networks have been set up around Novespace with a British partner and a German counterpart. They are conducting a pilot study on the valorization of technologies from programs managed by ESA. The initiative has brought together more than 60 innovative technologies, many of which are presented in the *Transferable European Space Technologies* (TEST) catalog edited by the ESA. Novespace is publishing the catalog in English, French, and German. The TEST catalog is similar to *Mutations*, a technology transfer report also published by Novespace. The seventh issue of *Mutations* has just been released.

The European Economic Community Council established a second network to transfer high technology among various member countries. Novespace is the leading partner in this network, in association with German, Spanish, and Danish aerospace companies.

To further promote effective exchanges of data and technologies, Novespace last year organized an international convention in Marseilles. Called Novespace 90, the conference was held with the support of Adhesion & Associes, a French consulting company. It brought together about 100 select participants for confidential meetings on possible technology transfers. In two days, more than 2000 privileged meetings were held. The success of this unique direct-encounter meeting process prompted Novespace and the Provence Cote d'Azur Regional Council Authority to hold a second conference this year in Cannes, on the French Riviera. Novespace 91 will take place November 12-14 at the Hotel Martinez.

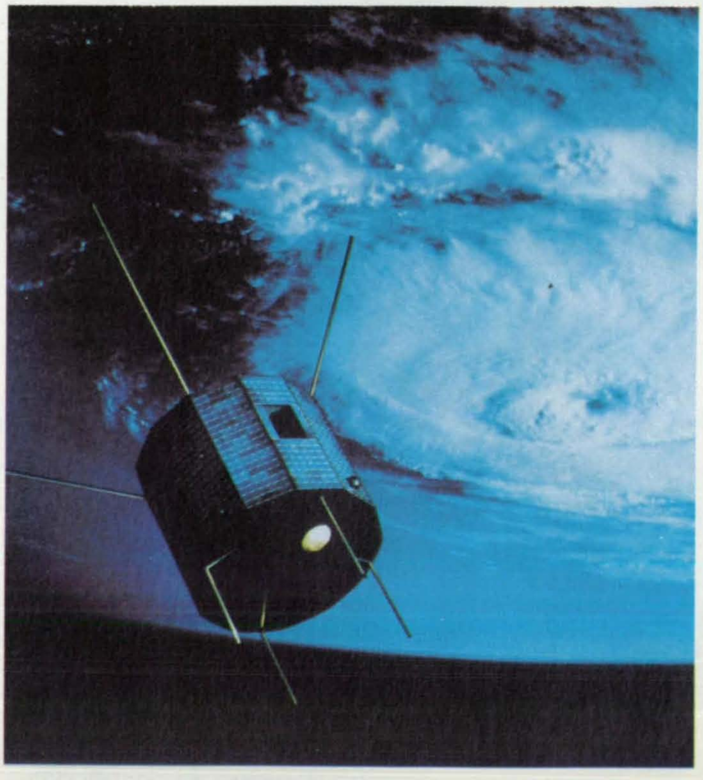
OHB Provides Engineering And Innovation Power

Founded more than 30 years ago to build naval hardware, OHB System GmbH entered the space business only six years ago. The small but innovative engineering company headed by Manfred Fuchs employs 90 people and last year achieved sales of $12 million.

The firm's space activities are focused on the design, development, and manufacture of prototype or limited-series hardware for microgravity experiments, environmental surveillance, and manned systems. OHB is building and flying Mikroba rocket-like recoverable capsules, which are dropped from high-altitude balloons to provide short periods of microgravity. The company also built electronic equipment for Cosima and other zero-gravity experiments for flight on Chinese and Soviet recoverable spacecraft. It is currently developing technology for a German recoverable capsule called Express which will be launched by Japan.

Fuchs' team participated in studies of advanced optical and microwave detectors for the Atmos environmental satellite sponsored by the German space agency. OHB has also proposed its own projects, including the Pollux and Safir satellites for pollution control and monitoring. The Bremen firm helped build the Bremsat mini-satellite (68 kg). It will be launched by the space shuttle during the Spacelab D2 mission in 1993.

Last year, OHB flight-tested for the first time the Falke (Falcon), a computer-guided scale model of the space shuttle measuring 7 m long and weighing 600 kg. Flight data gathered with the carbon-fiber replica will be compared to established characteristics of the real shuttle in order to validate techniques that will be applied to a balloon-borne scale model of Hermes. A model of the spaceplane may also be launched by an Ariane as part of project Cobra. OHB studied the air-launched Diana, a two-stage rocket carried atop a Concorde SST.



The OHB-built Bremsat will be launched by the shuttle in 1993.

Photo courtesy OHB System GmbH

SNPE: Mastering Solid Rocket Energy

Photo courtesy SNPE

SNPE's solid propellant mixing facility in Kourou features an 11-ton capacity.

SNPE is Europe's largest designer and manufacturer of solid propellant for civil and defense applications, including tactical and ballistic missiles and space rocket boosters. Its Space and Defense Division headed by Pierre Dumas is the most important branch of the company in terms of manpower and sales, with 4500 workers and $290 million in sales last year.

The division is heavily involved in the European space program through its development and production of huge solid strap-on boosters for the Ariane 5 heavy-lift rocket. The French company produces the solid propellant filling the rocket boosters, each having a total mass at lift-off of about 250 tons. Ariane 5 is flanked by a pair of three-part boosters that produce a total thrust varying from 540 to 630 tons between lift-off and the end of the 123-second burning time, when they are jettisoned at an altitude of about 60 km. Ariane 5 boosters are 25 times larger than Ariane 4 boosters, which are loaded with less than 10 tons of propellant.

Each Ariane 5 P230 booster is filled with 230 tons of Butalane, a solid propellant made of aluminum and ammonium perchlorate, hydroxyl-terminated. SNPE and an Italian partner, BPD Difesa e Spazio, have formed a company called EUPERA to produce the chemical agent in new facilities located in Toulouse and near Bordeaux. The modern, highly-automated plants produce thousands of tons of ammonium perchlorate each year for Ariane 5. They also produce the white "magic powder" for MLRS artillery rockets built under license from the USA.

The French-Italian team set up another joint venture called Regulus to build and operate the Butalane manufacturing facility in Kourou. Its production will fill the two largest segments of each Ariane 5 booster. The "Usine de Propergol de Guyane" (Guiana propellant plant) was built by SNPE Ingenierie, the engineering subsidiary of SNPE, under contract from CNES. The facility is scheduled for completion by mid-year. It will then begin manufacturing the first full-size test model of the huge solid booster.

Following the first two qualification flights of Ariane 5 in 1995, the UPG will begin production of solid propellant to fill 16 boosters per year in correspondence with the maximum annual launch rate of eight Ariane 5s. Only 110 workers will be needed to operate the plant in order to produce a maximum of 32 solid segments per year, loaded with a total mass of 3300 tons of Butalane. The UPG will be one of the world's largest solid propellant manufacturing facilities.

SNPE is also investigating new continuous production processes which could be used to manufacture the composite propellant if the production quantities become very large. "This new process involves precise on-line monitoring of the feeding of the ingredients to achieve continuous control over the composition of the propellant," says Alain Davenas, manager of research and technology for SNPE.

SNPE Chimie, another subsidiary of the French group, is lending the space group its expertise to manufacture and process rocket chemicals for Ariane 4 and 5. Facilities in Toulouse are producing liquid propellants such as monomethyl hydrazine for Ariane 5's upper stage, as well as the rocket's main fuel, unsymetrical dymethyl hydrazine. Pyromeca, yet another SNPE affiliate, is designing and manufacturing pyrotechnic elements for the Arianes, including igniters, cutters, and the device that frees the vehicle from the launch pad.

Spacebel Instrumentation Offers Belgian Expertise In Optics

Spacebel Instrumentation and Spacebel Informatique are Belgian twins in the space business. They have the same shareholders, including Matra Espace, which has 40% of their stock, and two Belgian companies, Informabel (10%) and SDS (50%). Thanks to their financial and technical support, Spacebel Instrumentation has grown rapidly. Started three years ago with only seven people, the firm now employs 30 specialized engineers and technicians, and expects sales of more than $4.3 million in 1991.

Headed by co-founder Daniel Malaise, Spacebel is developing and testing complete opto-electronic instrument packages for scientific observations and optical communications. It began by producing instruments for certification of the Hipparcos satellite while being familiar with the measurement of tiny angular movements down to 10 milliarcsec and linear displacements to 5 nanometers. The firm is now mastering a variety of metrology techniques, including interferometry and polarimetry. The skilled team has supported Matra and other space companies in integrating large scientific spacecraft and payloads such as the Hubble Space Telescope's Faint Object Camera.

In a short span, Spacebel has gained expertise in such techniques as optical design, electronics and software, mechanical and thermal design, integration tests, and verification activities. This rapid progress has led to Spacebel's selection as industrial contractor for development of the Extreme Ultraviolet Imaging Telescope which will be carried on the Soho spacecraft to study the solar corona. It also is working on the Silex optical intersatellite link developed by Matra Marconi Space. Spacebel is developing the optical ground support equipment for testing Silex terminals, and the bright beacon used for initiation of the acquisition phase between Silex terminals in geostationary and low-Earth orbits.

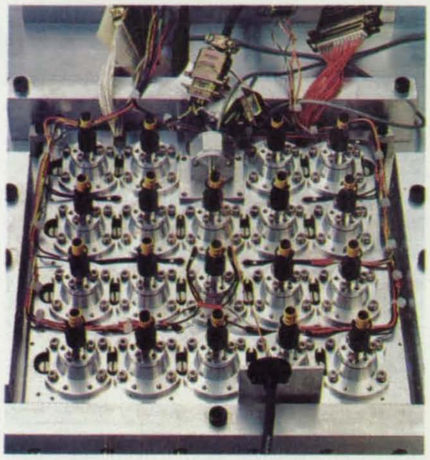


Photo courtesy Spacebel

Breadboard model of beacon developed by Spacebel for the Silex laser intersatellite link.

Spacebel also has received research and development contracts from the ESA, including work on the Small Optical Package, a set of instruments for the second generation of Meteosats, and the development of a phase-shifted point diffraction interferometer for high-accuracy wave front error measurement.

(Special Advertising Supplement)

Spot Image's Fast-Growing Sales Of French Remote-Sensing Data

Five years after the launch of the first French Earth observation satellite, Spot 1, Spot Image is experiencing booming worldwide sales of remote-sensing data. In 1990, the company turnover was $28 million, a growth of 33%, thanks to increased sales from its US subsidiary, SICorp. This year, sales are expected to exceed $34 million, according to Gerard Brachet, Spot Image's chairman.

The firm's growth has resulted from increased rates from direct-reception ground stations around the world and expanding sales of raw data and custom-designed services and products. Large contracts were recently secured with several foreign countries, including Bangladesh ($850,000), Argentina ($1.7 million), Mongolia ($2 million), and Egypt ($6.8 million). The latter, for mapping agricultural land in the Nile Valley, is the largest contract the company has ever received.

Its latest deal is to provide remote-sensing data and services to the Mongolian Geophysics and Geology Agency. This includes the construction of a satellite data center at Ulan-Baator to process remote-sensing data for applications such as geology, mining, and land resource management. Mongolia's geologists will begin training on remote-sensing techniques next September at GDTA and at the French geophysics agency, BRGM. The project is co-funded by BNP, the French national bank.

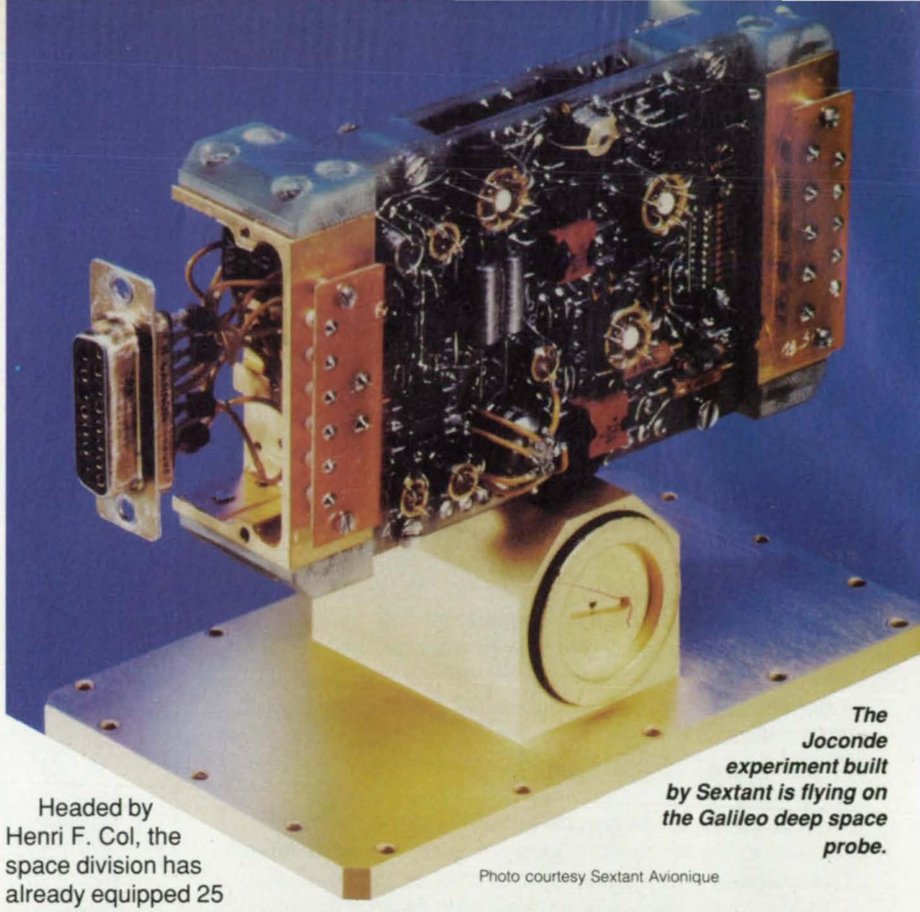
This year, large single-customer contracts are expected to amount to $6.8 million. "This service will grow rapidly because developing countries want useful data but cannot afford to pay for expensive aerial surveys," explains Brachet. Spot Image expects to sell 1000 copies of its "spatiocarte" in 1991. Another best-selling new product is digital terrain-mapping in 3D. "This product, obtained from stereo images, is unique on the remote-sensing market, even in the United States," says Brachet. Spot's leader is confident that the firm's sales will grow by more than 5% annually through 1995.

In partnership with Eurimage and Radarsat International, Spot is preparing to enter the radar satellite data business. The three companies recently received approval to establish a unique international consortium for marketing and selling radar data from the ERS-1 satellite. Soon, customers will be able to obtain optical and/or radar data from a single international supplier.

Satellite image processed by Spot Image and IGN shows the delta rivers in Bangladesh.

Photo courtesy Spot Image

Sextant Avionique, Europe's Largest Producer Of Spaceborne Electronics



The Joconde experiment built by Sextant is flying on the Galileo deep space probe.

Photo courtesy Sextant Avionique

Sextant Avionique, the largest avionics group in Europe and the fifth largest in the world, was founded in July 1989 by merging the avionics activities of Aerospatiale and Thomson-CSF. The new company has emerged as a powerful force, with nearly 10,000 workers and sales of over $1 billion in 1990.

The French group provides electronic equipment for civil and military aircraft, tactical and strategic missiles, satellites, and launchers. Its activities are split between two sectors, one dedicated to components and industrial systems and the other dealing with aerospace and defense business.

Today, the avionics sector is not only booming, but rapidly evolving towards integrated systems featuring comprehensive flight management, advanced man-machine interfaces, and mission management computers. Sextant Avionique is mastering key avionics technologies such as fly-by-wire controls (already used in the Airbus A320), voice-controlled units, head-up and eye-level displays, helmet-mounted sights, and holography.

Thanks to its parent companies' experience over the past 25 years, Sextant's space division has already equipped over 50 launchers and 70 satellites. It is a key partner in some of the most important European space programs: Ariane 4 and 5, Hermes, Columbus, Granat, Ulysses, ISO, Eutelsat 2, Telecom 2, Spot, Helios, Poseidon, Meteosat, MOP, and ERS. Its product line features a wide range of high-tech equipment, including advanced navigation and flight management computers for satellites and rockets, and a ring laser-gyro inertial platform for Ariane 4.

Headed by Henri F. Col, the space division has already equipped 25 scientific satellites, including Giotto, Granat, Galileo, and Ulysses. Recent achievements include 28 kg of Sextant data processing, control and power equipment for the Sigma telescope installed on board the Granat high-energy astronomy satellite, and the preamplifiers and power supply for the Mona Lisa experiment carried on the Galileo deep space probe.

Mona Lisa is designed to detect and analyze natural waves emitted in the magnetosphere of Jupiter. The tiny electronics package, weighing only 200 grams, was developed in association with the University of Iowa and the French Environmental Physics Research Center, a scientific laboratory jointly operated by CNET and CNRS.

Sextant Avionique also has significant experience in data management, power conditioning, signal processing, and instrumentation. It has produced 250 data management units for satellites and rockets. Its modular data processors include the radiation-hardened DATA 2 which uses 16K-RAM and 32K-PROM. A data bus for either centralized or distributed data processing systems has been developed based on European standard OBDH (1553-B). Further, VLSI bus interface units made by Sextant are used on the Spot, Helios, and Telecom 2 satellites.

The company produces semiconductor memory storage units—the latest of which feature CMOS static RAM of 16K, 256K, or 1MB—and builds on-board management and power conditioning equipment for European communication satellites. The space division has developed power control and distribution units for the Eutelsat 2s and payload interface units for the Telecom 2s using monolithic technology comprised of hybrids integrating ASICs. It is producing thick-film hybrid circuits and ASICs according to quality standards specified by the ESA and CNES.

More than 400 power distribution and conditioning units have been produced for satellite power generation up to 3 kw and 150 v. Sextant is developing solid-state power controllers for Hermes and Columbus, and has been selected for management system bus-1553, remote terminal units, electronics for thermal and attitude control, and air data sensors.

For manned systems, Sextant has produced voice communication units to process low-level digital speech signals. Voice interaction and speech processing systems are being developed for modern combat aircraft and space vehicles. In cooperation with Sait (Belgium) and Leica (Switzerland), Sextant is designing head-up and head-down displays for the Hermes cockpit using flat-panel liquid-crystal technology. ❑

Hardware, Techniques, and Processes

h-Parameter Analysis of Teleoperators

An electromechanical system is characterized by a mathematical model originally developed for electrical networks.

NASA's Jet Propulsion Laboratory, Pasadena, California

The hybrid two-port input/output mathematical model originally developed for the small-signal analysis of transistors, amplifiers, and electrical networks in general has been adapted to the analysis of a teleoperator that senses forces and velocities at the master and slave. The hybrid two-port model is well suited to characterization of the bidirectional flows of energy in terms of the relationships between input and output signals. The hybrid model (as distinguished from other two-port models) leads to an intuitive representation of the performance of the system and can be used to design the system according to the concept of bilateral impedance control.

The interface between the human operator and the master and the interface between the slave and the environment are the two ports through which the teleoperator exchanges energy between the human operator and the environment. In this exchange, the human operator exerts controlling forces on the environment through the teleoperator, while feedback from the slave back to the master increases the sense of realism with which the human operator senses the environment (which includes the manipulated object).

The two-port hybrid model is extended to the teleoperator by the analogy between effort (force) and voltage and the analogy between flow (velocity) and electrical current (see Figure 1). Thus, the parameters of the hybrid two-port model of a real or simulated teleoperator system can be obtained from its measured or computed input and output dynamical properties, in analogy with the input/output electrical properties and corresponding transimpedance and transadmittance parameters (h parameters) of a purely electrical two-port system.

The hybrid two-port model is linear: The h parameters are derived, in effect, from the second term of a Taylor-series expansion that describes the behavior of the system in the vicinity of the operating point. Thus, in the purely electrical case, the hybrid two-port model is used for small-signal analysis and is applied to a nonlinear electrical system by specifying the operating point in question (e.g., the dc biases on a transistor). Analogously, the hybrid two-port model can be applied to a nonlinear teleoperator by specifying the operating point in terms of the applicable position and velocity vectors.

Figure 2 illustrates the incorporation of the hybrid two-port model into a mathematical model of bilateral impedance control. Existing systems like those of Figure 1 cannot operate well with even small delays because information on impedances is transmitted piecemeal as efforts and flows are iterated around the complete control loop. In bilateral impedance control, a local servoloop enforces a commanded effort and impedance. The information communicated across the delay can be appropriately filtered to stabilize the system. In the steady state, this enables the operator to perceive the characteristics of the environment accurately and presents the environment with a suitable impedance selected by the operator.

Bilateral impedance control depends on estimators that are capable of identifying the impedance of the environment and of the human operator. In general, such estimation is very difficult because of problems posed by numerical conditioning and noise. Although ideal responses may be difficult to achieve, assumptions about the environment can extend the usefulness of this approach. For example, the estimators can be assisted by an intelligent system with a reduced set of impedance vectors ($\hat{Z}_i$). The task of each estimator is then to classify the effort- and flow-sensor readings into one of the $\hat{Z}_i$.

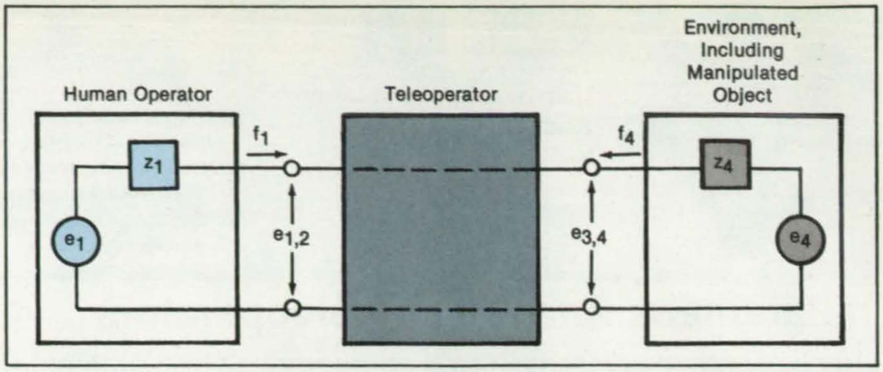


Figure 1. The **Teleoperator Acts as a Two-Port** input/output "black-box" device between the human operator and the environment.

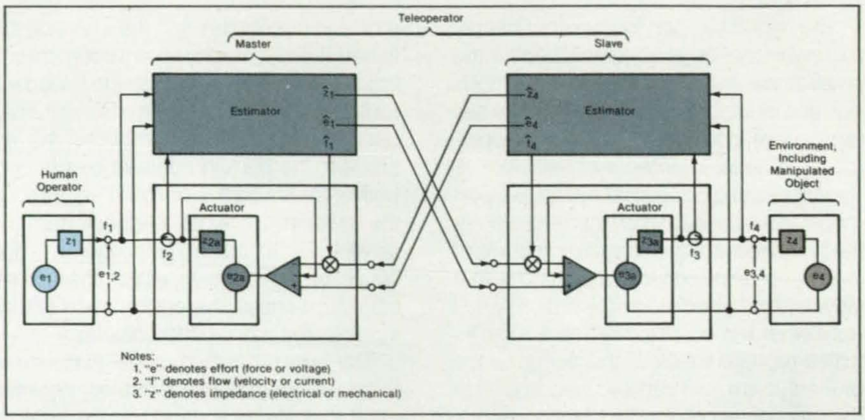


Figure 2. This **Teleoperator Incorporates Bilateral Impedance Control** for improved performance in the presence of delays in propagation of signals through the teleoperator.

This work was done by Blake Hannaford of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 100 on the TSP Request Card. NPO-17527*

Computing Flow in a Labyrinth Seal

A variety of geometries, including multiple chokes, can be accommodated.

Marshall Space Flight Center, Alabama

A mathematical model and a computer program have been developed to simulate the flow in a labyrinth seal. The primary purpose of the program is to determine the drop in pressure across the primary labyrinth seal of the high-pressure-oxygen turbopump of the Space Shuttle main engine, including the portion of that drop caused by the resistance to flow in the gaseous-oxygen drain. However, the flexibility of the program should make it applicable to other machinery. The program accommodates a variety of geometries and includes an iterative routine that enables the simulation of flows that choke in multiple places. The model and program provide for improved study of various types of seal failures and for reviews of the mechanics of seal regions.

The user enters input data that describe the geometry of the seal and of the slinger upstream of the seal. These data include various radii, the number of lands, the number of teeth on each land, and clearances for the slinger and each land of the seal. The user must also provide input data on the pressure at the drain exit, the pressure and temperature upstream of the slinger, the speed and torque of the pump, the pump coefficients of the slinger, and various loss coefficients that are determined from literature and from test data. The user must also enter the rate of flow and the temperature of helium flowing through the purge, because mixing occurs at the exit of the seal. Although the program in its present form works only for oxygen and a purge flow of helium, it contains routines that can be modified to express the properties of other fluids.

When beginning a computation with this program, one makes an initial guess of the rate of flow through the seal. An iteration is then performed on the rate of flow until the boundary conditions of pressure are satisfied. Supersonic flow is not allowed in this program, but multiple sonic conditions can occur. Incremental steps are taken up and down the slinger to determine where the liquid oxygen turns to gaseous oxygen. (The program can also simulate a completely-liquid-phase flow.) Heat is added to the simulated flow in the slinger and seal regions. The flow is allowed to choke only at the end of each land because each land is assumed to have constant area at the tips of each tooth. Further development of the program would include providing for lands of variable area (variable radius) and improving the mathematical model of the drain system.

This work was done by Tyn S. Smith 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 14]. Refer to MFS-29682.

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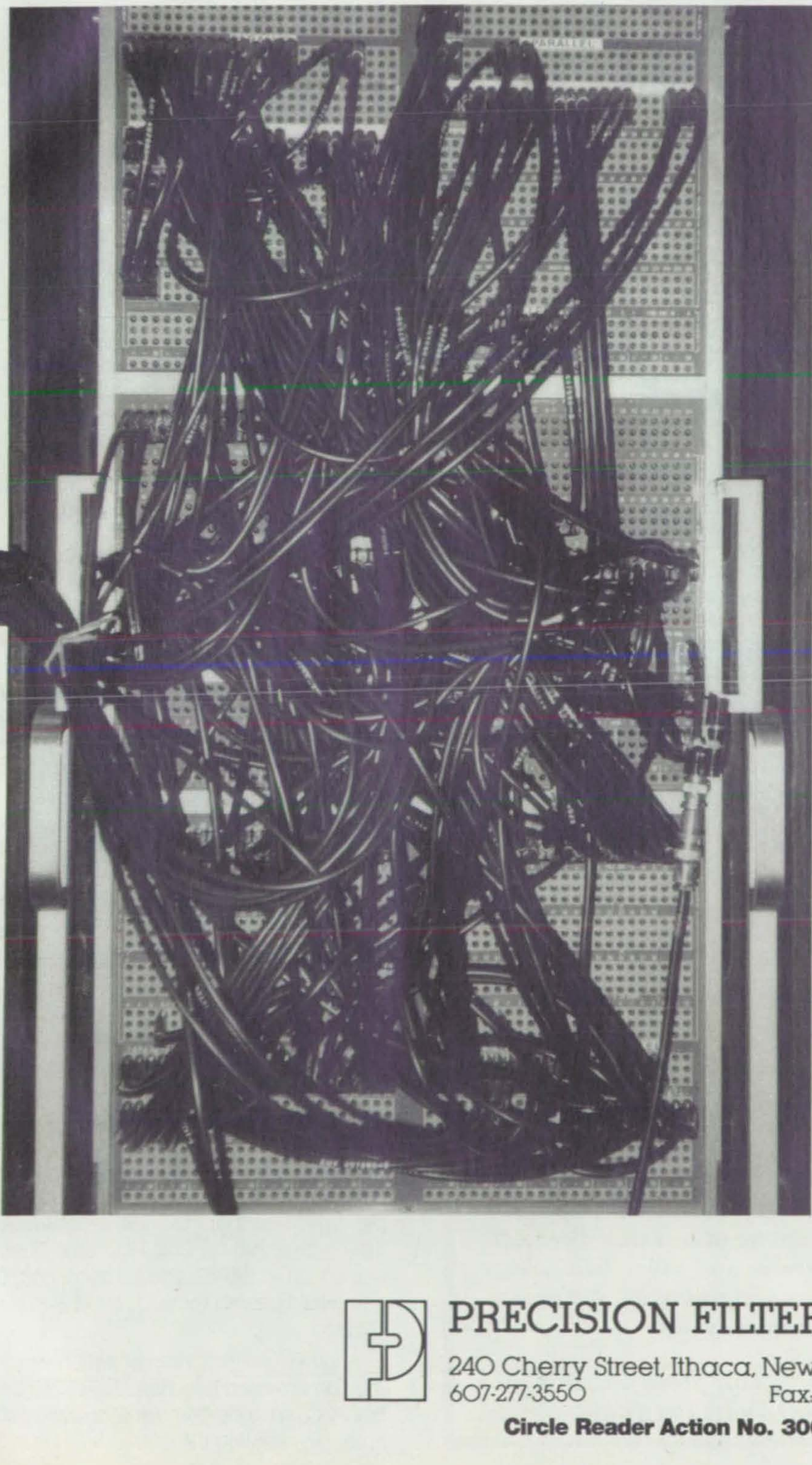

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Concentric Regenerative Sorption Compressor

Required power would equal that of a mechanical compressor.

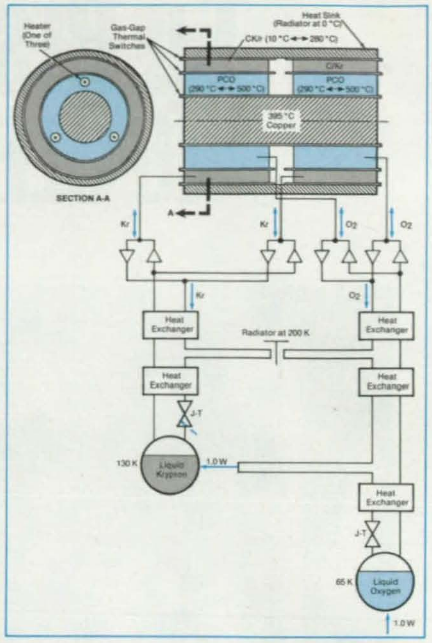
NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed sorption compressor for a cryogenic system would feature four sorption units that would operate in phased alternation in a heat-cascading manner. A refrigerator based on the proposed compressor would require about 60 W of input power to produce 1 W of cooling at a temperature of 65 K. This equals the power required by a mechanical compressor designed to produce the same cooling effect. However, the sorption compressor would vibrate less than a mechanical compressor does, and it would be more reliable because it would contain only a few moving parts that would be actuated relatively infrequently.

In the refrigerator (see figure), a cooling loop in which krypton circulates would provide cooling to about 130 K, and a cooperating loop containing oxygen would provide further cooling to 65 K. The compressor would include two praseodymium cerium oxide (PCO) chemisorption units that would pump the oxygen and two carbon/krypton (C/Kr) physisorption units that would pump the krypton. During each half of the operating cycle, waste heat from one of the PCO units would power the other PCO unit, and waste heat from this second unit would power one of the C/Kr units. If one of the C/Kr units is replaced by a carbon/xenon (C/Xe) unit, then all heat rejection may be made at 0 °C (273 K), thus eliminating the 200-K radiator. There would then be three stages of J-T cooling at about 165 K, 120 K, and 65 K for the same heat input.

At the beginning of a cycle, internal electrical heaters would raise the temperature of one of the PCO units to 500 °C, causing it to desorb oxygen at high pressure for use in the O_2 cooling loop. Gas-gap thermal switches would then be activated to transfer heat from this PCO unit into and along a copper rod to the other PCO unit, which would initially be at 290 °C. Both PCO units would equilibrate at 395 °C, and the second PCO unit would desorb more O_2 for use in the O_2 loop.

Another gas-gap thermal switch would then be activated to transfer heat from the first PCO unit to the C/Kr unit concentric with it, thereby heating the C/Kr unit to 280 °C



Concentric Sorption Units would be alternately connected and disconnected via timed gas-gap thermal switches. During a given half cycle, one of the C/Kr sorption units would operate on waste heat from one of the PCO sorption units, which in turn would operate partially on waste heat from the other PCO sorption unit.

and cooling the first PCO unit to 290 °C. The cooled first PCO unit would reabsorb O_2. The heated C/Kr unit would give off Kr gas, which would be used in the Kr cooling loop. Meanwhile, heat from the other C/Kr unit would be transferred through a gas-gap switch to a 0 °C heat sink, cooling that unit to 10 °C and causing it to absorb Kr. The second half cycle would then begin with the heating of the second PCO unit to 500 °C, and the roles of the various components would be appropriately reversed.

This work was done by Jack A. Jones of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 123 on the TSP Request Card.*
NPO-17877

Sorption Compressor With Rotary Regenerator

Features would include less required power and greater reliability.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed two-stage sorption compressor for a cryogenic system would feature a rotary regenerator. At each stage, a rotor would interact with a stator to provide quadruple regeneration. A refrigerator based on the proposed compressor would require 35 W of input (heat and electrical power) to produce 1 W of cooling at a temperature of 65 K. This input power is 78 percent less than the 160 W input required by a comparable nonregenerative sorption refrigerator to produce the same cooling effect. The proposed compressor would contain no valves, and the only moving part would be the rotor, which would turn very slowly. Therefore, the compressor should be more reliable than prior compressors have been.

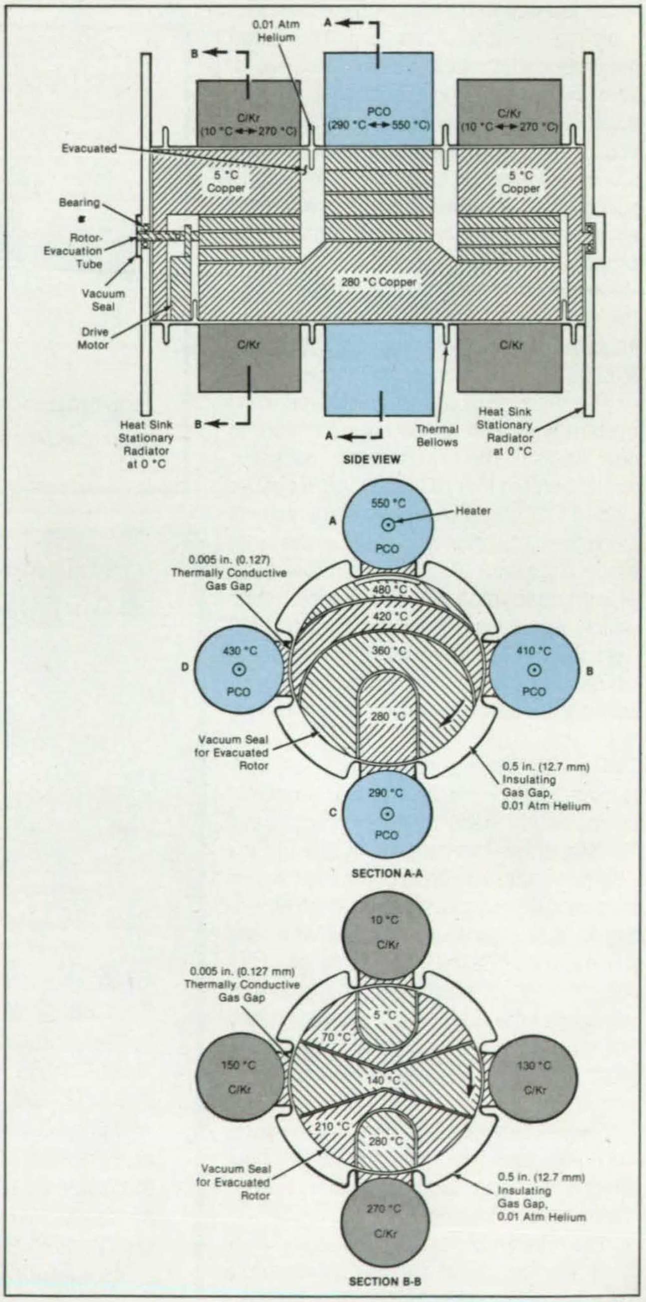
The working fluids of the refrigeration system would be oxygen and krypton. In one stage of the compressor, the stator would contain four praseodymium cerium oxide (PCO) sorption units, which would enforce the circulation of oxygen. In the other stage, the stator would contain four pairs of carbon/krypton (C/Kr) sorption units, which would be powered by waste heat from the PCO units. The PCO units would contain electrical heaters, which would be activated at appropriate phases of the rotation.

The rotor would consist of thermally conductive sections made of copper separated by insulating gaps to effect the phased transfer of heat among the PCO and C/Kr sorption units. The ends of the rotor would be thermally connected to a heat sink in the form of a stationary radiator at a temperature of 0 °C. The insulating gaps in the rotor would be evacuated. The chamber containing the rotor would contain helium gas at a pressure of 0.01 atm (≈1 kPa). Heat would be transferred through the helium gas across gaps 0.005 in. (0.127 mm) wide between the rotor and the sorption units and from the rotor to the heat sinks. Other gaps would be made wider to minimize the transfer of heat.

The rotor would turn intermittently, in angular increments of 45° at intervals of 7.5 minutes, thus completing a cycle every hour. In the figure, the rotor is shown at the 0 °C position. By rotating clockwise 45° from this position, the rotor would establish a conductive path from PCO unit A to PCO unit B. During the ≤ 7.5-minute interval, the temperature of A would be reduced to about 490 °C, while that of B would increase to about 470 °C. Simultaneously, a similar conductive path in the rotor would transfer heat from D to C, causing the temperature of C to rise to about 350 °C and the temperature of D to fall to about 370°C.

The rotor would then be turned another 45°, causing D to cool to 290°C, at which temperature it would reabsorb O_2. At this phase, B would be electrically heated to 550°C, causing it to liberate O_2. Simultaneously, the rotor would conduct heat from A to C, cooling A to approximately 430°C and warming C to 410°C. Also simultaneously, heat from D would be transferred to the rotor block labeled "280°C." From this block, heat would be transferred to the C/Kr sorption units, which would operate in a manner similar to that of the PCO units. Ultimately, the heat would be transferred from the C/Kr units into the rotor blocks labeled "5°C," then out to the heat sinks at 0°C.

This work was done by Jack A. Jones, Steven Bard, and Ronald G. Ross of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 28 on the TSP Request Card. NPO-17876*



The **Rotary-Regenerator Sorption Compressor** would include a rotor that would transfer heat in phases (in a 1-hour cycle) among sorption units. This compressor would consume less power and be more reliable, in comparison with nonregenerative compressors of similar capacity.

Synchronizing Rotation of a Heavy Load

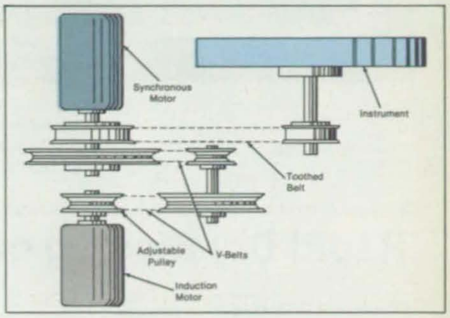
A simple setup of motors, pulleys, and belts provides both torque and synchronism.

Goddard Space Flight Center, Greenbelt, Maryland

A drive system rotates a large-inertia load at constant low speed. The system was developed to rotate a large instrument — a differential microwave radiometer that measures cosmic background radiation — at 120 rpm in synchronism with 60-Hz alternating-current power.

Synchronous stepping motors were originally selected for driving the instrument. These motors, however, were found to be incapable of starting or maintaining the desired synchronous rotation. The solution was to add an induction motor and a belt-and-pulley transmission, which effectively connects the outputs of the induction and synchronous motors in parallel (see figure). The induction motor provides the starting and maintaining torque. The diameters of the pulleys are chosen so that at the shaft on which the instrument rotates, the rotation that would be caused by the induction motor acting alone slightly leads the rotation that would be caused by the synchronous motor acting alone. The synchronous motor thus becomes an additional load with a fixed rate of rotation and forces the induction motor into synchronism with the ac power.

This work was done by Roger Ratliff of **Goddard Space Flight Center**. *No further documentation is available.*
GSC-13325



The **Induction Motor Drives** two loads: a rotating instrument and a slightly lagging synchronous motor. The induction motor provides ample torque to start and maintain rotation, and the synchronous motor ensures that the rotation is synchronized with the ac power supply.

Circle Reader Action No. 415

Fabrication Technology

Hardware, Techniques, and Processes

Rapid Dry Etching of Photoresists Without Toxic Gases

A room-temperature process may not damage underlying semiconductor wafers.

Ames Research Center, Moffett Field, California

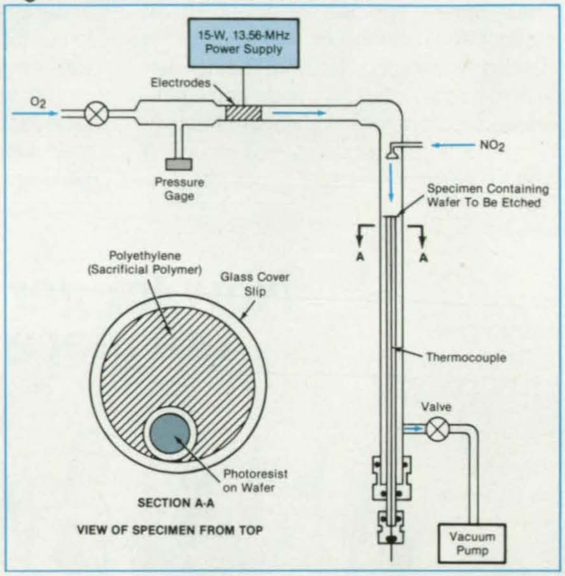
An experimental dry etching technique may have the potential to strip photoresists from semiconductor wafers without damaging the semiconductor materials. The technique strips quickly at room temperature; it is not necessary to heat the substrates and thereby cause unwanted diffusion of dopants in the semiconductors. No hazardous or toxic chemicals are used.

The technique makes use of the afterglow that exists downstream from plasma generated by a radio-frequency electric field. The constituents of the afterglow react with a sacrificial polymer to make reactive gases that quickly etch-away the photoresist. The use of the afterglow instead of the plasma itself avoids exposure of the semiconductor wafer to most of the high-energy ions, electrons, photons, and electric fields that are likely to damage devices — especially integrated circuits — in the wafer.

A plasma reactor with external electrodes generates reactive species from glowing oxygen gas (see figure). The wafer with photoresist is positioned on a pedestal at least 16 cm downstream from the reactor and around a 90° bend in the gas stream.

A sheet of polyethylene is placed next to the wafer on the pedestal. The oxygen species in the afterglow act on the polyethylene so that it outgasses substances that attack the photoresist on the wafer, converting the photoresist to harmless vapors that flow away with the oxygen stream. Such other polymers as polyoctenamer are also effective. The main criterion is that the sacrificial polymer have a low vapor pressure — less than 0.001 torr ($\lesssim$0.1 Pa) — and that it react readily with the afterglow species.

In a demonstration, a 7.5-μm-thick layer of Shipley Microdeposit S1400-27, a commonly used photoresist, was deposited on a glass cover slip and hard-baked according to the manufacturer's directions. When it was exposed to the afterglow with the sacrificial polymer, it was etched away 35 times faster than was a similar specimen without the sacrificial polymer.



The Water is Separated From the Radio-Frequency Plasma by distance and a bend. In one of the many possible configurations of the wafer and the sacrificial polymer, the wafer is almost entirely surrounded by the polymer.

This work was done by Narcinda R. Lerner and Theodore Wydeven of **Ames Research Center**. *For further information, Circle 164 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, Ames Research Center [see page 14]. Refer to ARC-11873.

Silane-Pyrolysis Reactor With Nonuniform Heating

Improved control of the pyrolysis conditions inhibits the formation of undesired hard silicon crust.

NASA's Jet Propulsion Laboratory, Pasadena, California

An improved reactor serves as the last stage in a system that processes metallurgical-grade silicon feedstock into silicon powder of ultrahigh purity. In the reactor, silane is pyrolized to silicon powder and hydrogen gas via a homogeneous decomposition reaction in free space.

In the reactor (see Figure 1), a turbulent stream of silane is injected downward from a nozzle at the top into a zone surrounded by electrical heaters. The incoming silane stream mixes with a recirculating flow of hot gasses; this heats the silane and causes it to decompose into the product silicon powder and hydrogen gas. Downstream of this recirculation/mixing/reaction zone, the flow becomes essentially a downward pipe flow consisting of the stream of spent hydrogen and suspended fine particles of silicon. A quartz liner helps to keep the product pure by preventing chemical reactions with the metal outer wall of the reactor. The hydrogen is removed through filters and recycled to an earlier stage of the overall process, while the silicon particles fall into a hopper for subsequent collection.

Some silicon powder adheres loosely

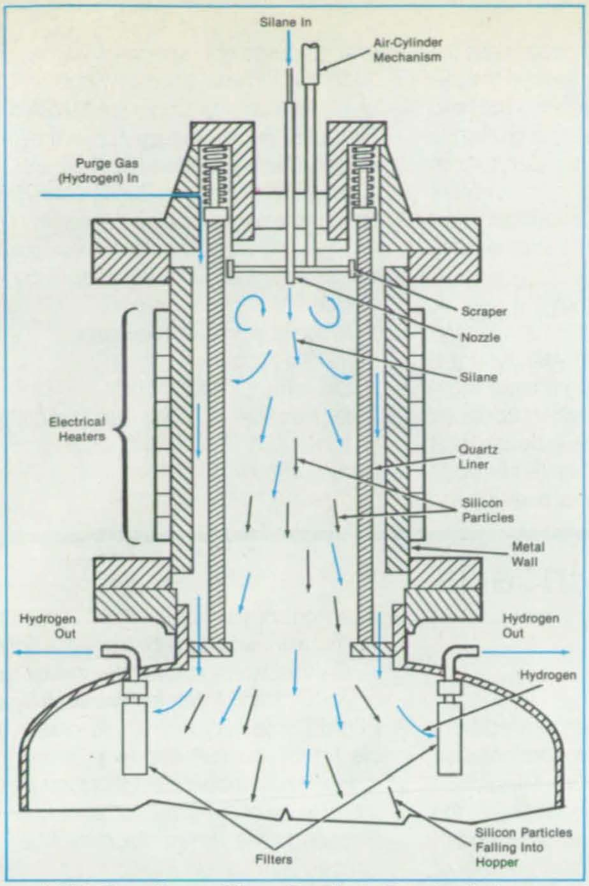


Figure 1. This **Free-Space Silane-Pyrolysis Reactor** features a set of individually adjustable electrical heaters and a purge flow of hydrogen to improve control of the pyrolysis conditions.

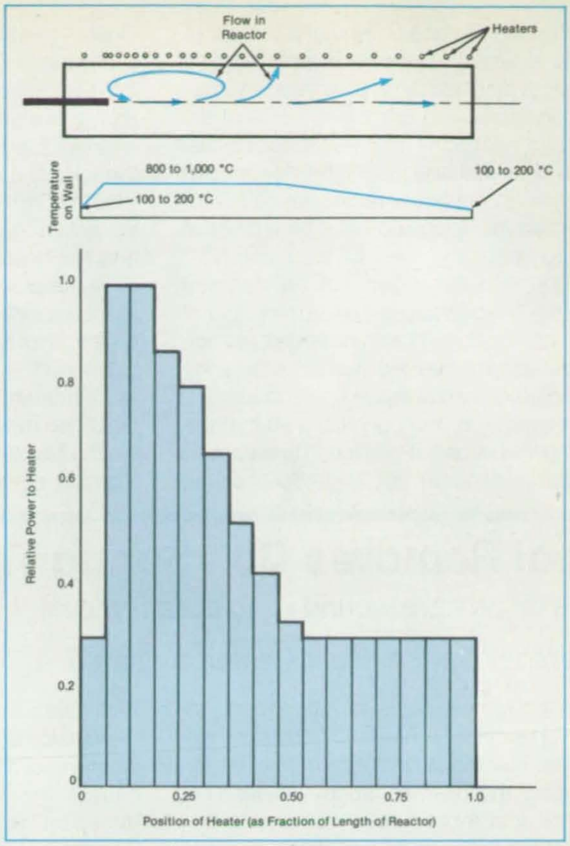


Figure 2. The **Power Supplied to Each Heater** is set in conjunction with the flow in the reactor to obtain the desired distribution of temperature as a function of position along the reactor.

to the inner surface of the quartz liner. From time to time, this powder is removed by a scraper actuated by an external air-cylinder mechanism. In a previous version of the reactor, heating by uniformly spaced induction coils resulted in a highly nonuniform distribution of temperature, which in turn caused the deposition of a hard crust of silicon near the inlet. Often, these hard silicon deposits could not be removed readily by the scraper and led to failure of the quartz liner. In the improved reactor, the average power fed to each heater zone is adjusted to a different value in accordance with the flow conditions so that the temperature on the wall along the reaction zone lies between 800 and 1,000 °C (see Figure 2) — high enough to decompose the silane but not high enough to melt the silicon (which would later freeze into the hard crust). The nonuniform heating pattern is also adjusted so that the temperature at the inlet and outlet is kept near ambient (100 to 200 °C) to prevent chemical reactions with the nozzle, the reactor vessel, and the hopper.

In the previous version of the reactor, silane migrated into the space between the quartz liner and the metal wall, where it corroded the wall. In the improved reactor, a relatively inert gas, which could be hydrogen recycled from the exhaust ports on the hopper, is continually fed through the space between the metal wall and the liner to purge this space of silane.

This work was done by Sridhar K. Iya of Union Carbide Corp. for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 35 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

Union Carbide Corporation
39 Old Ridgebury Road
Danbury, CT 06817-0001

Refer to NPO-17932, volume and number of this NASA Tech Briefs *issue, and the page number.*

Tool Removes Coil-Spring Thread Inserts

The inserts are wound up to ease removal.

Marshall Space Flight Center, Alabama

A tool removes coil-spring thread inserts (e.g., Helicoil or equivalent) from threaded holes. The tool effects essentially the reverse of the insertion process to ease removal and avoid further damage to the threaded inner surface of the hole.

The main parts of the tool are a locating cylinder, an externally threaded disk, a shaft, and a handle (see figures). A different tool must be used for each hole thread because the external thread on the disk must engage the internal thread in the hole, and the locating cylinder must guide the tool into engagement with the internal thread. The threaded disk includes a cutout that imparts a sharp edge to the forward end of the thread.

The tool is slid into engagement with the hole, then turned as though to thread it into the hole (for a right-handed thread as in the figures, clockwise when viewed from the outside of the hole, counterclockwise when viewed from the inside). This action causes the sharp leading edge of the thread on the disk to pry the outer end of the insert away from the inner surface of the hole. When the tool comes to rest after this initial motion, the end of the insert lies between two toothed clamping surfaces: one stationary in the disk and the other on a part that rotates about a pin and that is pressed against the insert by a spring.

The tool is then turned in the opposite direction, and the ratcheting action of the rotatable part of the clamp grips the end of the insert tightly. As the tool continues to turn, this action winds up the insert to a slightly smaller diameter, thereby reducing the friction between the insert and the inner surface of the hole as it threads the insert out of the hole.

This work was done by Gerald J. Collins, Jr., Gary J. Swenson, and J. Scott McClellan of Morton Thiokol, Inc., for **Marshall Space Flight Center**. *For further information, Circle 111 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 14]. Refer to MFS-28432.

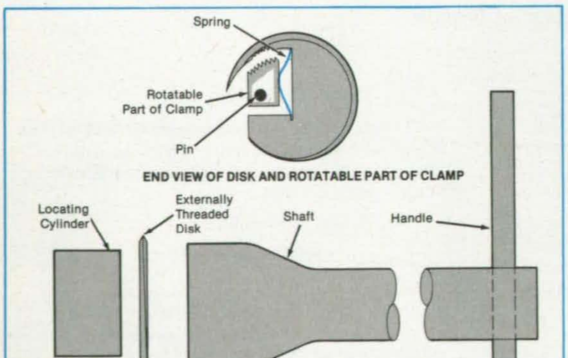


Figure 1. The **Tool Threads into the Hole**, pries the insert loose, grips the insert, then pulls the insert to thread it out of the hole.

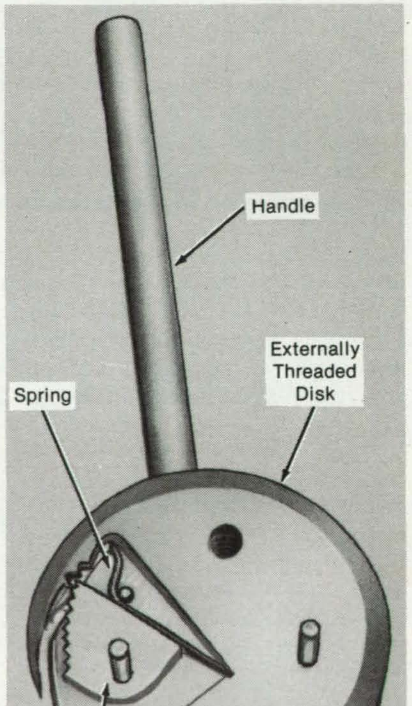


Figure 2. The **Locating Cylinder Has Been Removed** to show the working end of the tool more clearly in this photograph.

Self-Aligning Sensor-Mounting Fixture

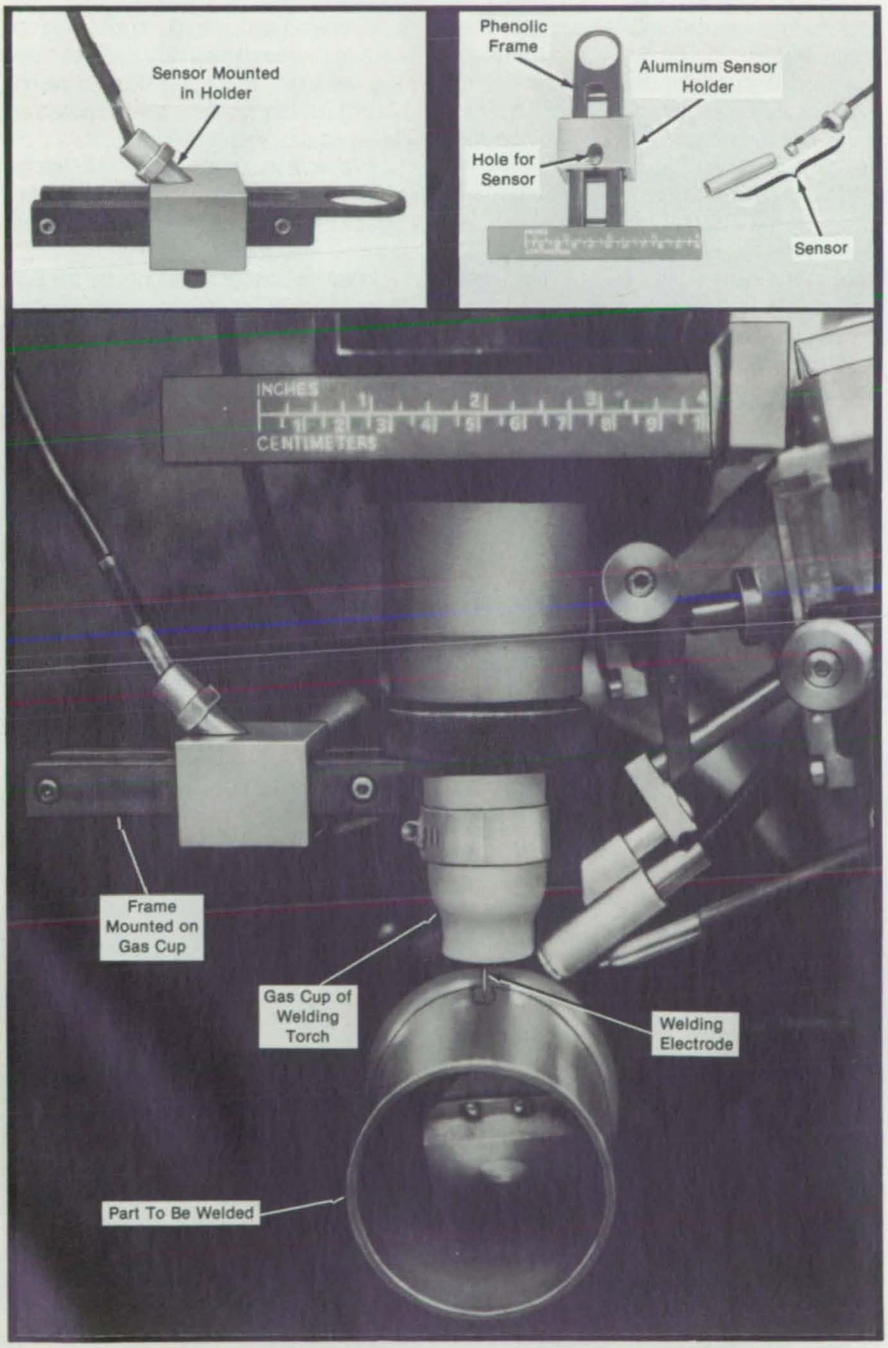
Optical welding sensors can be replaced without realignment.

Marshall Space Flight Center, Alabama

A mounting fixture for an optical weld-penetration sensor enables accurate and repeatable alignment. Designed for use on a gas/tungsten arc-welding torch, the fixture replaces a multipiece bracket that was inaccurate and fragile and required time-consuming custom setup.

The new fixture includes a linen-phenolic frame and an aluminum sensor holder (see figure). At one end of the frame, a ring encircles the gas cup of the torch; at the other, a pair of tracks support the holder. The holder maintains an optical sensor at an angle of 47° to the welding plane, an angle that provides an optimum feedback signal from the weld pool.

If it is necessary to replace a sensor, the sensor is simply removed from the holder, and a new one is inserted. The holder automatically aligns the new sensor in the position and orientation of the previous sensor. If it is necessary to move the sensor to accommodate a longer or shorter cup or electrode, a setscrew on the bottom of the holder



The **Sensor-Mounting Fixture** is simple and easy to use. Assembled on a welding torch, it holds the sensor securely and keeps it pointed toward the weld pool.

is loosened, and the holder is translated along the tracks until it once again points directly at the weld pool. The holder keeps the sensor at the same 47° viewing angle.

Adjusting screws serve to remove side play from the holder. The phenolic frame insulates the holder electrically from the torch.

This work was done by Jeffrey L. Gilbert and Rhonda J. Mills 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 14]. Refer to MFS-29663.

A Compact Gas/Tungsten-Arc Welding Torch

Despite its extremely small size, the torch contains all the usual components and delivers high current.

Marshall Space Flight Center, Alabama

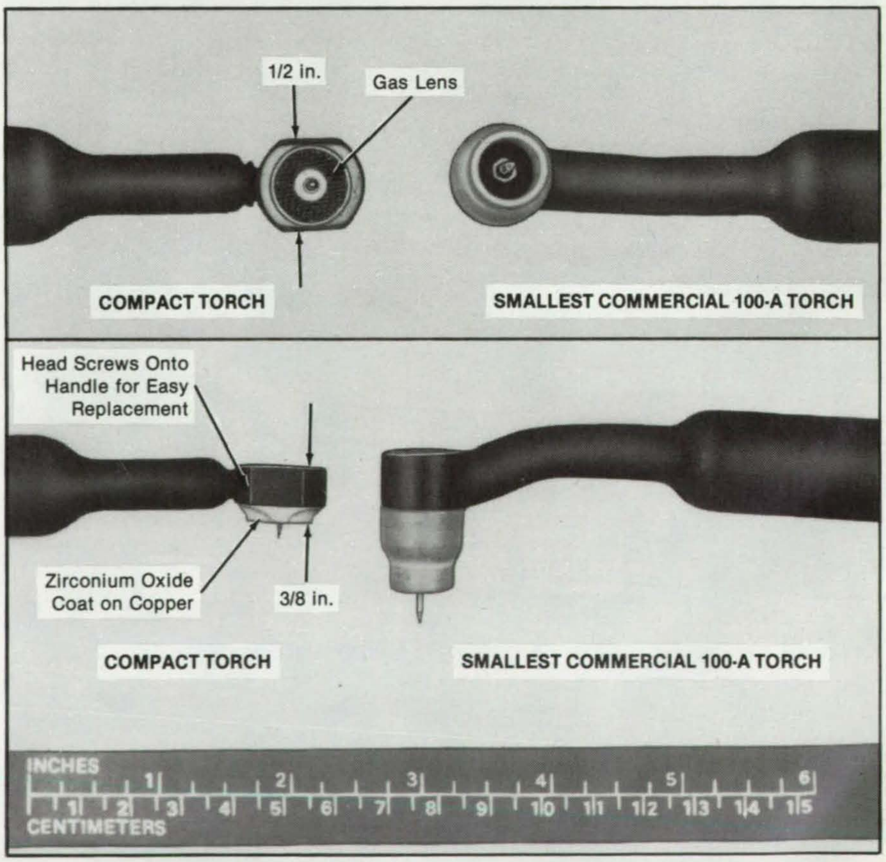
A compact gas/tungsten-arc welding torch delivers 100-A current, yet can be used in confined spaces inaccessible to even the smallest commercially available torch. The torch is only 3/8 in. (9.5 mm) high and 1/2 in. (12.7 mm) wide (see figure).

The torch was developed for welding fuel lines on the Space Shuttle main engine (where the clearance on the back side of the weld between a fuel line and its jacket is about ½ in., too small to permit access by a commercial welding torch). The compact torch should also be useful for welding in other normally inaccessible locations.

The copper cup of the torch is plasma-spray-coated with zirconium oxide. The coat insulates the torch thermally and electrically. The welding head is screwed onto the handle of the torch; it can thus be removed and replaced easily and quickly.

This work was done by Gene E. Morgan 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 14]. Refer to MFS-29668.



The **Compact Torch** is smaller than the smallest gas/tungsten-arc welding torch on the market. The torch nevertheless accommodates the usual components, including an inert-gas lens around the electrode holder.

Compact Pinch Welder

An air-driven handtool makes precise spot welds.

Marshall Space Flight Center, Alabama

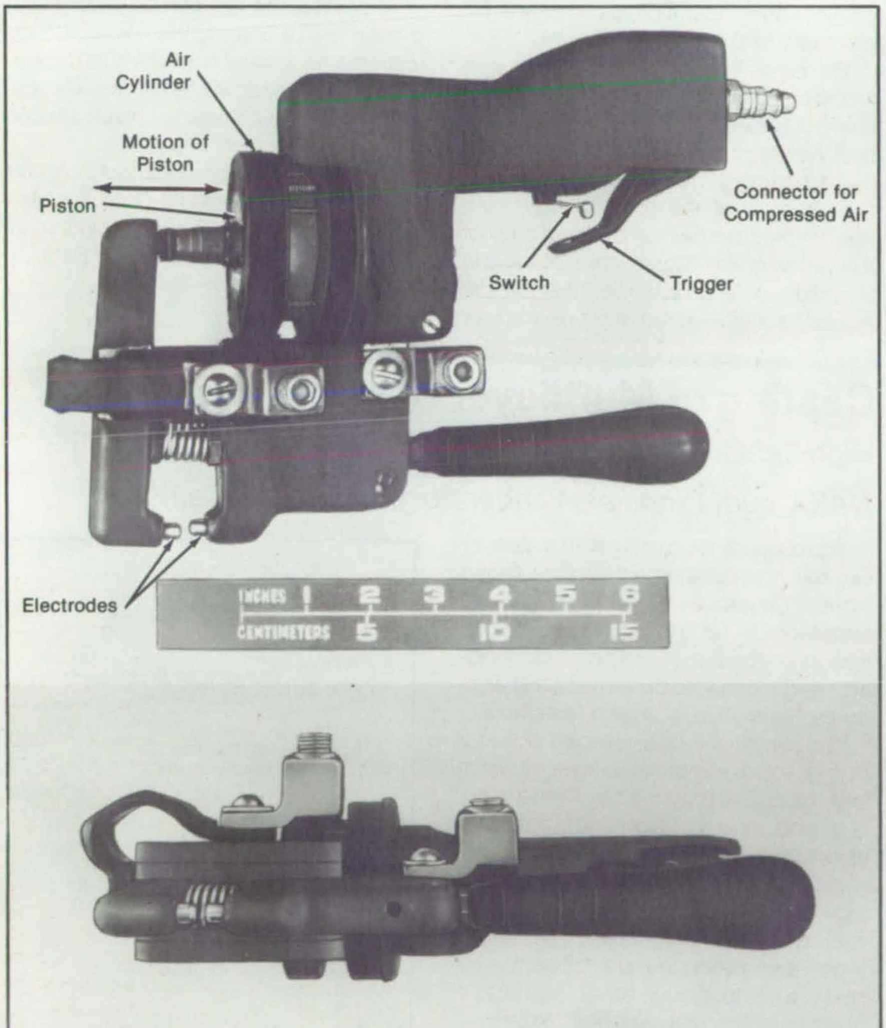
A spot welder is designed for bonding insulated metal strips together. The welder is compact, measuring only about 33.5 cm in its largest linear dimension (see figure).

The hand-held unit is a welding gun that uses compressed air to drive its opposed electrodes into the workpiece. It provides a higher, more repeatable clamping force than does a manually driven gun and thus produces weld joints of higher quality. It is light in weight and therefore can be positioned precisely by the operator.

Holding the gun by its handles, the operator places the electrodes at the spot-weld site and presses the trigger on the handle. Partially depressing the trigger activates the pneumatic cylinder, thereby clamping the electrodes on the workplace. Fully depressing the trigger closes the welding circuit and enables welding to take place. Releasing the trigger breaks the welding circuit and allows the pneumatic cylinder to vent, which enables the return spring to return the welding electrodes to the original position.

This work was done by Gene E. Morgan and Clark S. Thomas 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 14]. Refer to MFS-29670.



The **Pinch Welder** clamps electrodes on weldments with a strong, repeatable force. Compressed air is supplied through a fitting on one handle. A small switch on the same handle starts the welding process when the operator presses it with the trigger.

Penetrant-Indication-Measuring Compass

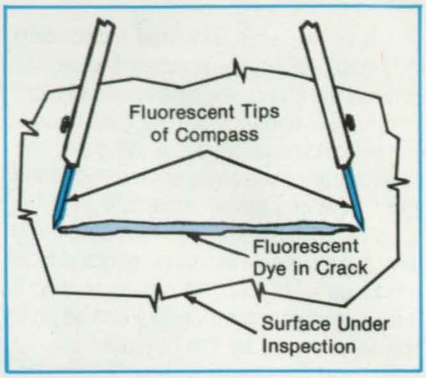
Fluorescent tips are easily viewed against the background.

Marshall Space Flight Center, Alabama

A modified drafting compass is well suited to measurement of the length of a crack or the width of an area stained by the penetrant-dye-inspection method. The compass can be equipped with any of a variety of standard curved or straight pointed tips. The modification consists in coating the tips with a dye that fluoresces light pink under the same ultraviolet inspection light that causes the penetrant dye to fluoresce yellow green.

The compass can be used in locations inaccessible to a conventional fluorescent comparator; e.g., where the curved tips might be needed to reach around a corner, where a comparator might not fit. The compass can eliminate errors of optical distortion in the comparator. It can also eliminate errors of interpolation, which can be significant inasmuch as standard fluorescent comparators give linear indications only in increments of 0.030 in. (0.75 mm).

By use of the microadjustment screw on the compass, the distance between the tips is adjusted in the customary manner until the tips point to the ends of the crack. The adjustment is easy because the pink fluorescence of the tips is easily seen against the dark background and against the yellow green fluorescence of the dye (see figure). The distance between the points is then measured with a micrometer or scale in the usual way.



The **Tips of the Compass** fluoresce with one color, the penetrant dye in the crack with another color. The contrast between the colors facilitates measurement of the length of the crack.

If desired, the tips can be coated with plastic before coating them with fluorescent dye, to prevent scratching of the surface to be inspected. All of the components can be purchased at hardware and drafting-supply stores.

This work was done by Lloyd Schaefer of Rockwell International Corp. for **Marshall Space Flight Center.** *For further information, Circle 12 on the TSP Request Card.*
MFS-29643

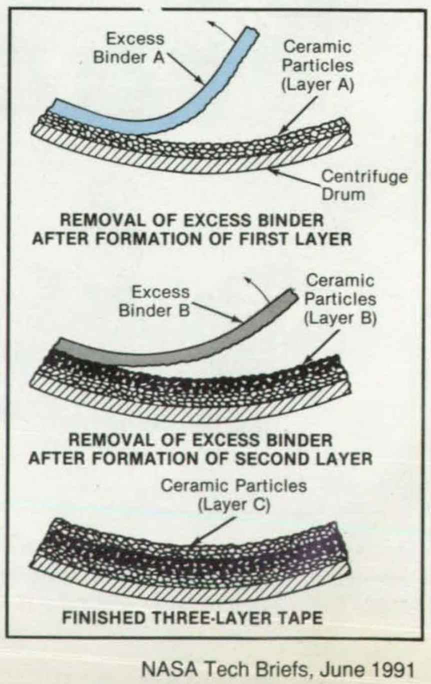
Casting of Multilayer Ceramic Tapes

High-density ceramic tapes are made by centrifugal casting.

NASA's Jet Propulsion Laboratory, Pasadena, California

A procedure for casting thin, multilayer ceramic membranes, commonly called tapes, involves centrifugal casting at accelerations of 1,800 to 2,000 times the normal gravitational acceleration. These tapes are used in capacitors, fuel cells, and electrolytic separation of oxygen from the air.

The layers of a tape are cast one at a time on top of any previous layer or layers (see figure). Each layer is cast from a slurry of ground ceramic suspended in a mixture of solvents, binders, and other components. The high casting force in the centrifuge produces very uniform and tightly packed cast ceramic layers. The flexible tapes thus produced are subsequently fired in a kiln to remove solvents and other impurities. The resulting hard multilayer ceramic "sandwiches" can contain elec-



A **Three-Layer Ceramic Tape** is cast in a centrifuge. After a ceramic layer is cast and cured, the film of excess binder is peeled off before casting the next layer.

trode and insulating layers.

Having a density lower than that of the ceramic, the excess solvent/binder floats to the surface during centrifugation. Because only the minimum amount of solvent/binder necessary to fill the interstices remains in the ceramic layer, the strength of the bonds in the ceramic layer is very high. After curing, the film of excess binder on top of the ceramic layer can be peeled off easily without disturbing the ceramic layer beneath.

The next layer can then be cast on top of the exposed layer, provided that it is made with a different solvent/binder solution that does not attack the exposed layer. Even if several layers are to be cast, only two solvent/binder mixtures, used in alternation, should be required, because only the immediately preceding layer is exposed and therefore likely to be affected by the solvent in the next layer.

To enhance ease of handling and to provide easier removal of the tapes from the centrifuge drum, a protective coating layer can be deposited and cured before casting the first ceramic layer. A similar layer can also be added after casting the last ceramic layer.

This work was done by Earl R. Collins, Jr. of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 93 on the TSP Request Card.*

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

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

Refer to NPO-17166, volume and number of this NASA Tech Briefs *issue, and the page number.*

Computed Tomography for Inspection of Thermistors

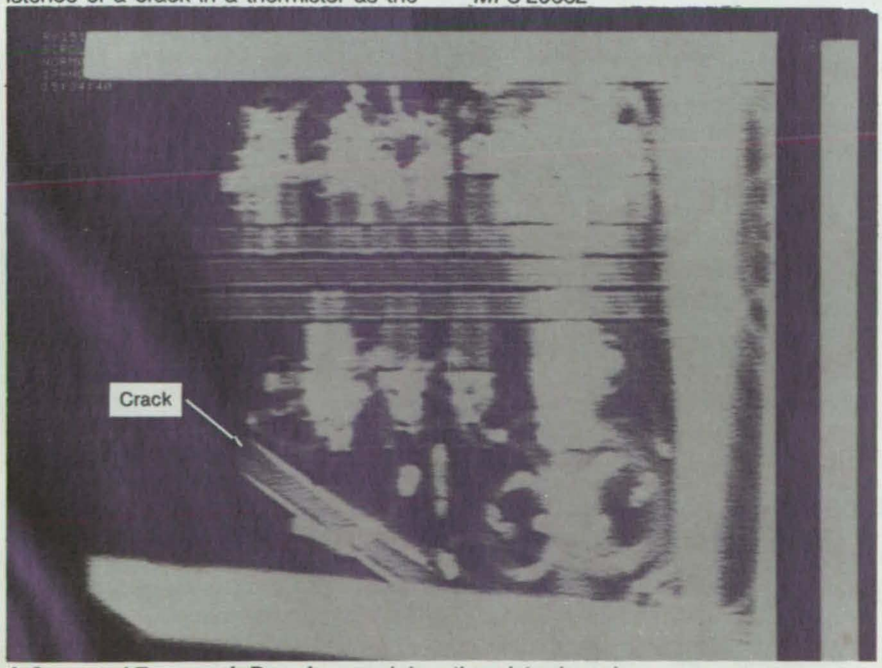
Cracks invisible in conventional x-radiographs can be seen.

Marshall Space Flight Center, Alabama

Computed tomography (CT) enables the identification of cracked thermistors without disassembly of equipment that contains them. CT digital radiography can resolve 65,000 shades of gray; it can be used to discern cracks in thermistors that go unnoticed by conventional radiographs and image enhancers, which offer gray scales of only 16 and 256 shades, respectively. It is unnecessary to destructively open sealed equipment to confirm or deny the supposed existence of a crack in a thermistor as the source of an electrical failure.

A CT unit is used to scan the equipment and locate the thermistors. Further scans are then made in various radial orientations perpendicular to the plane of the devices to find cracks (see figure).

This work was done by Lloyd A. Schaefer of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information, Circle 71 on the TSP Request Card. MFS-29662*



A **Computed Tomograph Reveals** a crack in a thermistor (arrow).

Apparatus for Chemically Treating Graphite Fibers

The apparatus dries fibers in an inert gas and is adaptable to different chemical solutions.

Langley Research Center, Hampton, Virginia

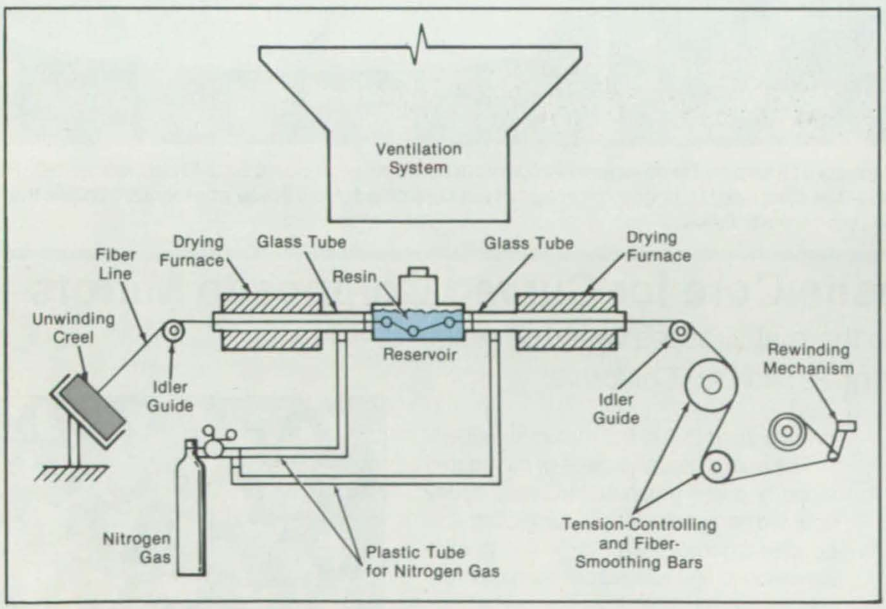
A new apparatus for the chemical treatment of graphite-fiber tow has been developed. The apparatus applies chemical solutions to commercially purchased unsized fibers or in-house-made fibers, to improve the following: handling of fibers, interface bonding of fiber to resin matrix during prepreg fabrication, and interface bonding in laminates during molding process. The apparatus is ideally suited for research and development of prototype, tailor-made low-solid-content solutions.

Standard units used by manufacturers to apply sizings to fibers are not designed for research and development and do not provide for predrying and postdrying in inert gases. They are also not easily adaptable to different chemical solutions. The new apparatus was designed for all thermoplastics and thermoset resin solutions to be used with graphite-fiber tow consisting of 3,000 to 12,000 filaments per tow, but it will accommodate other solutions, other numbers of filaments, and other types of fibers.

The apparatus is illustrated in the figure. A spool of unsized graphite fiber is attached to an unwinding creel and guided to a glass tube that runs through a furnace. The furnace is used to remove any moisture that may be on the fiber and to prepare the surface of the fiber for the application of resin. The fiber runs through a reservoir of resin, and after leaving the reservoir, it enters a second furnace, which removes the solvent picked up in the reservoir. The fiber is next run over a round bar 12 in. (30.5 cm) in diameter and under a round bar 3 in. (7.6 cm) in diameter, to control its tension and to smooth it. Nitrogen gas is run through the glass tube to prevent the fiber from picking up moisture and to maintain an inert environment, which is especially important when flammable solutions are employed. The fiber is rewound onto a bar that contains an empty cardboard core. The bar is turned with a hydraulic pump.

This system was designed for research and development, with predrying and postdrying in inert environments. It is easily adaptable to different chemical solutions and is well suited for small-scale, prototype, tailor-made fiber systems. The system can be used to develop fiber/resin composites for aerospace, automotive, marine, and other applications.

This work was done by Clarence E. Stanfield of **Langley Research Center**. *No further documentation is available.*
LAR-13959



This **Research-and-Development Apparatus** is designed for the application of all thermoplastics and thermoset resin solutions to fibers.

Verifying X-Radiographs With Computed Tomographs

A nondestructive technique gives added confidence in inspection.

Marshall Space Flight Center, Alabama

Ambiguous indications in radiographic inspections of metal castings can be checked by computed tomography. Fast and inexpensive conventional x-ray inspection is used to make a film image of the overall casting, and slower, more costly computed tomography is used to reinspect the relatively few parts of the casting that present possible diffraction patterns or other difficult-to-interpret features.

The method has been effective in resolving ambiguities in radiographs of turbine blades. A nondestructive technique, computed tomography provides the same information as does metallurgical sectioning.

In computed tomography, x or γ rays penetrate a casting in a fan-shaped pattern. An array of detectors on the opposite side collects the energy that passes through the casting (see Figure 1). A computer analyzes the detector signals and constructs a density map of the casting at various cross sections on a video monitor.

For example, a conventional radiograph may contain a "ghost" indication, caused by grain diffraction, that may be misconstrued as a flaw or may hide a real flaw (see Figure 2). A tomograph of the affected area shows whether the pattern in it is a diffraction "ghost" or representative of a real feature of the casting.

This work was done by Jagatjit Roy and Antonio G. Pascua 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 14]. Refer to MFS-29649.

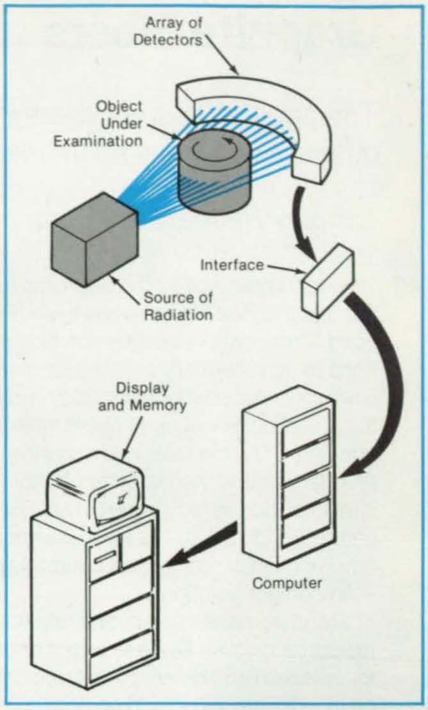


Figure 1. **X- or γ-Ray Computed Tomography** can be used to verify ambiguous indications in conventional radiographs.

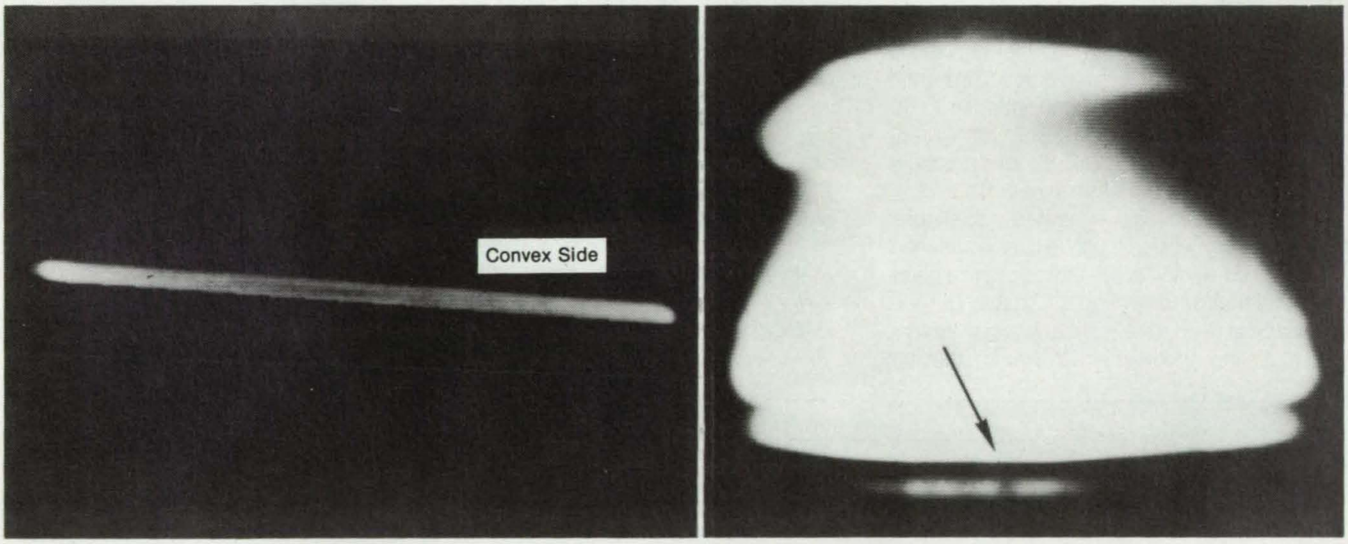


Figure 2. An **Enhanced Conventional X-Ray Image** of a turbine blade (upper photograph) contains what could be a diffraction "ghost" in the "fir tree" region just below the root of the blade. The computed tomographic image of the suspected ghost (lower photograph) shows that the ghost is, indeed, caused by grain diffraction, not by inner flaws.

Lightweight Composite Core for Curved Composite Mirrors

Complicated figure errors due to thermal stresses would be reduced.

NASA's Jet Propulsion Laboratory, Pasadena, California

A new type of composite core material for curved composite mirrors has been proposed. In comparison with honeycomb and other lightweight core materials, this structure is less mechanically anisotropic, can be tailored to have less distortion due to temperature changes, is naturally vented, and is easily fabricated. This core material also conforms readily to spherical and paraboloidal curvatures and can be fabricated in large sizes (1.0 to 2.0 meters or larger).

The core material is made of corrugated strips of cured graphite-reinforced epoxy oriented perpendicularly to each other and bonded together (see Fig. 1) The core is sandwiched and bonded between two con-

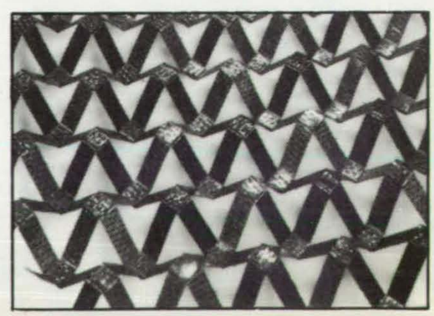


Figure 1. **Strips Cut From Corrugated Sheets** of graphite/epoxy are bonded together at crests and valleys.

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cave facesheets (see Fig. 2). It will conform to the highly curved mirror facesheets with low bending stresses. If the facesheets and the core materials are tailored to have the same thermal expansion coefficient, thermal distortions, which give rise to complicated figure errors, can be minimized.

The development of corrugated-strip core material continues. Researchers are seeking the best adhesive, bonding method, and corrugation width and will evaluate the thermal and mechanical properties of various cores.

This work was done by Christopher C. Porter, Paul J. Jacoy, and Wesley P. Schmitigal of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 7 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 14]. Refer to NPO-17858.

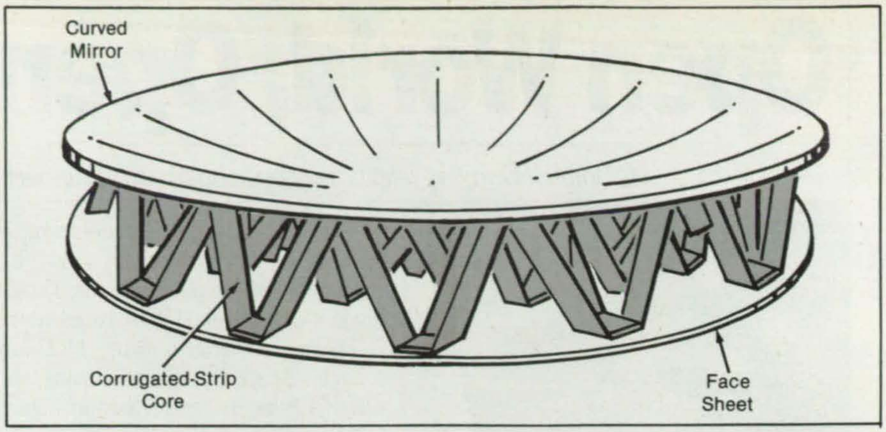


Figure 2. A **Corrugated-Strip Core** like that shown in Figure 1 would be bonded to a curved mirror and to a face sheet, forming a supporting structure for the mirror.

Plasma-Arc Torch for Welding Ducts in Place

Modifications enhance maneuverability in confined spaces.

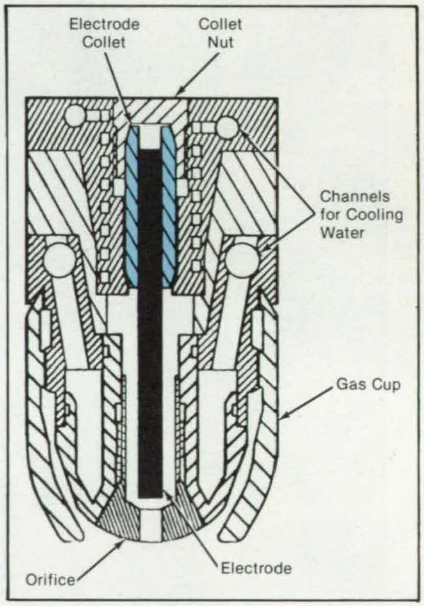
Marshall Space Flight Center, Alabama

A plasma-arc-welding torch has been redesigned to make it more suitable for applications in which it must be moved in circular or other orbits about stationary cylindrical workpieces. It could be used, for example, to weld a duct that is already mounted in place for its intended use.

The improved design (see figure) preserves those elements of the original design that are critical to performance and endurance, but modifies other elements to decrease the overall size of the torch. The original torch works well where radial access is unrestricted and the torch is not moved beyond ±90° around the workpiece. The improved torch can be used where access is restricted to tightly radially confined spaces and is compatible with mechanisms that rotate it 360° around a stationary part with a circular weld joint.

The height of the torch has been reduced from about 6 in. (15.2 cm) in the original to 2.4 in. (6.1 cm) in the improved design. Whereas the fittings for cooling water were placed on the top in the original design, they are placed on the side in the improved design. Side-mounted fittings are preferable for orbital motions because they improve radial clearance, make the water hoses less vulnerable to crimping, and reduce the mechanical load on the torch. Also in the improved design, the electrode collet and collet nut are installed and removed through a hole in the top; this makes installation and removal much easier than in the original design.

This work was done by Kenneth J. Gangl of Rockwell International Corp. and Ernest Bayless and Alan Looney of **Marshall Space Flight Center**. *No further documentation is available.*
MFS-29701



The **Improved Plasma-Arc Torch** is configured for compactness and maneuverability to facilitate welding of stationary ducts in confined spaces.

Stacking Oxygen-Separation Cells

Solid-electrolyte units feature decreased complexity in structure and assembly.

NASA's Jet Propulsion Laboratory, Pasadena, California

A simplified configuration and procedure have been developed for the assembly of stacks of solid-electrolyte cells that separate oxygen from air electrochemically. A previous, more complicated version of such a cell is described in "Improved Zirconia Oxygen-Separation Cell" (NPO-16161), *NASA Tech Briefs*, Vol. 12, No. 4 (April 1988), p. 42. The new configuration and procedure reduce the number of components and thus reduce the probability of such failures as gas leaks, breakdown of sensitive parts, and electrical open or short circuits.

Electrode and electrolyte layers are stacked alternately. Such essential features as seals, gas-distribution channels, and manifolds are built into the components; they do not have to be added externally. The electrode material is strontium-doped lanthanum manganite (LSM). The electrolyte is yttria-stabilized zirconia (YSZ).

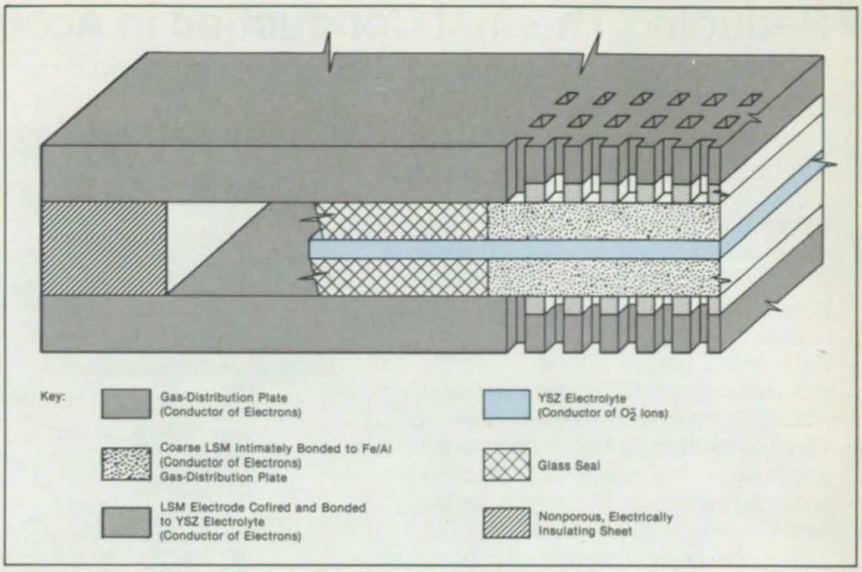
First, an inner sandwich of LSM/YSZ/LSM (see figure) is made. The sandwich is placed in a fixture, and a recess about 1 mm wide is etched or removed mechanically around the rim of each LSM layer.

Glass powder in an organic binder, which will be heated subsequently to make an edge seal, is applied to these recesses.

A gasket of nonporous, electrically insulating material is placed around the edge of a gas-distribution plate. Made of dense iron/aluminum or nickel/aluminum alloy, the electrically conductive plate contains an array of channels.

The LSM/YSZ/LSM sandwich, its rim coated with the glass powder, is placed on the gas-distribution plate. A second gas-distribution plate, also gasketed, is placed on top of the LSM/YSZ/LSM sandwich. Sandwiches and gas-distribution plates are added to the stack until the requisite number of cells have been assembled.

As the stack is brought up to operating temperature, the glass powder turns into a nonporous seal around the rim. The stack is compressed during heating to ensure that the glass spreads out to form the seal and that an intimate contact of low electrical resistance forms between the gas-distribution plates and the electrode/electrolyte sandwiches.



One Cell of a multicell stack includes an electrolyte layer between two electrode layers. Gas-distribution plates above and below the electrodes bring reactants to and from the surfaces of the electrodes.

This work was done by James E. Schroeder of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 25 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 14]. Refer to NPO-17223.

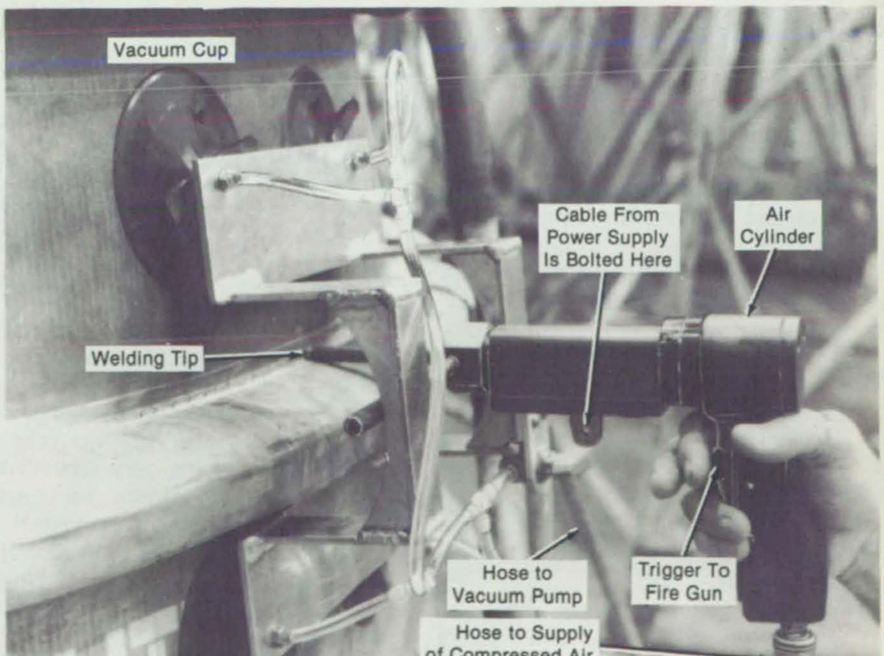
Spot-Welding Gun Is Easy To Use

Air pressure and vacuum, rather than the technician, provide the welding force.

Marshall Space Flight Center, Alabama

An electrical-resistance spot-welding gun is designed to produce more welds per unit time by decreasing the technician's effort and fatigue. The gun is connected by a hose to a supply of compressed air, and vacuum cups on a frame that holds the gun on the workpiece are connected by a hose to a vacuum pump. When the technician depresses a trigger on the handle of the gun (see figure), the air actuates a piston in an air cylinder, pressing the welding tip against the workpiece with a force of about 40 lb (178 N). The force of the atmosphere against the vacuum cups holds the tool securely when the air pressure drives the welding tip against the workpiece; the technician does not have to furnish the reaction force. The only force the technician need exert is the squeeze on the trigger.

Welding current is automatically turned on when the force of contact reaches the required level and turned off before the welding tip is withdrawn from the workpiece. A cable (not shown in the figure) carries the current from the welding power supply to the gun.



Vacuum Cups on the Frame Secure the Welding Gun to the workpiece while compressed air drives the welding tip against the workpiece to make a spot resistance weld. When the weld has been completed, the vacuum in the frame cups is released so that the frame and gun can be moved to the position of the next spot weld.

This work was done by Gene E. Morgan and Francis H. Nguyen of Rockwell International Corp. for **Marshall Space Flight Center.** *For further information, Circle 60 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 14]. Refer to MFS-29693.

Reducing Thermal Conduction in Acoustic Levitators

Piezoelectric driving elements would be protected from excessive temperatures.

NASA's Jet Propulsion Laboratory, Pasadena, California

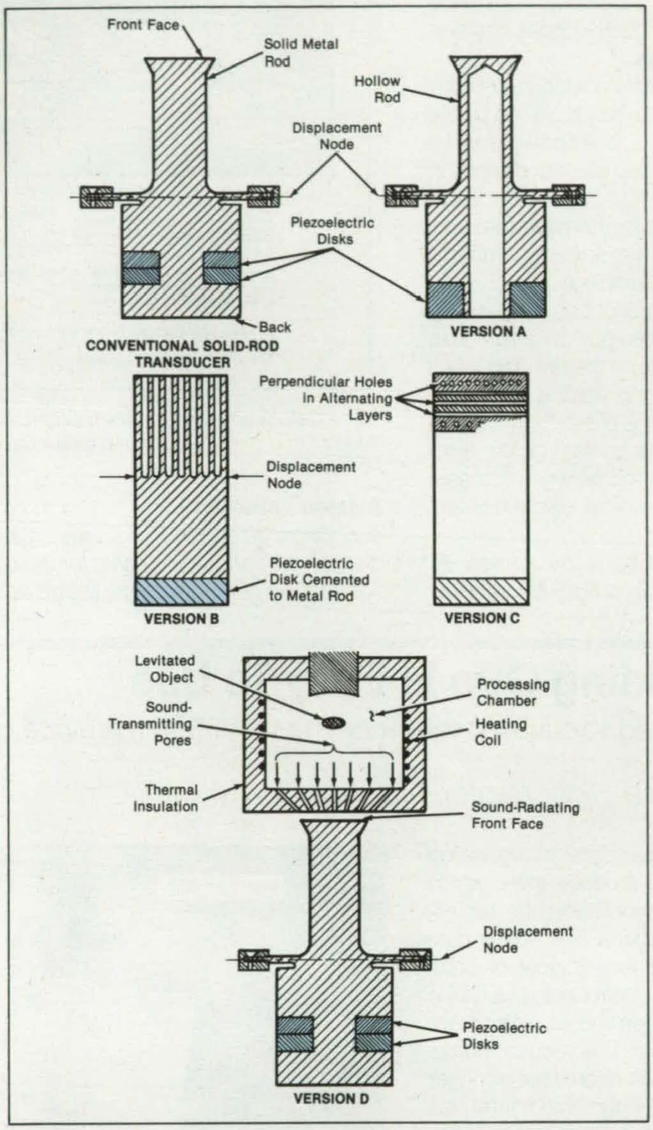
Acoustic transducers containing piezoelectric driving elements would be made more resistant to heat by reduction of the effective thermal-conductance cross sections of the metal vibration-transmitting rods in them, according to a proposal. Such transducers are used to levitate small objects acoustically for noncontact processing in furnaces. The reductions in the cross sections could also increase the amplitudes of the transmitted vibrations and reduce the loss of heat from the furnaces.

In a conventional piezoelectric transducer, the rod is solid and extends into the furnace (see figure). The transducer is mounted to the furnace housing at the zero-displacement node. Piezoelectric disks in the back section drive the transducer, causing the front face of the rod to vibrate like a piston so that it couples sound waves into the furnace levitation chamber. Unfortunately, the solid core readily conducts heat away from the furnace. This not only reduces the efficiency of the furnace but also increases vulnerability to fatigue at the zero-displacement node and endangers the piezoelectric disks, which depolarize above a critical temperature and no longer function.

Several versions of the reduced-cross-section configuration are envisioned. In one (version A in the figure), the rod would contain a hollow central core. The cross-sectional area available for the conduction of heat toward the back section would, therefore, be reduced. To prevent the transfer of heat along the core by convection, the core would not be made to extend through the front face. The end of the core, just behind the front face, would be made conical or hemispherical to avoid bending resonance of the front face.

In general, the amplitude of the displacement of the front face of such a transducer varies in inverse proportion to the effective cross section of the rod; therefore, as the cross section is decreased, the acoustic output should increase. The device would act as a stepped-horn transducer.

In version B, many small axial holes would be drilled in the rod from the front face to the zero-displacement node. A thin plate would cover the front face. The holes would reduce the flux of heat to less than one-tenth that of a solid rod. Again, the acoustic output would increase with the decrease in the effective cross section. Version B would also act as a stepped-horn transducer.



A Conventional Solid-Rod Transducer Contrasts with reduced cross-section version (A through C) and a porous-heat-barrier version (D). All four new concepts are intended to reduce the flow of heat to the transducer, both to protect its piezoelectric driving elements and to increase the efficiency to the furnace.

In version C, holes would be drilled perpendicular to the axis of the rod, orthogonal to each other in alternating layers. To maintain adequate dynamic strength, the number of holes per layer would be decreased toward the zero-displacement node. This would reduce the effective cross section exponentially toward the front end, producing the amplification characteristic of an exponential-horn transducer. A further advantage of the clear transverse holes is that they could be used as channels for cooling gas, which would help to keep the piezoelectric disks at a safe temperature without interfering with the radiated sound field.

In version D, the cross section for thermal conduction would be reduced, not by holes in the transducer, but by interposing a porous barrier between the furnace levitation chamber and the front face. The pores would be large enough to carry adequate acoustic energy into the chamber and would be inclined at various angles to minimize the transfer of heat to the transducer. This version would be less acoustically efficient but more thermally efficient.

This work was done by Ernst G. Lierke, Emily W. Leung, and Balakrishna T. Bhat of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 11 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 14]. Refer to NPO-17620.

Growing Cobalt Silicide Columns in Silicon

Codeposition by molecular-beam epitaxy would yield a variety of structures.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed fabrication process would produce three-dimensional nanometer-sized structures on silicon wafers. It would enable control of the dimensions of metal and semiconductor epitaxial layers in three dimensions instead of the usual single dimension (perpendicular to the plane of the substrate). The process might be used to make arrays of highly efficient infrared sensors, high-speed transistors, and quantum wires, for example.

In an experimental version of the process, cobalt and silicon are deposited together by molecular-beam epitaxy on a silicon substrate in the atomic ratio of about 1:10. The silicon-rich mixture produces a layer of single-crystal, epitaxially aligned columns of cobalt silicide ($CoSi_2$) in a silicon matrix (Figure 1). The columns are about 50 nm across, 200 nm apart, and — depending on the total amount of material deposited — 100 nm high. Other diameters and spacings can be produced by adjusting the ratio of cobalt to silicon, the temperature of the substrate, and the rate of deposition. In the proposed process, $CoSi_2$ columns would be started and stopped by turning the cobalt beam on and off during deposition.

For the fabrication of electronic devices, both the shapes and the locations of the columns would have to be controlled. One possible technique for doing this is electron-beam lithography [See "Making Submicron $CoSi_2$ structures on Silicon Substrates" (NPO-17736), *NASA Tech Briefs* Vol. 13, No. 9 (September, 1989), page 105]. An electron beam could be used to crystallize selected sites on a layer of amorphous $CoSi_2$, and then the amorphous material surrounding the single-crystal sites would be selectively etched away. If a new layer were then added by silicon-rich molecular-beam epitaxy, it seems likely that the $CoSi_2$ columns would be located predominantly on the crystallized sites, and the silicon matrix would form around them. It may even be possible to form walls, in addition to columns, of $CoSi_2$ by this method.

If free-standing columns are needed, the silicon matrix could be removed by plasma etching in carbon tetrafluoride, which attacks silicon 100 as fast as it attacks $CoSi_2$. Thus, all the matrix could be removed before the columns were altered substantially.

Metal/semiconductor systems other than cobalt/silicon are also promising for the growth of columns. They include nickel/silicon, and platinum/silicon. Germanium/germanide and compound semiconductors may also be suitable.

A variety of devices might be made by the proposed three-dimensional-fabrication technique. These include the following (see Figure 2):

- The metal contact of a Schottky diode would be formed as a comblike silicide structure. This would increase the quantum efficiency.
- Vertical "wires" of $CoSi_2$ would be formed in a silicon matrix. The diameter of the wires would be so small — only a few nanometers — that quantum electronic effects would come into play. The quantum wires would have novel electrical and optical properties that could lead to entirely new types of semiconductor devices.
- Horizontal-geometry versions of such devices as the metal-base transistor and the permeable-base transistor could be fabricated. The fabrication of such devices would require fewer processing steps than those of vertical-geometry devices.
- Layers of short silicide columns embedded in the silicon matrix could be used as internal photoemission detectors.

Figure 1. **Cobalt Silicide Columns Are Embedded** in a silicon matrix, as shown in this cross-sectional transmission electron micrograph. The columns rest on a silicon substrate.

Figure 2. A **Variety of Device Structures** are possible with cobalt and silicon codeposition by molecular-beam epitaxy. The structures can be fabricated in fewer steps than in conventional processes and offer either improved or entirely new properties.

This work was done by Robert W. Fathauer of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 97 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 14]. Refer to NPO-17835.

Fabrication of Lightweight Mirrors Via CVD

A scalable, rapid process yields parts in nearly net shape.

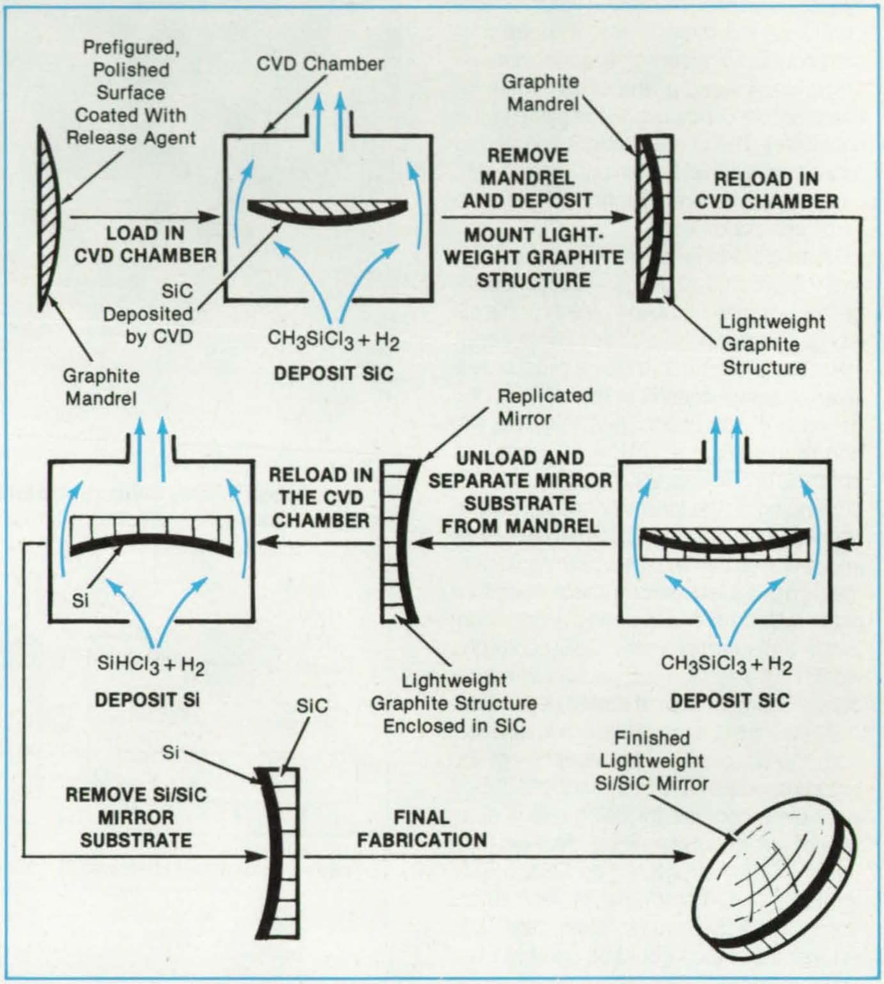
Langley Research Center, Hampton, Virginia

There continues to be a need to develop new methods and technologies capable of efficiently and cost-effectively producing high-performance optics in large and small sizes. Large, lightweight optical components, particularly mirrors, are required for many space-based systems, such as light detection-and-ranging (LIDAR) systems; astronomical telescopes; solar collectors; and concentrators and deflectors for ions, other high-energy particles, and laser beams. Current processes for the fabrication of optical components are not capable of rapidly producing high-performance optics, particularly large mirrors with diameters of 1 meter or more.

A new chemical-vapor deposition (CVD) process has been developed for fabricating lightweight Si/SiC mirrors. The process involves three CVD steps: one to produce the faceplate of the mirror, the second to form the lightweight back structure that is deposited integrally with the faceplate, and the third and final step to deposit a layer of optical-grade material (e.g., Si) onto the front surface of the face plate. The figure and finish of the mirror are fabricated into this latter material.

The figure shows in detail the CVD fabrication procedure. Ideally, the three CVD depositions can be completed in about 6 weeks, in sharp contrast to the fabrication of glass mirrors, which can take several months to a few years. CVD can produce dense, highly pure polycrystalline materials that can be polished to surface figures of high precision and finish.

Using this process, 7.5-cm-diameter flat and curved lightweight mirrors of Si/SiC were successfully fabricated. The mirrors were polished to a figure better than one-fifth of a wavelength and a finish of better than 10 Å rms. This process is scalable and is quite general in that mirrors of other ceramic materials can also be fabricated. For instance, such advanced ceramic materials as TiB_2 and B_4C have physical, mechanical, and optical properties comparable to those of SiC and are suitable for use in mirrors.



Three Chemical-Vapor Depositions Are Used to fabricate lightweight mirror substrates.

This work was done by Jitendra S. Goela and Raymond L. Taylor of Morton International, Inc., for **Langley Research Center**. *No further documentation is available.*

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

Dr. Raymond L. Taylor
CVD, Inc./Morton International, Inc.
185 New Boston Street
Woburn, MA 01801

Refer to LAR-14299, volume and number of this NASA Tech Briefs *issue, and the page number.*

Preventing Chemical-Vapor Deposition in Selected Areas

A gas shroud isolates a specific area from the rest of the deposition system.

Langley Research Center, Hampton, Virginia

A method for the prevention of the chemical-vapor deposition of material in selected areas has been developed. The method differs from previous deposition methods in which selected areas are isolated by reducing the amounts of materials deposited around those areas. In this method, a gas shroud is used to isolate the selected area from the rest of the deposition system.

A substrate of any shape or size is first mounted on a material, such as graphite support pillars or graphite felt, compatible with the deposition process. The substrate is enclosed by a ring, also made from graphite or other compatible material, which matches the shape of the substrate. The distance between the outer edge of the substrate and the inner edge of the ring is a few millimeters. An inert gas, such as argon, is made to flow from beneath the substrate. This flow prevents deposition between the substrate and the ring (see figure).

The rate of flow is chosen to maintain a small differential pressure between the gas in the ring and the gas in the furnace. The isolation of the substrate from the rest of the deposition furnace prevents the propagation of cracks from the wall of the furnace to the substrate. This method also prevents deposition on the back of the substrate, which deposition often produces cracks in the deposited material.

This method has been extremely successful in the selective deposition of SiC in a chemical-vapor-deposition reactor. It is used in the deposition of SiC mirror blanks in the Large Mirror Substrate and Lidar Mirror programs. It is a critical element in the overall chemical-vapor-deposition process for producing large, lightweight mirrors.

This work was done by Joseph T. Keeley, Jitendra Singh Goela, Michael A. Pickering, and Raymond L. Taylor of Morton International, Inc., for **Langley Research Center.** *No further documentation is available.*

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

Dr. Raymond L. Taylor
CVD, Inc./Morton International, Inc.
185 New Boston Street
Woburn, MA 01801

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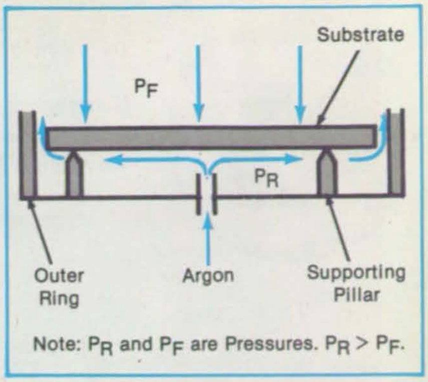


Inert Gas Flowing From Beneath the Substrate prevents deposition between the substrate and the outer ring.

Hand Broaching Tool for Use in Confined Areas

A slim tool fits where others cannot.

Marshall Space Flight Center, Alabama

A broaching tool cuts keyslots in tapped holes. With an exceptionally slim outer body, the tool is well suited for work in areas of limited accessibility, particularly when features of the workpiece create obstructions.

The inner body of the tool fits in a cylindrical outer body (see figure). A guide tip aligns the tool axially when inserted in a hole. A double-edged cutting blade extends radially from the upper portion of the tip. A striking surface at the top of the inner body protrudes from the outer body; this surface absorbs hammer blows and transmits them to the blade. The blade is thus gradually forced into the workpiece, cutting keyslots on opposite sides of the hole as it proceeds.

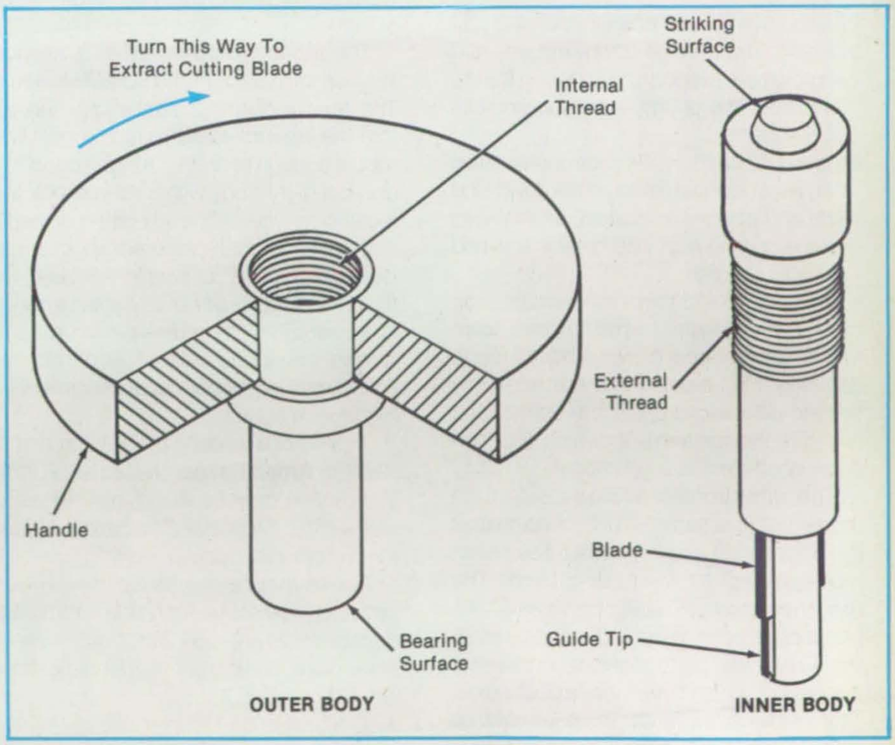
The outer body aids in extracting the tool from the hole without damage after the slots have been cut. Its internally threaded collar mates with an externally threaded section on the inner body. To extract the tool, the user turns the disk-shaped handle on the outer body clockwise. This action translates the outer body downward as it moves on the threaded inner body.

When the bearing surface on the outer body makes contact with the workpiece, the user continues to turn the handle. The inner body now translates upward on the screw thread, pulling the blade and tip from the hole.

The broaching tool previously used had an outer body considerably larger in diameter. So that the old tool would fit around an obstruction next to the tapped hole, a portion of the outer body had to be cut away — a time-consuming and costly process. The old tool had two single-edge blades on its periphery; the new double-edge blade, extending through a collet on the tip, is stiffer and lasts longer.

The previous tool was developed for broaching 44 stud holes, each 0.250 in. (6.35 mm) in diameter, in a circle on the Space Shuttle main engines. The new tool reduces the time for broaching the holes from 4 h to 1 h. The blade has to be replaced only twice per circle, whereas about 50 blades were consumed per circle with the old tool.

This work was done by Arthur A. Beach of Rockwell International Corp. for **Marshall Space Flight Center.** *For further information, Circle 160 on the TSP Request Card.* *MFS-29669*



Threaded Sections on inner and outer bodies mate. After the inner body has been used to broach keyways in a hole in a workpiece, turning the outer body by its handle forces the bearing surface against the workpiece and pulls the inner body tip out of the hole.

Mathematics and Information Sciences

Artificial Dissipation in Computations of Hypersonic Flows

Four schemes are tested on strong shocks.

Ames Research Center, Moffett Field, California

Four artificial-dissipation mathematical models have been introduced to suppress spurious numerical oscillations in finite-difference computations of hypersonic external flows. The models were tested for their effects in capturing the details of shocks in hypersonic flows about bodies of various shapes (see figure).

The mathematical context is the lower-upper/symmetric-Gauss–Seidel (LU-SGS) algorithm for the solution of the Navier–Stokes equations of flow in two dimensions. Within this context, a variety of schemes can be developed by choices of difference operators, Jacobian matrices, and inviscid-flux vectors:

- If one uses upwind operators on the split inviscid fluxes on the downwind side and true Jacobian matrices on the upwind side, one obtains an upwind LU-SGS scheme.
- If one uses upwind operators on the split inviscid fluxes on the downwind side and approximate Jacobian matrices on the upwind side, one obtains a semiupwind LU-SGS scheme.
- If one uses central difference operators on the unsplit inviscid fluxes on the downwind side and approximate Jacobian matrices on the upwind side, one obtains a hybrid LU-SGS scheme.

In the first-and-third-order-dissipation model, third-order terms formed from fourth differences provide background damping. First-order terms are added by second differences under the control of a pressure-sensor term, to which the low-order coefficient is proportional.

The directionally-scaled-dissipation model has the same structure as that of the original first-and-third-order-dissipation model, except for the scaling factor. The use of directional scaling provides anisotropic dissipation to each direction, resulting in improved performances on meshes, the cells of which have high aspect ratios. This model is more accurate on coarse grids than is the first-and-third-order-dissipation model.

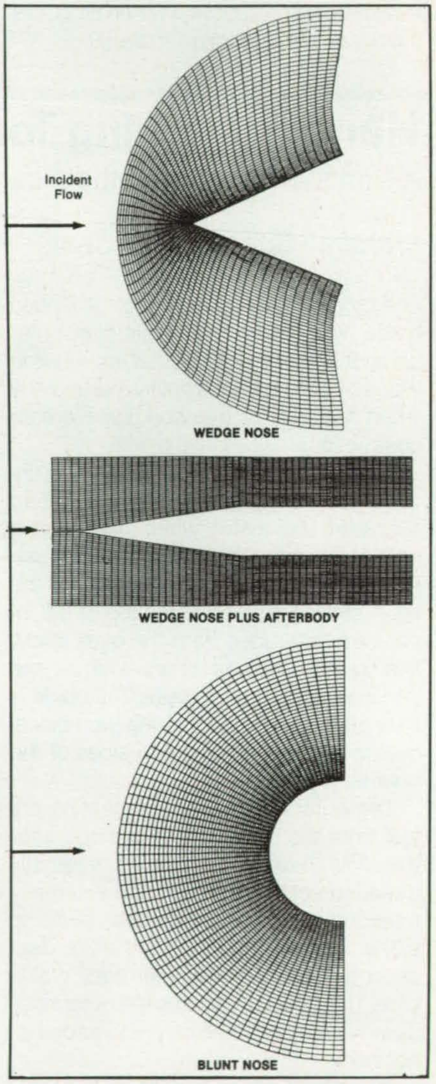
In the flux-limited-dissipation model, the dissipative flux is not constructed by adding low-order terms. Instead, functions to limit antidiffusive fluxes are introduced into the high-order terms. The constant parameters of these functions are chosen to provide enough dissipation to suppress numerical oscillations in the neighborhoods of shock waves.

The dissipative fluxes of the three preceding models have scalar coefficients. However, the dissipative coefficient for a system of equations must be a matrix, to meet the requirement of upwinding. In the flux-difference-split-dissipation model, this matrix is constructed by splitting flux differences in a way that separates the characteristic fields that correspond to the different wave speeds. This model and the flux-limited-dissipation model can be regarded as total-variation-diminishing schemes.

The models were tested in a Newton-iteration form of the hybrid LU-SGS scheme. The results of these simulations showed that the flux-limited-dissipation model was robust enough to predict a high-speed flow about a blunt body with strong shock and expansion waves. The flux-difference-split-dissipation model captured shocks with higher resolution but was less robust. The first-and-third-order-dissipation and the directionally-scaled-dissipation models turned out to be neither accurate nor robust enough for computations of flows at high mach numbers.

This work was done by S. Yoon and D. Kwak of **Ames Research Center**. *Further information may be found in AIAA paper 88A-44819, "Artificial Dissipation Models for Hypersonic External Flow."*

Copies may be purchased [prepayment required] from AIAA Technical Information Services Library, 555 West 57th Street, New York, New York 10019, Telephone No. (212) 247-6500.
ARC-12260



Hypersonic-Flows About Three Bodies were computed by a finite-difference implementation of the Navier-Stokes equations. Four mathematical models of artificial dissipation were compared in computations on these grids.

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Circle Reader Action No. 524

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.

How Safe Is Control Software

Backup systems are still needed to prevent catastrophic software failures.

A paper examines the issue of software safety and concludes that, to be safe, software, for all practical purposes, must be free of errors. Developers of real-time control systems are concerned about safety because a software error, or "bug," may suddenly surface, even in a mature system, and cause damage to property, injury, or death.

In the case of software, safety is synonymous with ultrareliability. An error rate no greater than 10^{-6} errors per hour is expected in any software in commercial, industrial, and medical applications in which property and life are at risk. In other words, software should have a mean time between failures of at least 100 years.

The paper presents four case histories of software-safety analysis:

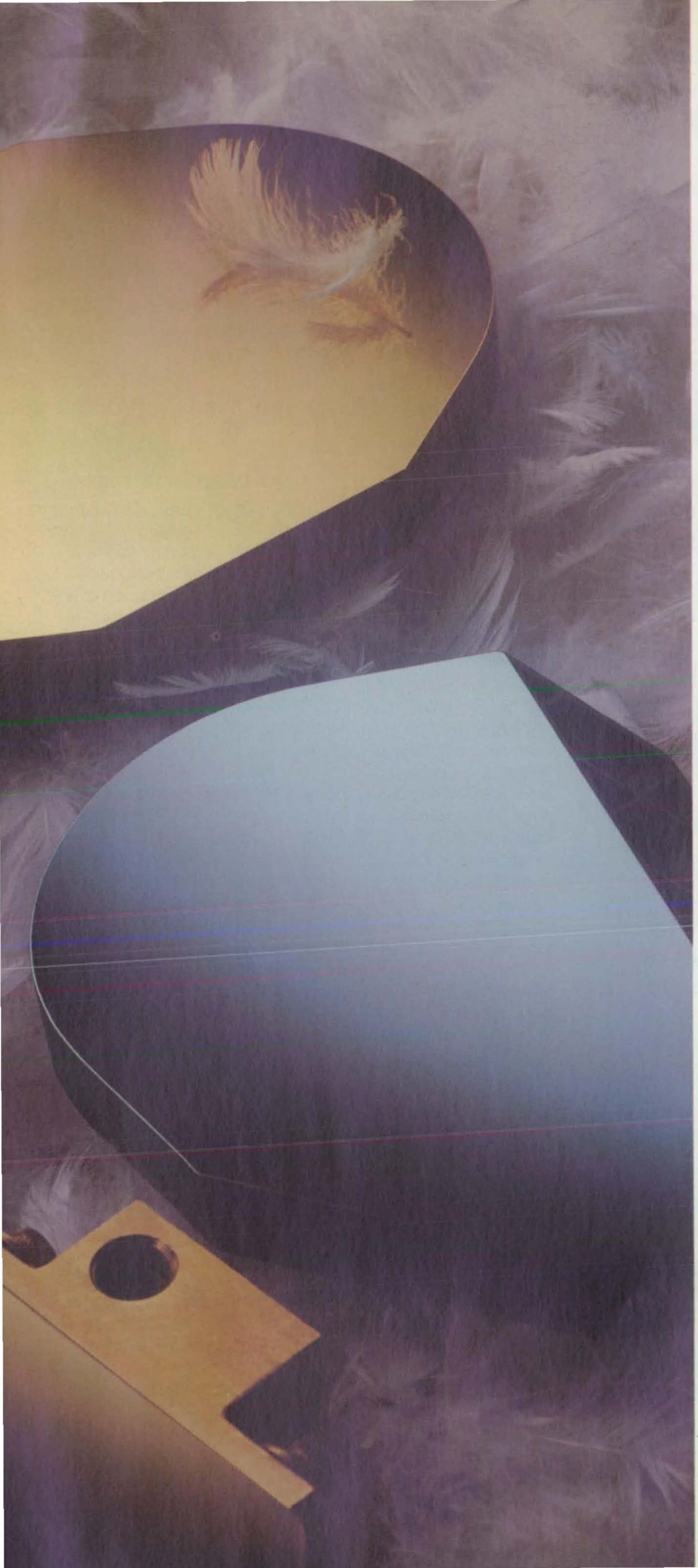
- The flight-control system of the proposed X-wing aircraft;
- The flight-control system of the vertical/short-takeoff-and-landing research airplane;
- The high-pressure-air distributed-control system for several wind tunnels at Ames Research Center; and
- A control system for operating wind tunnels and collecting and processing experimental data.

In each case, it is found that practices for assuring software safety are primitive. In each case, an independent, simple, predictable backup element — either software or hardware — is needed to protect the system and its environment if and when the basic software goes bad.

Moreover, it is unrealistic to expect safety-assurance practices to improve much in the near future. It is not likely that repeated life-cycle testing and analysis will be able to bring safety up to the required level.

On the other hand, it seems reasonable that safe software can be achieved through design. To be effective, safety-assurance practices of the future will have to take into account the processes used in the development of software and show that the software product can be executed correctly under all possible conditions.

This work was done by William R. Dunn of the University of Southern Colorado and Lloyd D. Corliss of **Ames Research Center**. *To obtain a copy of the report, "Software Safety: A User's Practical Perspective," Circle 9 on the TSP Request Card.* *ARC-12710*



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Properties	Be	SiC(*)	Al	ULE™
Physical				
Density ($g\ cm^{-3}$)	1.85	2.92	2.73	2.21
Mechanical				
Young's Modulus (GPa)	303	311	71	68
Microyield Stress (MPa)	35	(**)	98	24
Thermal				
CTE ($10^{-6}\ K^{-1}$)	11.4	2.57	24.0	0.03
Diffusivity ($cm^2\ s^{-1}$)	0.52	0.80	0.96	0.008
Specific Heat ($J\ kg^{-1}\ K^{-1}$)	1,880	670	900	766
Conductivity ($W\ m^{-1}\ K^{-1}$)	180	156	237	1.3
Figures of Merit(***)	**Be**	**SiC(*)**	**Al**	**ULE™**
Structural (higher is better)				
Specific Stiffness (E/ρ)	164	107	26	31
Thermal (lower is better)				
1st Order Distortion (CTE/k)	0.063	0.017	0.101	0.023
Thermal Distortion (CTE/D)	22.2	3.26	25.0	3.92
Dim. Change ($CTE \cdot \rho/k$)	118	48.1	276	51.0

(*) Values shown are for CERAFORM®.
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UNITED TECHNOLOGIES OPTICAL SYSTEMS

Circle Reader Action No. 331

Life Sciences

Books and Reports

Books and Reports

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

Computation of Facilitated Transport of O_2 in Hemoglobin

Unsteady transport is simulated with more-realistic mathematical models of dissociation.

A report describes computations of the unsteady facilitated transport of oxygen through a liquid membrane of hemoglobin. As used here, "facilitated transport" means the diffusion of a permeant through a membrane in which that diffusion is enhanced by a reversible chemical reaction between the permeant and the membrane. In this case, there are reversible reactions between the hemoglobin and oxygen.

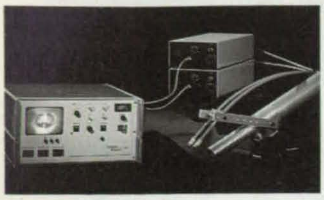
The differential equations that describe unsteady transport of oxygen (including the reactions of higher order) in one dimension across a solution containing hemoglobin are presented. First, the steady state is considered, and the equations are linearized into a coupled set of ordinary differential equations. These equations are put in a matrix form that highlights the disparate time scales related to rates of transport and of reaction of the various chemical species. This linearized form is used to develop an explicit formula for the size of the boundary-layer region. The facilitated-transport problem is shown to be "stiff" in the sense that the solution includes eigenmodes of disparate spatial scales.

The full nonlinear time-dependent equations are solved by the method of time linearization, using an explicit numerical-integration algorithm with direct block tridiagonal solvers. The method of time linearization involves the expansion of the nonlinear term in a Taylor series about the solution at a previous time step. The solutions of the full nonlinear equations are presented and compared with results published previously. The most important results of the analysis are the following:

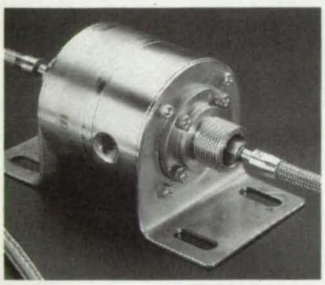
- Reaction models of higher order, which match oxygen-dissociation-curve data better than do models of lower order, yield better agreement between theory and experiments in vitro.
- The steady-state oxygen flux through a membrane is independent of the initial conditions.
- In the computation, the sigmoid oxygen-dissociation curve (the ratio of the concentration of oxyhemoglobin to the total concentration of hemoglobin) causes almost 100 percent oxygen saturation of the high-pressure side of the membrane and increases the thickness of the boundary layer on the low-pressure side. This latter effect relaxes the stringent grid-resolution problems when numerical methods are used.

This work was done by Sanford Davis of **Ames Research Center**. *To obtain a copy of the report, "Computation of the Unsteady Facilitated Transport of Oxygen in Hemoglobin Solution," Circle 18 on the TSP Request Card.* ARC-12417

New on the Market



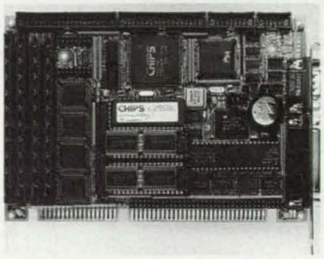
The LaserStrobe™ **diagnostic video camera system** from Control Vision Inc., Idaho Falls, ID, is designed for viewing and controlling high-temperature industrial and scientific processes, including laser welding, plasma spray processes, and powder metal production. Using intense stroboscopic illumination in combination with high-speed electronic shuttering, the system penetrates a plasma or flame to reveal the dynamic behavior of superheated material. LaserStrobe can freeze the motion of small fast-moving particles and, with the use of an optional double-shuttering system, can produce double-exposure images for measuring particle speed and acceleration.
Circle Reader Action Number 788.



Pictured above is a new **transmittance sensor** designed for pressures up to 1000 psi. Developed by Galileo Electro-Optics Corp. of Sturbridge, MA, this liquid cell is easily connected to optical fiber cables for remote fiber optic spectroscopy or applied on-line for process monitoring. The wetted materials are 316 stainless steel, sapphire, and application-dependent O-ring seals.
Circle Reader Action Number 786.

Integrated Measurement Systems Inc., Beaverton, OR, has introduced the Logic Master XL series for **test and verification of custom and semicustom devices**. The product combines integrated functional test and AC and DC measurement capabilities. It features a 5-bit architecture for fast analysis, clock and data rates to 100 MHz, and system accuracy of ±200 ps.
Circle Reader Action Number 784.

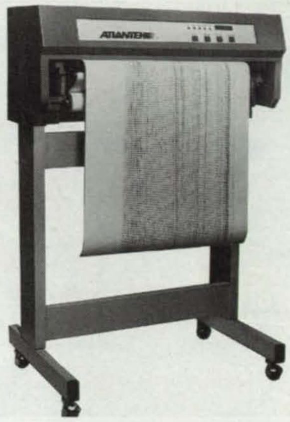
MathSoft Inc., Cambridge, MA, has released version 3.0 of its Mathcad **technical calculation software**. The new version adds support for Microsoft Windows; an on-line reference library called Electronic Handbooks which allows instant access to standard formulas and constants; and symbolic calculations for computer algebra. Other new features include improved equation editing, enhanced plotting and memory support, and additional numerical functions.
Circle Reader Action Number 778.



A **palm-size single-board computer** created by Teknor Microsystems of Montreal, Canada, uses CMOS technology to achieve extended temperature operation (-40° to 85° C). The ruggedized industrial PC measures 7" x 4.7" and offers up to 16 Mbytes of mixed DRAM support with optional 1 Mbyte Flash EPROM, and 1 Mbyte SRAM with battery backup. It features a 16 or 20 MHz 80386SX processor, hard and floppy disk controllers, two serial COM ports, and one parallel port.
Circle Reader Action Number 780.

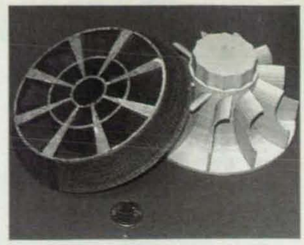
A compact **MeV ion beam materials analyzer** from National Electrostatics Corp., Middleton, WI, provides nondestructive elemental analysis of surfaces to depths in excess of 5000A. The model MAS1000 can perform a wide range of analysis techniques, including RBS, PIXE, channeling, target recoil analysis, and resonant and reaction techniques with energy-variable Helium ion and proton beams to 3 MeV.
Circle Reader Action Number 782.

The Model 2400P **raster plotter** produces plots four times faster than the current electrostatic systems, according to its manufacturer, Atlantek Inc. of Wakefield, RI. Designed for use in high-volume CAD environments, the 2400P offers continuous plot speeds of 0 to 4 inches per second. It produces smooth, consistent plots regardless of host data transmission regularity.
Circle Reader Action Number 796.

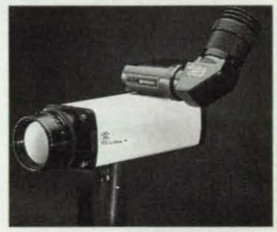


Evans & Sutherland, Salt Lake City, UT, has unveiled the ESIG-2000 **image generator** for the low-end simulation market. The system features full color texture, large area database and advanced scene management, atmospheric effects, sensor simulation, antialiasing, R-buffer, and image mapping. It is adaptable to networked simulators involving ground vehicles and aircraft, gunnery training, and maritime, driving, and engineering applications.
Circle Reader Action Number 794.

The Z88 **lubricant spray** from Tiodize Co. Inc., Huntington Beach, CA, loosens frozen parts while leaving a protective barrier against future corrosion. Originally developed to prevent corrosion in aerospace and military applications, Z88 is suited for a variety of industrial, automotive, marine, and industrial uses. It removes oil and grease from tools and machinery parts, and drives moisture out of engines and electrical systems.
Circle Reader Action Number 798.



The Laminated Object Manufacturing (LOM) System from Helisys Inc., Torrance, CA, **rapidly produces 3D prototypes** from a CAD image without any tooling. With the system acting as a 3D laser printer, the object is manufactured by sequentially laminating and cutting its 2D cross-sections. The compact system uses thin layers of sheet materials such as paper, plastics, and composites to form parts up to 13" x 10" x 15".
Circle Reader Action Number 792.



ISI Group Inc., Albuquerque, NM, has introduced the Model 91 VideoTherm, a **handheld, real-time thermal imager** compatible with standard videotape recorders. The VideoTherm camera converts infrared radiation to black and white television images showing gradations from hot (white) to cool (black). It can handle target temperatures from -30° to 1375° C in the 8 to 14 micron range, with a thermal resolution of .15° C at a target temperature of 25° C.
Circle Reader Action Number 790.

Combining a scanning laser microscope with a personal computer, The LAB-TEC™ 1000 **particle size analyzer** from Laser Sensor Technology Inc., Bellevue, WA, measures size distributions directly in slurries over a wide range of concentrations without sample dilution. It measures up to 200,000 particles/sec. in 28 size increments from 0.7 to 250 microns, and provides 20 types of graphical displays. Applications include quality control in industrial processes, filtration processes, and grinding circuits.
Circle Reader Action Number 800.

NASA's Innovators

(continued from page 11)

the various receptive fields.

While much remains to be learned from advanced versions of the model, we already have found that inhibition is important in a neural network. When all elements are excitatory, the simulated network quickly saturates so that all units stay on continuously. Only when inhibition is introduced does neural coding appear. It is also apparent from the model that branching over short distances makes the unit more sensitive to different inputs at its calyceal sites, leading to a more irregular discharge pattern. Lengthening the branches tends to make the unit more regular in its responses.

About The Author

Dr. Muriel D. Ross is director of NASA-Ames' Biocomputation Center, where computer visualization techniques are used to explore the structures and functions of biological systems. She previously served as chief of space biology at the Ames Center. Dr. Ross holds a master's degree in anatomy and a PhD in neuroanatomy from the University of Michigan.

In complementary models, we have reproduced the maculas' receptive fields using the Monte Carlo simulation method. We derived constraints such as the number of type I and type II hair cells and the number and lengths of the nerve fiber branches in the various fields. Probability tables were used with a random number generator to reproduce examples of biological receptive fields. The results strongly suggest that biological neural networks develop by constrained randomness in wiring and are not entirely genetically determined. In future research, we hope to design artificial neural nets completely by constrained randomness to determine whether or not a degree of randomness in wiring is beneficial to artificial systems.

As we continue to refine our simulations, we also are beginning to reduce the macular architecture to symbolic block diagrams. Next, these block diagrams will be reduced to electronic circuit diagrams, using small- and medium-scale integrated circuit devices, for implementation in hardware. Development of a prototype linear accelerometer chip based on its biological counterpart should be possible within a few years.

In the meantime, what are the attributes of biological neural nets that could help us design better parallel-processing computers? One major observation is that the nervous system appears to be organized on the basis of two circuits: highly-channeled and distributed-modifying. There are highly-directed inputs to an area, carrying specific data, but the data is processed further by local or intrinsic circuits that modify the output to another station. Because we find that part of the distributed circuit dampens type II hair cell activity following calyceal voltage changes, it is possible that lateral inhibition is a fundamental feature of distributed-modifying circuits.

Our research suggests, however, that a third kind of circuit may exist. This is a system of nerve fibers that comes into an area or layer from another site and provides a widely-distributed, biased background of activity against which the channeled and distributed-modifying circuits operate. In natural systems, background activity can be raised or lowered hormonally through increased input or local, reciprocal control. Heightened activity in a neuron could release a neurotransmitter to terminals of reciprocal type, activating them to modulate the responses of more distant neurons. This kind of circuit might prove essential to learning, cognition, and creativity, as it could help focus attention to certain incoming information, correlate neural activity over variable distances, and result in disregard of other simultaneous inputs that might otherwise be distracting. In the human brain, such circuits may provide the emotional context within which higher cognitive functioning occurs.

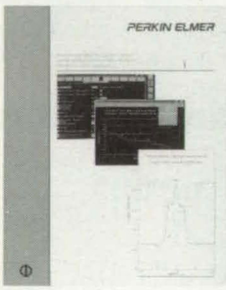
Four other factors appear important for incorporation into artificial neural networks and computer technologies. First, biological neural nets are not modular. Variation in receptive field and network organization is important to parallel processing of incoming information, to segregate discrete parts of the message for different distributions. Second, biological systems are robust and tolerant of neuron failure. Robustness is achieved in part through redundancy, but probably also through nonmodularity and constrained randomness in wiring. Third, individual neurons are tiny bits in the machine of intelligence. They are not smart enough to tell another neuron that it is responding in error. Therefore, backpropagation as utilized in engineered neural networks does not exist in biological systems. Feedforward-feedback loops and lateral inhibition may be essential, however, to neural functioning. And fourth, constrained randomness in wiring may be typical of all advanced biological neural networks. This suggests that natural neural networks are dynamically nonlinear.

While we still have a long way to go to understand even this simple mammalian neural network in sufficient detail for extrapolation to computers and robots, a start has been made. Moreover, the insights we are obtaining and the technologies we are developing should help advance our understanding of the more complex neural networks that underlie human intelligence. Progress in this area should lead to ever more sophisticated machines. ❑

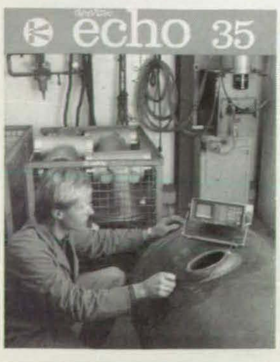
New Literature

Holography Market Place, a new sourcebook from Ross Books, Berkeley, CA, features applications of **holography**, an international directory of holographers, and a bibliography. The 172-page softbound publication contains exact procedures for producing holograms, manufacturers' data on the chemical composition of recording materials, and details on lasers for holographic applications.
Circle Reader Action Number 712.

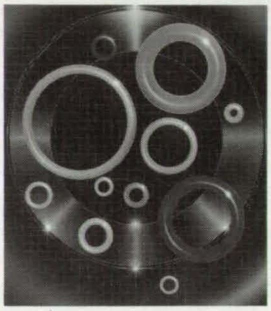
Perkin-Elmer's Physical Electronics Div., Eden Prairie, MN, has published a full-color brochure describing the PHI 6600 Secondary Ion Mass Spectrometry (SIMS) **surface analysis system**. Designed for R&D, analytical, and quality control labs, the system delivers SIMS data with high spatial resolution, depth resolution, and sensitivity. Applications include analysis of thin films, insulating coatings, and bulk insulators such as polymers and ceramics.
Circle Reader Action Number 706.



Ultrasonic nondestructive testing procedures and products are discussed in a 48-page booklet from Krautkramer Branson, Lewistown, PA. Included are articles on testing of ceramics and thermoplastics, characterization of reflectors, and binding tests of pistons. The full-color publication also features details on products such as a portable flow detector, a thickness gauge with an on-board data logger, and a new hardness tester.
Circle Reader Action Number 704.



More than 3000 products are highlighted in the 1991 catalog from Tektronix, Beaverton, OR. It covers three broad areas: **electronic test and measurement instruments, professional broadcast equipment, and computer peripherals**. New products include digital signal analyzers, a battery-operated portable scope, X-Window-based color graphics terminals, stereoscopic 3D display systems, HDTV sync generators and oscilloscopes, and fiber optics testers.
Circle Reader Action Number 714.



A new reference chart lists standard **O-rings** available from Apple Rubber Products Inc, Lancaster, NY. It contains dimensional data and describes basic O-ring materials offered by Apple, including silicone, cast polyurethane, fluorocarbon, and fluorosilicone. A guide to determining the proper material for a particular application is included.
Circle Reader Action Number 702.

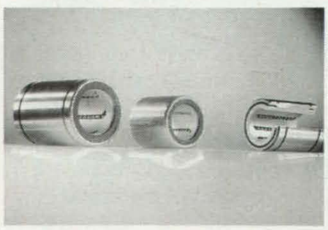
Encouraging Private Investment in Space Activities, a new study from DIANE Publishing, Upland, PA, examines three areas of **private investment in space**: space launch services by large-capacity launch vehicles; production of information based on satellite data; and materials processing in space, along with the provision of necessary orbital facilities. The 109-page report describes commercial applications of microgravity and includes a directory of Centers for the Commercial Development of Space, as well as a chart detailing sales of raw data from land remote sensing in US markets.
Circle Reader Action Number 710.

A free brochure published by Leap Technologies, Otsego, MI, describes **advanced computer technologies** that accelerate the design, development, and manufacturing of new products. It covers solid modeling, mold filling simulation, 3D stereolithography, and DNC machined tooling.
Circle Reader Action Number 708.

A reference guide to **interconnects and connector design** is available from Samtec Inc., New Albany, IN. Sections describe pin-out configurations, contact and terminal design, cable connectors, base metals, plating, body materials, and quality standards. The pocket guide includes reference charts, conversion tables, and a glossary.
Circle Reader Action Number 724.

Locon Sensor Systems Inc., Holland, OH, is offering an eight-page guide to its line of **capacitive proximity sensors**. Arranged according to model series and temperature ratings, the guide presents sensor specifications and dimensional drawings within selection charts. It describes the Locon® analog and high-temperature models, as well as new quick-disconnect styles.
Circle Reader Action Number 718.

Schneeberger Inc., Bedford, MA, has released a 68-page **ball bearing handbook and design guide**. The free publication is divided into three sections: linear ball bearings, SFERAX shafting, and high-precision linear motion components. It contains graphs, tables, and comparisons with industry-standard performance charts, and describes a new systematic approach to linear ball bearing selection.
Circle Reader Action Number 726.



Particle Measuring Systems, Boulder, CO, has issued a brochure describing its **laser-based air particle counting systems**. The microprocessor-controlled instruments size and count particulates at minimum sensitivities of 0.1 to 0.5 μm with sample flow rates from 0.1 to 1.0 CFM. Suited for environmental monitoring and cleanroom certification, the instruments feature selectable alarm functions, a built-in printer, and computer interface capabilities.
Circle Reader Action Number 722.

Direct drive vacuum pumps are the subject of a new brochure from Welch Vacuum Technology Inc., Skokie, IL. It highlights three new models in the 3 to 7.6 CFM range, including the model 8910—the smallest 3-CFM pump in its class. The brochure includes technical specifications and a pump selection guide, and describes a variety of accessory fittings, filters, and traps.
Circle Reader Action Number 728.

The latest edition of *Mutations*, a French/English publication featuring more than two dozen **space-based technologies available for transfer**, is free from Novespace, Paris, France. Inventions described in the four-color booklet include an optical fiber transducer system, an ultra-high-speed acousto-optical correlation processor, a pressure transmitter-recorder for high-precision industrial measurements, a mass flowmeter, and a multipin connector locating device.
Circle Reader Action Number 720.

A 16-page catalog of RF and microwave **signal sources** is available from Communication Techniques Inc., Whippany, NJ. It summarizes the features and benefits of CTI's products, which include phase-locked and free-running DROs, VHF and microwave frequency synthesizers, mechanically-tunable and automatic phase-locked oscillators, and frequency multipliers. Designed for applications in digital communications, radar, telemetry, and instrumentation systems, the units offer low phase noise and low microphonics.
Circle Reader Action Number 716.

Subject Index

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PATENTS

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:

Flexible Diaphragm—Extreme Temperature Usage

(US Patent No. 4,989,497)
Inventor: **Guillermo Lerma**

Mr. Lerma has developed a flexible sealing membrane for applications from -101° to +260°C. Diaphragms made from the fiberglass-reinforced elastomer material have been tested and used repeatedly throughout this temperature range. The membrane can be formed in a variety of shapes.

Circle Reader Action Number 753.

Laterally-Stacked Schottky Diodes for Infrared Sensor Applications

(US Patent No. 4,990,988)
Inventor: **True-Lon Lin**

Laterally-stacked Schottky diodes have been fabricated using porous silicon. A Schottky metal contact is formed in the pores via electroplating. The sensors can be integrated with silicon circuits on the same chip with a high quantum efficiency, which is ideal for IR focal plane array applications.

Circle Reader Action Number 751.

Catalyst for Carbon Monoxide Oxidation

(US Patent No. 4,991,181)
Inventors: **Billy Upchurch**, **Irvin Miller**, **David Brown**, **Patricia Davis**, **David Schryer**, **Kenneth Brown**, and **John Van Norman**

Carbon monoxide buildup presents a major problem in closed environments. This invention offers an efficient way to convert carbon monoxide and oxygen to carbon dioxide under ambient temperatures in closed environments such as cigarette-smoke-filled rooms or facilities housing closed-cycle carbon dioxide lasers. The catalyst could also find utility in automobile catalytic converters, especially during the first minutes of operation, which occur under ambient conditions.

Circle Reader Action Number 745.

Lightweight Polymer Matrix Composite Material

(US Patent No. 4,992,528)
Inventors: **Kenneth Bowles** and **Carl Lowell**

A new process alters the properties of a fully-cured polyimide matrix composite by heating it in an inert gas such as nitrogen or argon at ambient pressure. The composite's temperature is raised to approximately 400°C, which is higher than its glass transition temperature, so that the material loses weight. The temperature is maintained at 400°C in the inert gas until the weight loss is complete.

Circle Reader Action Number 747.

Fiber Optic Sensing System

(US Patent No. 4,995,697)
Inventor: **Grigory Adamovsky**

A fiber optic interferometer uses as a light source a low-coherence LED laser which is filtered and driven at two RF frequencies, high and low. Displacement of a reflecting mirror changes the length traveled by the nonreferencing signal. The low-frequency light undergoes destructive interference, reducing the wave's coverage intensity, while the high-frequency light undergoes constructive interference, increasing the wave's average intensity. The ratio of these two measurements is proportional to the displacement incurred.

Circle Reader Action Number 743.

O-Ring Gasket Test Fixture

(US Patent No. 5,000,033)
Inventors: **James Turner** and **Donald McCluney**

An apparatus for testing O-ring gaskets under a variety of temperature, pressure, and dynamic loading conditions has been developed at the Marshall Space Flight Center. The apparatus can simulate a dynamic loading condition in which the sealing surface moves both away from and axially along the face of the O-ring.

Circle Reader Action Number 749.

Alignment/Positioning Mechanism

(US Patent No. 5,000,416)
Inventor: **Peter Fantasia**

This invention corrects misalignment or misplacement of a structure's interface with a mounting surface. Used in a set of three or four units, the mechanism alleviates stresses resulting from unequal loading, such as when a structure's legs are not the same length or are not parallel to one another. The manually-driven device can adjust the overall height of a structure and is equipped with a locking device. It offers most of the advantages of spacers, shims, and screw jacks with none of their shortcomings.

Circle Reader Action Number 741.

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