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Volume 14 Number 7

Transferring Technology to
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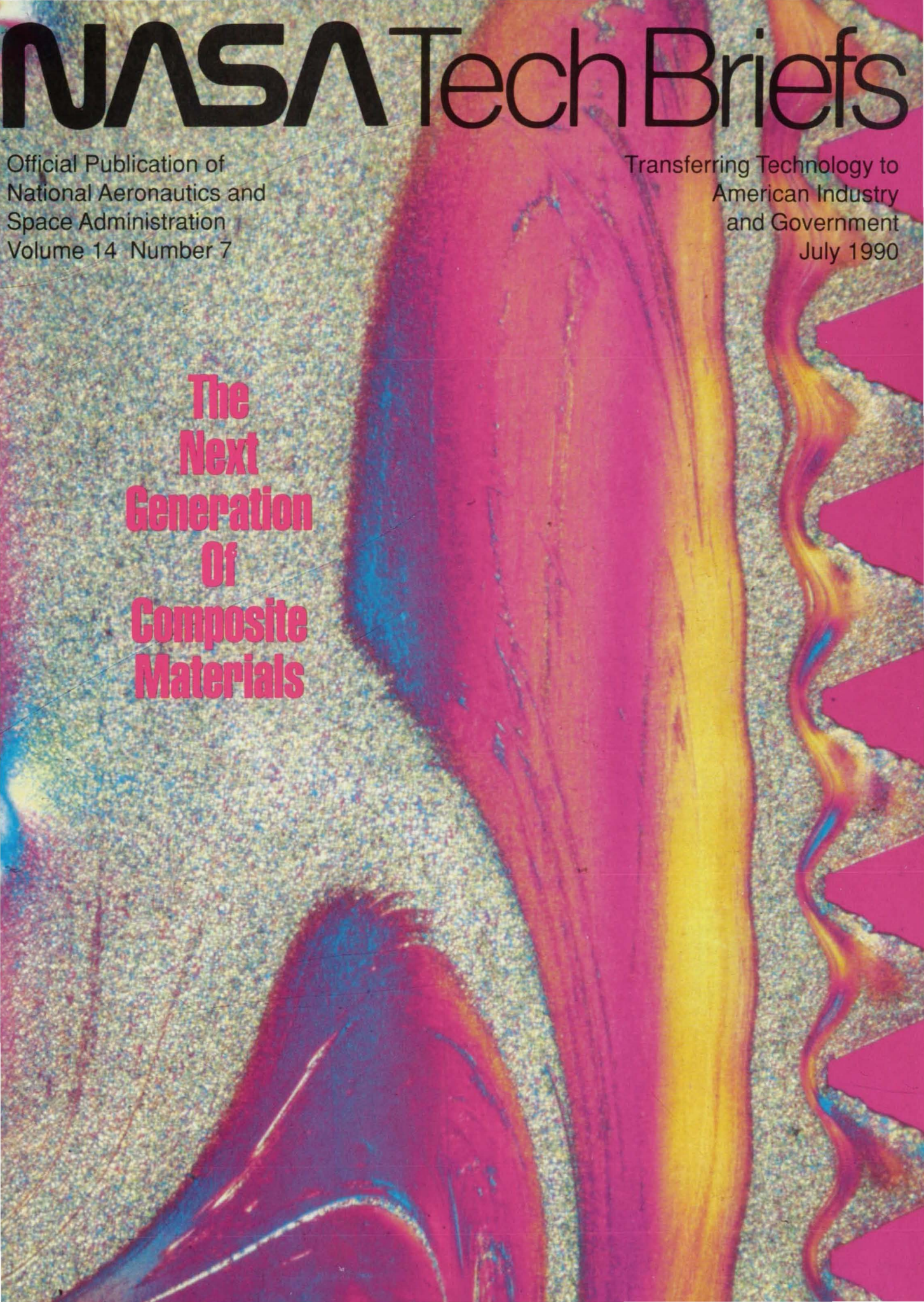
July 1990



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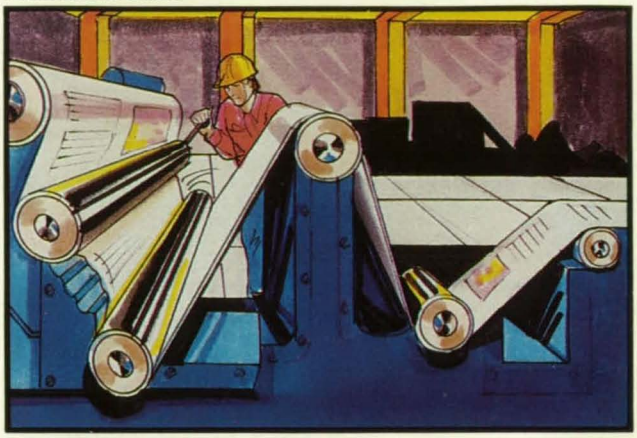

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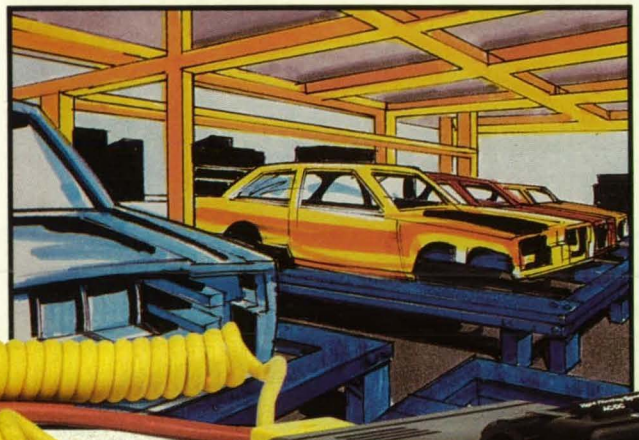

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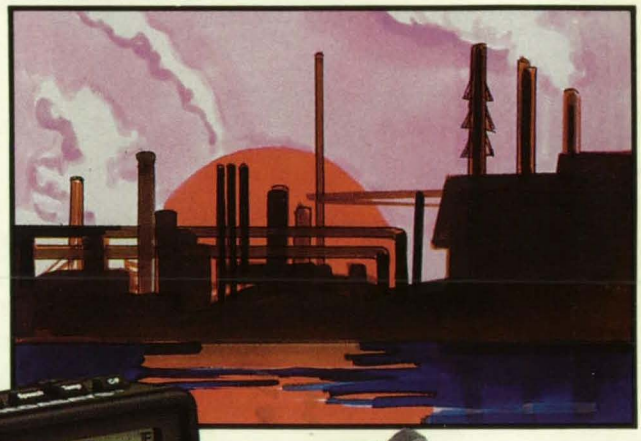

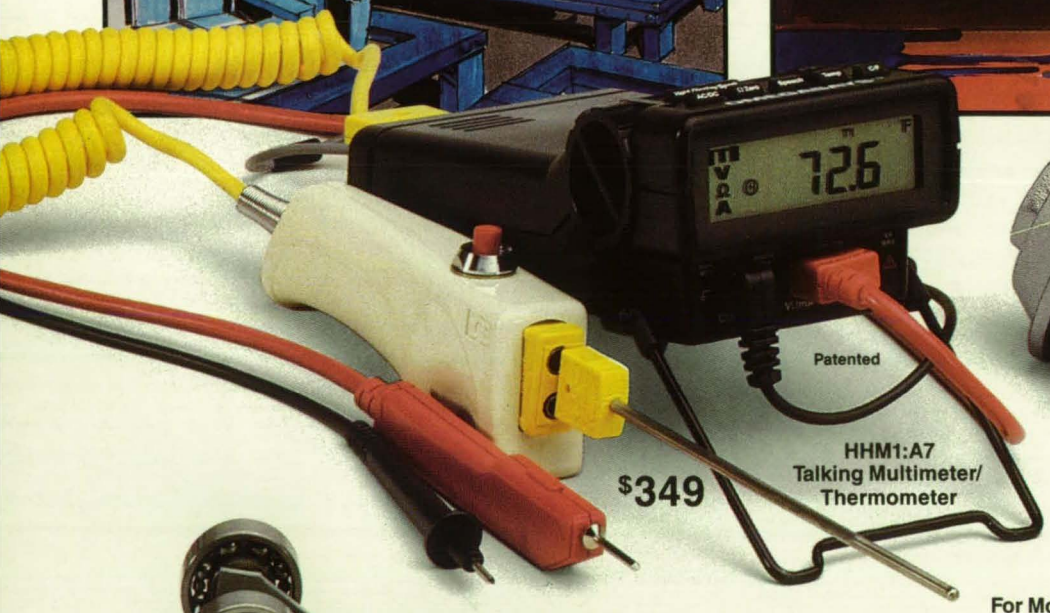

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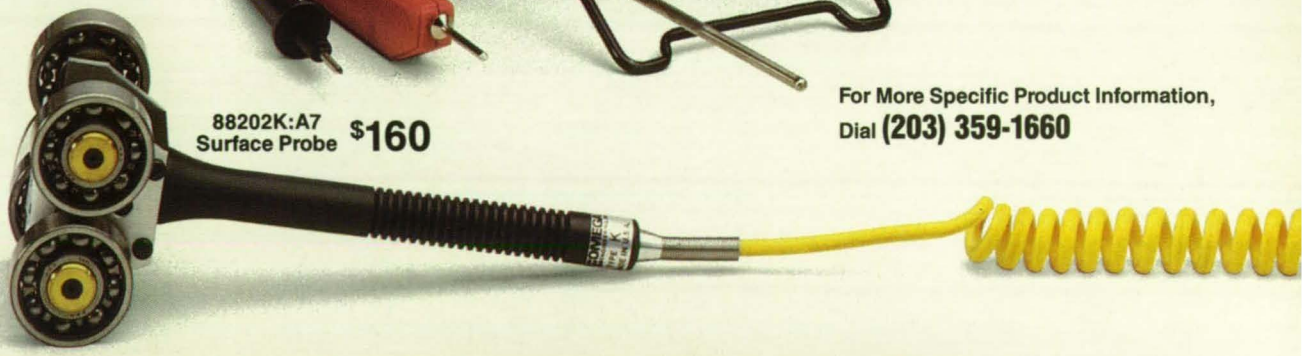

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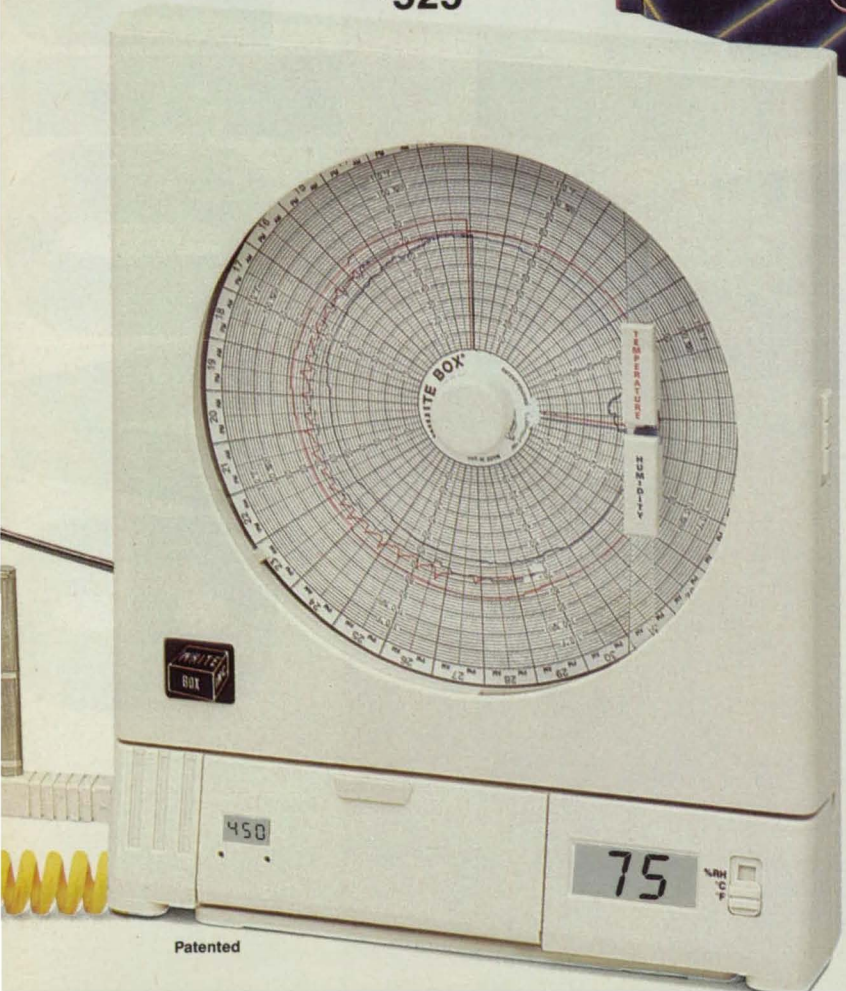

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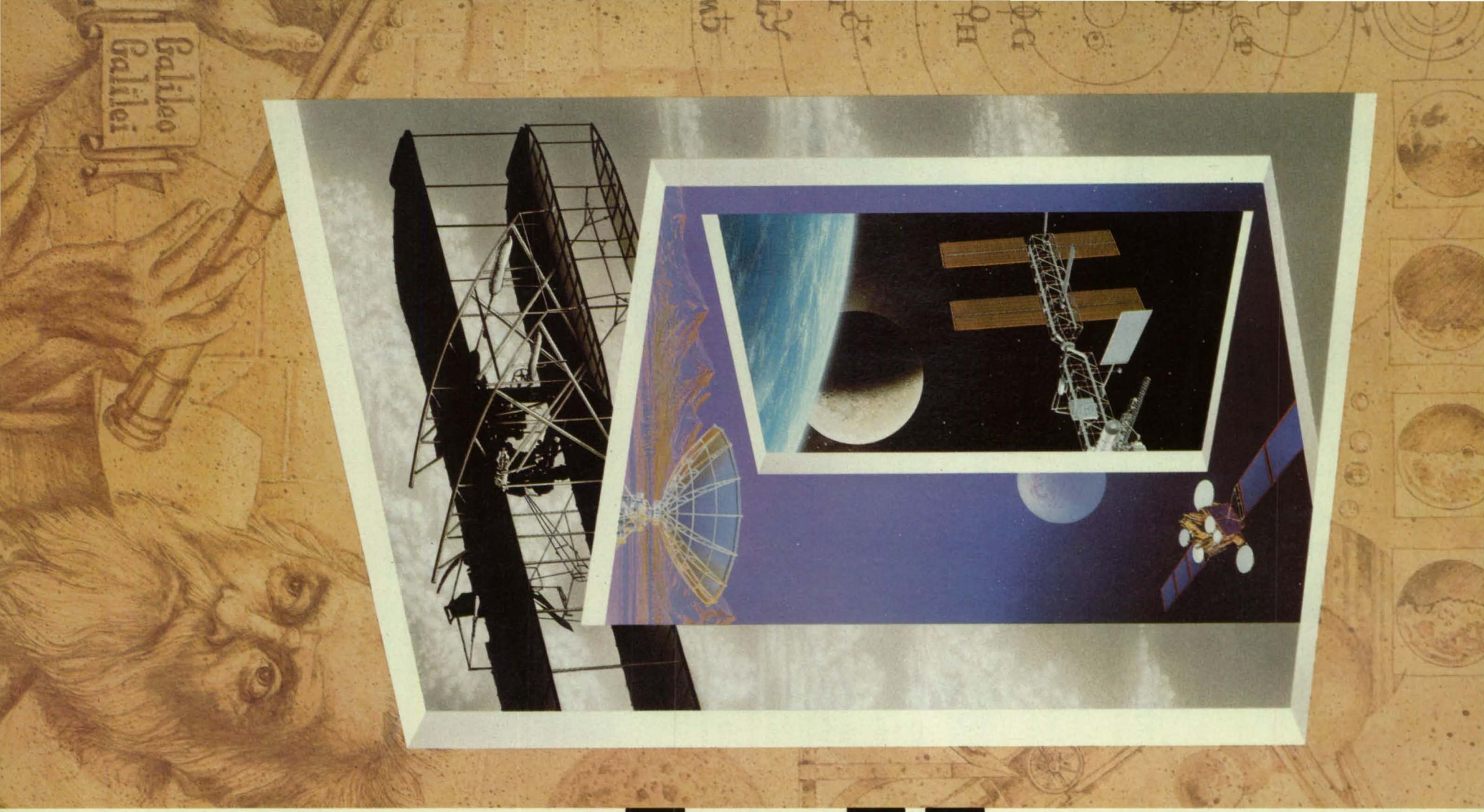

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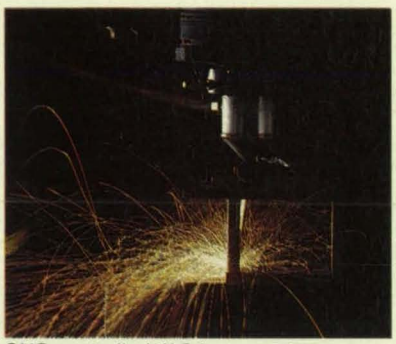

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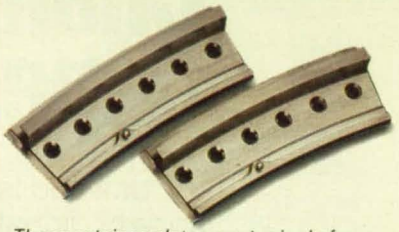

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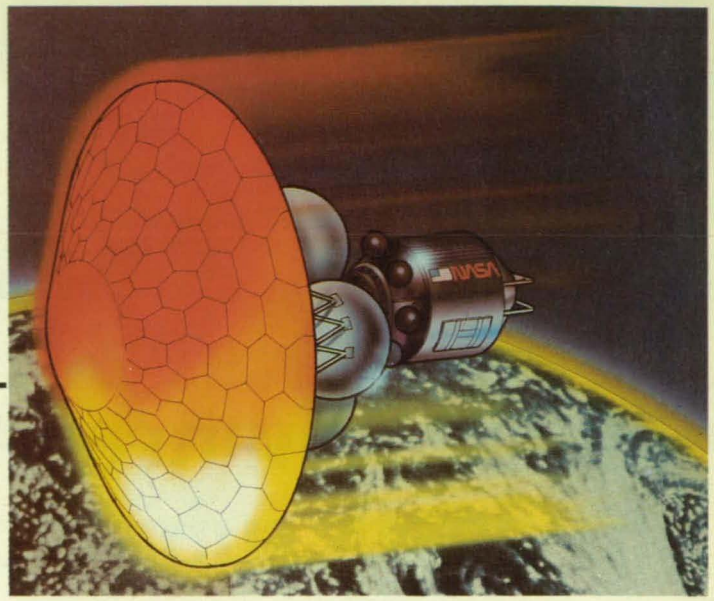

Illustration courtesy NASA

High-energy aerobraking will reduce fuel consumption and permit larger payloads on future Mars exploration missions. ***See page 78.***

SPECIAL FEATURE

TECHNICAL SECTION

DEPARTMENTS

On The Cover: Polarizing microscopy reveals minute defects in a plastic rack. In the Advanced Composites Technology program (page 10), NASA and its contractors are developing improved material forms, fabrication techniques, and analytical methodologies that could result in a new class of high-strength plastics. (Photo courtesy Carl Zeiss, Inc., Thornwood, NY)

Illustration courtesy NASA

A NASA-industry research team is investigating the application of advanced composite materials to the fuselage and wing structures of future transport aircraft. ***Turn to page 10.***

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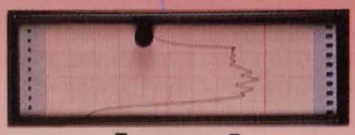

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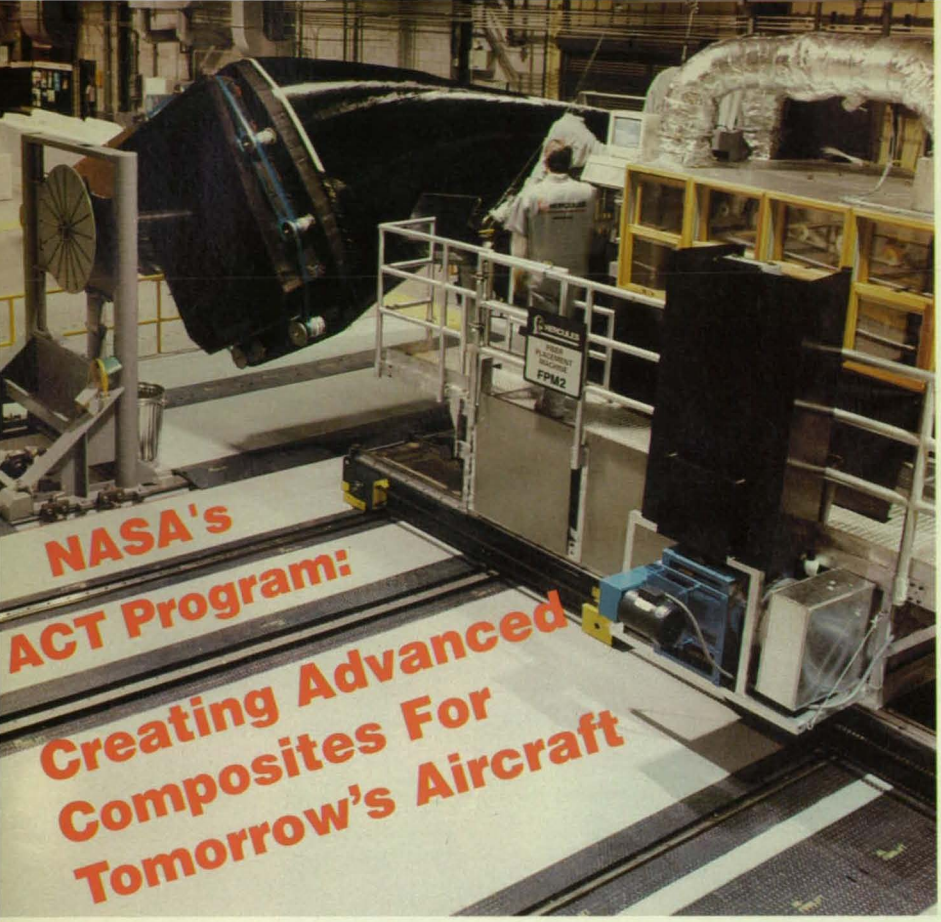


Photo courtesy Hercules Aerospace Company

Under a NASA ACT contract, Hercules is investigating the use of multiaxis tow placement technology to achieve low-cost manufacturing of complex composite structural forms.

by Randy L. Coggeshall, Larry B. Ilcewicz, Peter J. Smith, and W. Thomas Freeman

Over the past two decades, advanced composite materials have progressed from a laboratory curiosity to a production reality. Composites have demonstrated weight savings for aircraft structures and outstanding corrosion and fatigue damage resistance. Commercial aircraft applications have ranged from wide coverage on small flight control surfaces to a limited number of primary structures. Tens of millions of flight hours and cycles have been generated from these applications, but from a production standpoint we are just scratching the surface.

Starting with the existing secondary structure, including spoilers, flaps, and other flight controls, we are able to provide a modest weight reduction by using composite materials. These components tend to be relatively small and do not lend themselves to automated production techniques. As a result, they generally cost more than their metal counterparts. These applications have given us a great deal of production and service experience, however, and point the way towards larger and more complex composite structures, including empennages, wings, and fuselages. Large structures, with their large laminate areas, lend themselves to automated material placement techniques such as numerically-controlled tape lamination and advanced tow placement. They also allow designs that require fewer parts, such as integrally-stiffened co-cured wing panels, which help lower fabrication and assembly costs.

To assure the timely application of composites to the next generation of U.S. aircraft, we must improve our technology and manufacturing tools. Design and analysis tool capabilities are in their infancy, and cost-effective manufacturing techniques and materials have not been fully characterized. A number of service-related issues need to be resolved, especially for large wing and pressurized fuselage applications. These issues include lightning-strike protection and pressure containment of damaged fuselage structure. While much progress has been made, a significant amount of work remains before we will see an all-composite large commercial aircraft that is competitive with current aluminum planes.

Improved access to data is needed to promote efficient technology development. Although there has been a great deal of R&D across the aerospace industry, there exists an inter- and intra-company attitude of propriety regarding composites. The result is often duplication of effort and a proliferation of "point design" programs which have not provided the underlying science and technology needed for large-scale applications. To rectify this situation, composites technology must proceed through a maturation phase. The orderly development of a generic knowledge base will enable significant improvements in aircraft performance and reductions in manufacturing costs.

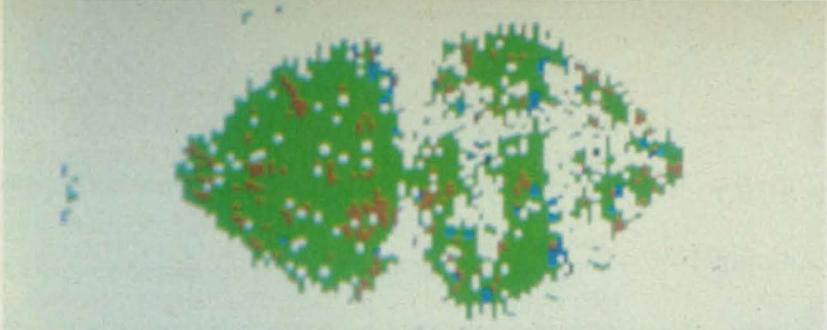
Such research will support numerous classes of aeronautical vehicles. The foundation laid to address the issues of subsonic aircraft structure will serve as the basis for the technology and methodology necessary to support supersonic and transatmospheric vehicles. Affordable aircraft structure is the ultimate goal and will be realized as the technology matures.

NASA Leads The Way

NASA has initiated a program which should become a model for composite materials technology development in the United States. The Advanced Composites Technology (ACT) program funds numerous research projects (see sidebar) with the objective being to develop and demonstrate an integrated approach to cost-effective use of composite materials in aircraft primary structures. It stresses the development of a basic understanding of advanced composites, as opposed to earlier point design efforts.

Photo courtesy NASA

A Langley engineer examines an advanced composites crippling specimen which failed during a compression test.



Ultrasonic C-scan shows impact damage in a graphite-epoxy laminate.

Photo courtesy Stanford University

The program philosophy centers on the creation of generic tools which can be applied to specific structures. Using the Boeing Company's portion of the ACT program as an example, the technology developed will be applied towards large pressurized fuselage structure. The application, or verification, phase will result in an understanding of design manufacturing trades which are typically measured in terms of cost and weight. Structural mechanics and material development will promote an understanding of the trade between analysis tool simplicity and accuracy. Data generated from the fabrication and test of full-scale components will result in technology verification.

The ACT program emphasizes an integrated approach. At Boeing this integration is called a "Design-Build Team" (DBT); members of the materials, manufacturing, structural mechanics, and design communities work together to develop new designs. This differs from the traditional linear approach in which the design concept is generated, a material is selected, the design is analyzed, and then it is turned over to a manufacturer to build. One common result of the linear approach is that manufacturing is left out until the end and must build the structure with a far less than optimum process in order to stay on schedule.

The key to the DBT is communication. Members of the various disciplines can resolve potential problems at any time during the design development and find solutions faster than with the linear approach. While all design development revolves around customer and structural guidelines, the linear approach can make timely access to this information difficult for some participants. The DBT allows all team members to be aware of criteria and guidelines and their impact on the design development.

Interactions between certain members of the team will concentrate on specific issues. Failure mechanism studies, for example, must be directed by both the materials expert, who understands the microscopic behavior, and the structures expert, who understands what it means to the mechanics of the material. Interaction between these two disciplines centers on development of a tie between material behavior and structural performance. The result is a set of verified analysis tools that accounts for basic material behavior. There is a trade involved as to how these tools are used during different design phases. Very accurate and complex tools such as detailed finite-element models can be used to predict and certify part performance at the culmination of design efforts. These often require specialists to operate. The converse is a simple model such as a spreadsheet template which may be less accurate but can be used quickly during preliminary design work. Simple models are also inexpensive, which allows them to be employed in an iterative manner to screen many potential designs. One disadvantage is that the operator of the simple job must have the experience and judgement to know when the tool is not doing the job.

ACT Contracts Aim At Technology Breakthroughs

NASA has teamed with 14 major aerospace companies and universities nationwide to develop innovative structural concepts, materials, and fabrication techniques as part of the Advanced Composites Technology (ACT) program. Researchers are seeking technology breakthroughs that will allow structures made of epoxy-type resins and high-strength carbon fiber to replace metal in the wings and bodies of future transport and fighter aircraft. "Our goals are to reduce structural weight by 40-50 percent, acquisition cost by 20-25 percent, and the number of individual parts by half compared to current production aluminum aircraft," said John Davis, head of the Structures Technology Program Office at NASA's Langley Research Center, which manages the ACT program.

Langley has awarded contracts to Boeing, Lockheed, McDonnell Douglas, Northrop, Grumman, Sikorsky, and Hercules to explore new structural design concepts and cost-effective manufacturing techniques. Hercules, for example, is using a multiaxis tow placement technique to build integrally-stiffened fuselage panels. This technology involves the precise automated placement and in-process consolidation of ribbonized prepreg tow. Material cut-and-add "on the fly" offers high production rate potential, enhances tailorability, and minimizes scrap.

Two contractors are developing novel materials: BASF is creating commingled yarns and powder-impregnated tows that can be used for braiding, 3D weaving, and other advanced textile processes, while the Dow Chemical Company is developing thermosetting resins with processing characteristics suitable for resin transfer molding.

Langley has awarded contracts to several universities—including Delaware, Cal-Davis, Stanford, and Utah—to develop new analytical models and analysis techniques to better understand the failure behavior of laminates and woven material forms. Stanford researchers, for example, are developing a 3D finite-element model to calculate stresses, strains, and displacements in a thermoplastic composite during impact based on Hertzian contact forces. The impact damage model for delamination size and location will be used as the basis for a model to predict residual compressive strength and stiffness.

Further, Rockwell International is developing experimental techniques to characterize the initiation and growth of fatigue damage in woven and stitched composites. Based on the damage characterization, a micromechanical model that includes mechanisms such as localized plasticity, microcracking, and fiber bridging will be created to predict fatigue behavior of new material architectures.

Present contracts represent about 60 percent of the ACT program. The balance of the work will be accomplished through in-house research at NASA's Langley and Lewis research centers and through additional contract awards. Solicitations for new concepts will be issued throughout the program, which is expected to extend through 1994. ❑

Study efforts within the materials and structural mechanics disciplines concentrate on basic material properties, failure mechanisms, and constitutive laws development. This research will be tied to efforts in the areas of stiffness and stability, strength assessment, damage tolerance, and durability.

Design Tools

The design and manufacturing disciplines typically interface in a cost and weight trade. The designer, charged with concept development, needs the tools supplied by the structural mechanics and materials communities to perform efficient trade studies. Their input allows design compromises to be made more efficiently. The point design approach does not offer this flexibility, as it is tied to past data bases and rigid rules of thumb.

Manufacturing capabilites are identified by the manufacturing representative through a technology assessment that includes tooling concepts, material placement equipment, and processing equipment. Fabrication technology has received much attention over the past few years, although few new production-ready concepts have been put in place. Assembly methods have received less attention, but additional gains appear possible. Composite structures usually can be manufactured with a lower part count than aluminum versions. Since a one-piece airplane is impractical from a maintenance standpoint, innovative and cost-effective joining technologies must be examined.

Fabrication of test hardware and structural testing are required to validate technology advances. The goal is to integrate the developed tools through use of the DBT and enhance them as hardware verification allows.

Ultimately, a set of common design practices will be established that will be easily accessible to all DBT members. This data base will include design curves, computer programs, and numerous other tools. Integration of the base with CAD data is another goal. The key, however, is to provide the engineer with a comprehensive guide to composite development that is accurate, cost-effective, and easy to use. ❑

About The Authors

Randy L. Coggeshall is a lead engineer on structural analysis of the Boeing 737 fuselage. He has worked 13 years with Boeing, 11 in composites, and has taught a course entitled "Advanced Composites Technology" to engineering and manufacturing personnel.

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New Product Ideas

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Perfusion Bioreactor Module

A perfusion bioreactor module monitors and maintains a cell culture in a growth or maintenance medium under controlled conditions. This equipment can support the cultures of human or other fragile cells for experiments in basic cell biology or process technology.
(See page 113)

Porous-Floating-Gate Field-Effect Transistor

A porous-floating-gate, "vertical" field-effect transistor is proposed as a programmable analog memory device. The device is particularly suited for hardware implementations of massively parallel neural-network architectures.
(See page 18)

Air-Velocity Sensor for Helicopter

A new airspeed sensor has been conceived for the accurate measurement of both the airspeed and the direction of flight of a helicopter. The direction of motion of the helicopter is displayed by the lighting of one of a series of lamps that encircle a digital display of the airspeed.
(See page 39)

Pressurized-Flat-Interface Heat Exchanger

A heat-exchanger interface enables the efficient transfer of heat between two working fluids without allowing the fluids to intermingle. A possible application is in chemical or pharmaceutical manufacturing when even trace contamination of the process stream with water or other coolant could ruin the product. It may also reduce costs when highly corrosive fluids must be cooled or heated.
(See page 68)

GTO/FET Cascode Three-Terminal Switch

A three-terminal semiconductor switching circuit features high switching speed, extremely high turnoff safe operating area, moderately low forward voltage drop, and efficient utilization of the silicon in the design of its components. The circuit requires no external bias power and contains neither inductors nor capacitors.
(See page 18)

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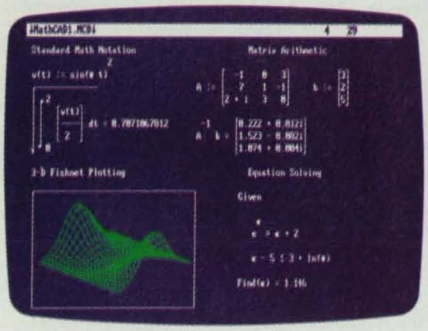

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Electronic Components and Circuits

Hardware, Techniques, and Processes

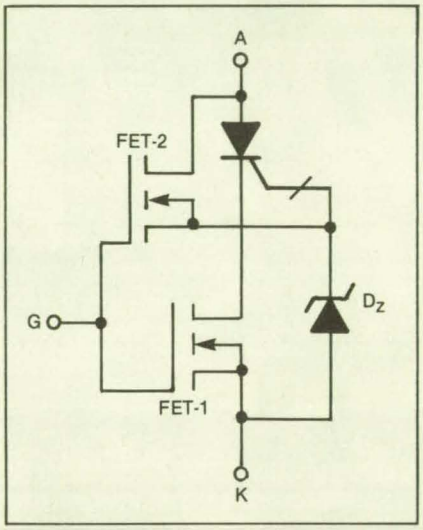
GTO/FET Cascode Three-Terminal Switch

Neither external bias nor energy-storage components are required.

NASA's Jet Propulsion Laboratory, Pasadena, California

A three-terminal semiconductor switching circuit features high switching speed, extremely high turnoff safe operating area (an area in the current-vs-voltage plane), moderately low forward ("on"-state) voltage drop, and efficient utilization of the silicon in the design of its components. The circuit requires no external bias power and contains neither inductors nor capacitors. It is suitable for both hybrid packaging and monolithic integration.

The circuit (see figure) includes a gate-turn-off thyristor (GTO) and a low-voltage (low-on-resistance) field-effect transistor (FET-1) connected in series to form a cascode pair. The GTO is turned on via a second field-effect transistor (FET-2) connected between the anode (A) and gate ports of the GTO. Both FET's have gates commonly connected to form a single control terminal (G). Finally, a Zener diode (D_z) is connected between the gate of the GTO and the source terminal (K) of FET-1 to provide a path for transient negative gate current during turnoff.



The **GTO/FET Cascode Three-Terminal Switch** can be made of commercially available, discrete components, as a hybrid circuit package or as a monolithic integrated circuit.

When terminal G is made sufficiently positive with respect to terminal K (e.g., +10 V), both FET-1 and FET-2 are made conductive. The turning on of FET-2 in turn provides a conductive path from terminal A to the gate of the GTO, thus turning the GTO on. Once the GTO is turned on completely, the current through FET-2 is relatively small because the voltage between the anode and the gate of the GTO is then small and the "on" resistance of FET-2 is relatively large.

When the voltage on terminal G is reduced sufficiently with respect to terminal K (e.g., 0 V), both FET-1 and FET-2 become nonconductive. When this happens, the path for current within the GTO is switched from anode/cathode to anode/gate. This, in turn, forces minority carriers out of the lower base and establishes a turnoff mechanism that is independent of Miller capacitance. This further results in a fast, high-safe-operating-area turnoff of the GTO. Results of tests indicate that this mode of turnoff includes a voltage equal to the peak off-state blocking voltage and a current density of up to 800 A/cm^2. The safe-operating-area current density is a function of the rate of change of current at turnoff; as the rate of change of cathode current is increased in magnitude, the safe-operating-area current density increases.

One of the reasons for the efficient utilization of silicon is that FET-1 experiences very low voltages (typically less than 10 V peak, assuming "tight" packaging). This means that available FET's rated at the lowest voltages will suffice. This, in turn, means that both low "on" resistance and low cost can be achieved simultaneously. Another reason is that FET-2 can be small because the GTO provides substantial turn-on gain, and turn-on current flows only during small duty cycles. Finally, D_z can be relatively small because low voltage (e.g., 3 V) and low duty cycles (typically less than 1 percent at 20 kHz) are involved.

This work was done by Wally E. Rippel of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 125 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 16]. Refer to NPO-17865.

Porous-Floating-Gate Field-Effect Transistor

A new electrically erasable, programmable, analog memory element is proposed.

NASA's Jet Propulsion Laboratory, Pasadena, California

A porous-floating-gate, "vertical" field-effect transistor is proposed as a programmable analog memory device that is especially suitable for use in electronic neural networks. Analog value of the electrical conductance of the device would represent a synaptic weight (strength of a synaptic connection) that could be repeatedly modified by application of a suitable writing or erasing voltage.

The device is particularly suited for hardware implementations of massively parallel neural-network architectures for two important reasons. First, contrary to the conventional three-electrode device configurations of the field-effect transistors, the proposed vertical transistor structure requires only two external electrodes (terminals). This feature would result in a substantial reduction in the hardware complexity in implementing large, high-density arrarys of such analog synap-

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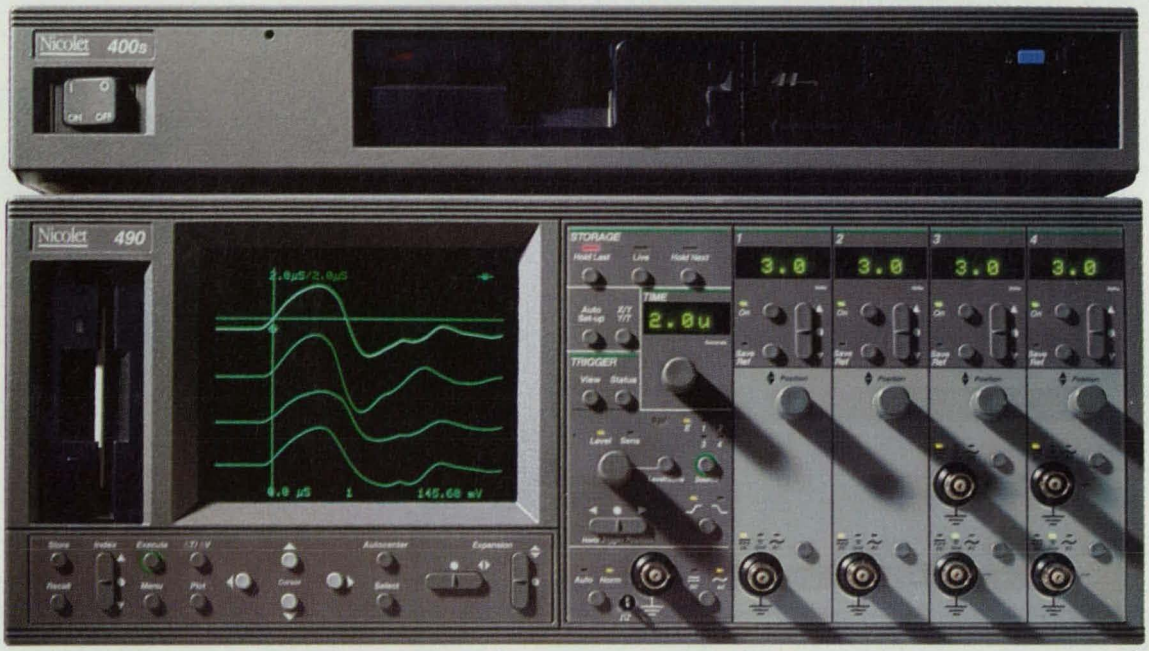

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tic-memory elements in cross-bar matrix designs for neural networks. Second, the use of tailored amorphous semiconductors (e.g., hydrogenated amorphous silicon, a-Si:H) provides a choice of a very wide range of low conductivity values, dictated by the overall power dissipation requirements in the massively parallel neural-network circuits.

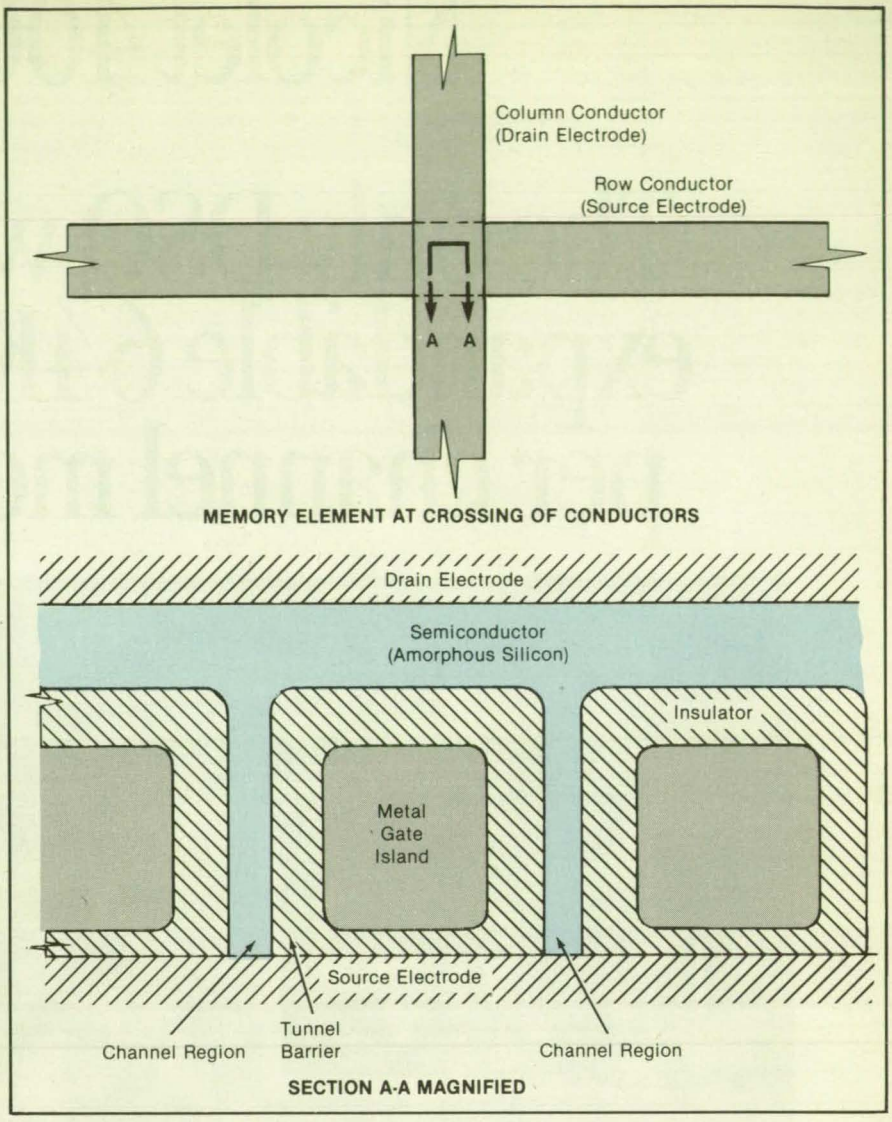
The active portion of each transistor (see figure) lies within the volume defined by the crossing of row and column conductors (metallic thin-film wires) of a large matrix of synaptic memory elements. One of these conductors constitutes the source electrode, while the other acts as a drain electrode. The electrodes are separated by a layer of a resistivity-tailored amorphous semiconductor (e.g., a-Si:H). The porous "floating" gate is formed within the amorphous semiconductor layer by embedded insulated metallic particles (e.g., magnesium oxide covered magnesium particles) close to the source electrode.

Typically, the amorphous semiconductor layer would be deposited by plasma-enhanced chemical vapor deposition, or magnetron sputter-deposition techniques, on top of the first set of parallel metallic electrodes, patterned on a suitable substrate (e.g., an oxide-coated silicon wafer). The incorporation of the insulated metallic islands in the semiconducting layer would be accomplished by first depositing a thin insulating layer over the source electrodes. This is followed by depositing a discontinuous layer of the selected metal on top of the first set of electrodes and growing an oxide over the metal islands prior to embedding them in the semiconductor layer. The deposition and patterning of the second set of perpendicular metallic electrodes on top of the semiconducting layer would complete the device structure.

The insulated metallic particles would therefore constitute the porous floating gate. Because the thin insulating layers in contact with the source would be quantum-mechanical-tunneling barriers, they would have nonlinear conductances. With the application of a sufficient voltage (the writing or erasing voltage) between the source and the drain electrodes, electrons would tunnel through the barriers, charging or discharging the metallic islands. As in conventional floating gate devices, the gate islands retain their charges or remain discharged once the writing or erasing voltage is removed.

The charge retentivity in such a device would of course depend on the quality of the dielectric layer as well as on the nature and characteristics of the metal–insulator interface. The floating gate, made up of several random disjointed islands, could alternatively be formed by more exotic and accurate lithographic techniques (e.g., electron-beam lithography). However, it is not necessary to arrange the islands in any specific geometrical fashion with close tolerance, since even if some of the islands (particles) were to "short" themselves with the source electrode, the charge retentivity of the overall porous gate would not be significantly affected.

The overall conductance of the vertical "channel" regions between the metallic islands would be affected by the charges stored at the islands. This conductance, representing the content of the memory element or effectively the synaptic weight, would be continuously variable because the charge could be varied continuously by controlling the polarity, amplitude, and duration of the write and erase pulses. The conductance would be sensed (the analog content of the memory element would be read) by applying a read voltage that is sufficient to generate a measurable current but much lower than the write or the erase voltage, so that the read voltage has a negligible effect on the stored charges and the analog memory.



Insulated Metallic Particles on the source electrode would constitute a porous floating gate. The particles would be charged or discharged by quantum-mechanical tunneling during the application of writing or erasing voltages.

This work was done by Anilkumar P. Thakoor, Alexander W. Moopenn, and John J. Lambe of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 131 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
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Refer to NPO-17532, volume and number of this NASA Tech Briefs *issue, and the page number.*

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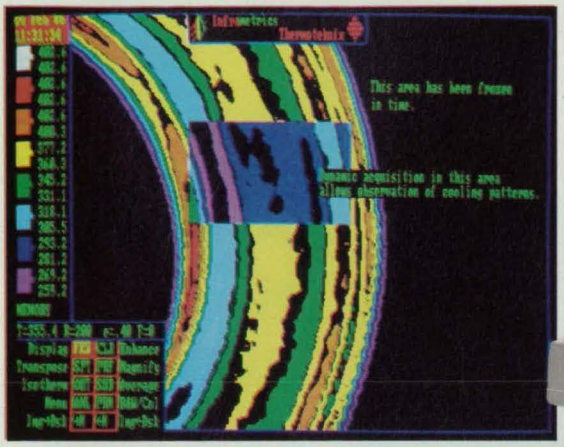
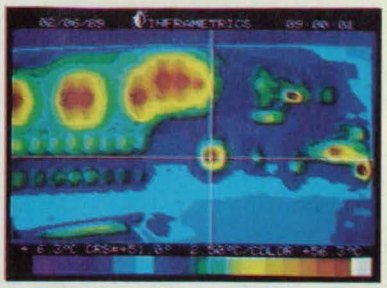


ThermaGRAM® image of an automotive brake rotor.



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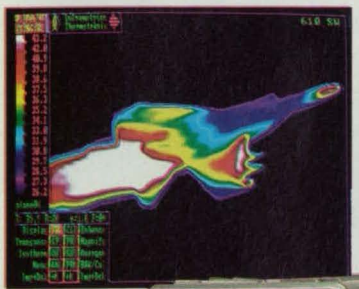

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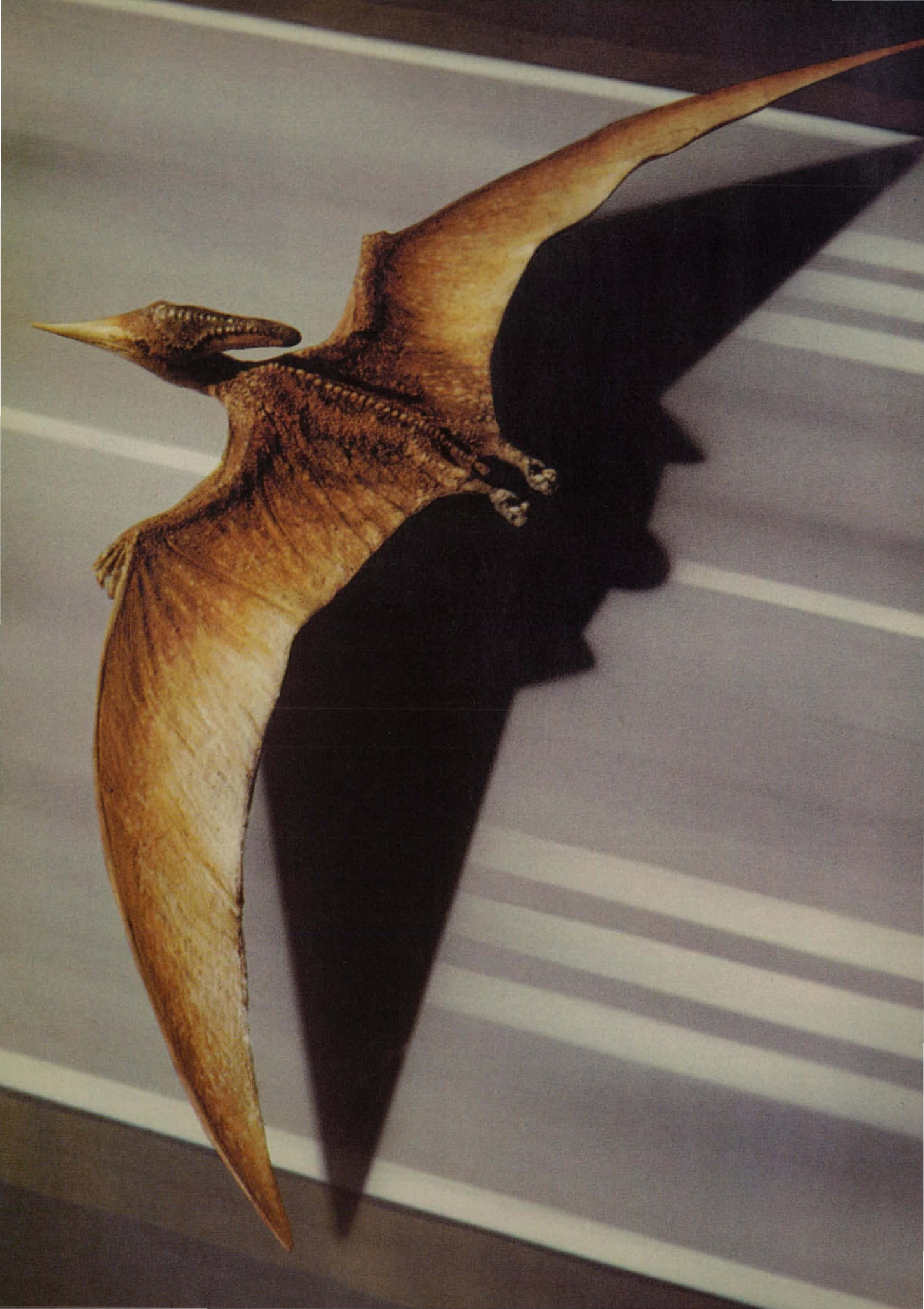

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Switching X-Ray Tubes Remotely

A convenient switch and relay circuit reduce the risk of accidents.

Marshall Space Flight Center, Alabama

A proposed switching circuit for an x-ray inspection system would enable an operator to change electrical connections to x-ray tubes remotely. Without the switching circuit, the operator has to climb to an equipment shelf 9 ft (3 m) above the shop floor to change low-voltage cables and coolant lines during a switch between 160-kV and 320-kV x-ray tubes. With the circuit, the operator would simply change the position of a switch (see Figure 1).

The switch would be mounted in a selector box about 4 ft (1.2 m) above the floor. There would be no need to climb a ladder — and perhaps fall from it — while changing connections.

A cable would connect the selector box to a changeover box on the equipment shelf. Relay switches in the changeover box would make the necessary powerline connections to provide −160 kV and water coolant for the lower-voltage tube and both −160 and +160 kV and oil coolant for the higher-voltage tube (see Figure 2). The chance of making the wrong connections and thereby damaging the equipment — a real possibility with a manual changeover — would be eliminated.

This work was done by Ronald V. Bulthuis of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information, Circle 27 on the TSP Request Card. MFS-29357*

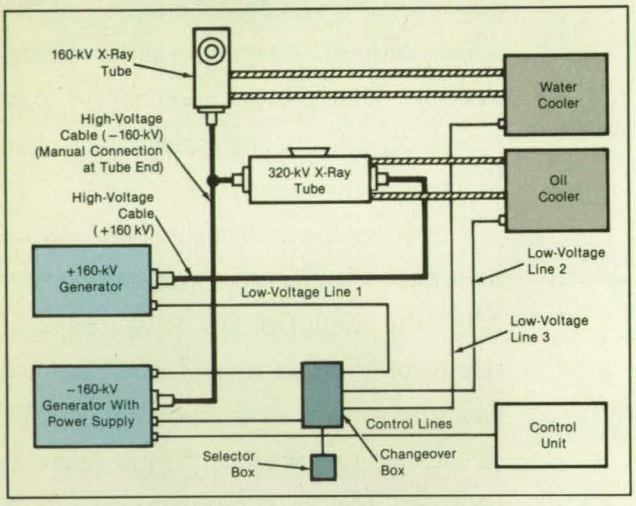

Figure 1. An **Operator Would Simply Flip a Switch** on the conveniently-located selector box to change x-ray heads. Indicator lights on the selector box would show whether the 160 or 320- kV head is connected. Relays in the changeover box would provide the proper voltages and coolants.

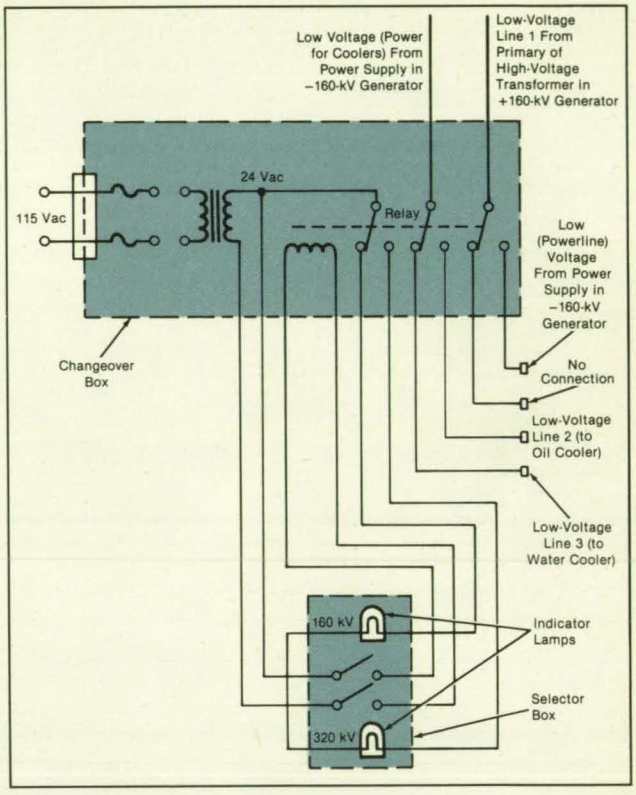

Figure 2. **Relays in the Changeover Box** would switch the low (powerline) voltages to the high-voltage generators and cooling units. Indicator lights on the selector box would show whether the 160- or the 320-kV x-ray tube is connected.

GaAlAs Traveling-Wave Electro-optical Modulators

Microwave signals modulate optical signals in a unit integrable with GaAs and GaAlAs devices.

Lewis Research Center, Cleveland, Ohio

Experimental GaAlAs electro-optical modulators have been designed and built for operation at a wavelength of 0.82 μm. Unlike $LiNbO_3$ devices, these modulators are expected to be easily integrable with GaAs monolithic microwave integrated circuits. Unlike modulators of pure GaAs, these modulators do not exhibit the excessive absorption at 0.82 μm that would prevent the use of them with GaAs/GaAlAs laser diodes.

Each modulator is configured as an optical-waveguide Mach-Zehnder interferometer. Microwave modulation is applied to two arms of the interferometer via traveling-wave electrodes that constitute a coplanar waveguide (see upper part of figure). Because the characteristic impedance of the waveguide is 50 Ω — a standard value — no impedance-matching network is required.

The modulator is fabricated on a GaAs substrate. The problem posed by the absorption of 0.82-μm light in pure GaAs is solved by adding more than 10 percent of aluminum to three layers of the modulator. This forms GaAlAs, which shifts the absorption edge of the compound semiconductor to a shorter wavelength. As a result, all three GaAlAs layers are transparent at 0.82 μm. The effect of the aluminum on the electro-optical response is believed to be insignificant.

The optical waveguides have the strip-loaded ridge structure shown in the lower part of the figure. Three layers of GaAlAs with differing aluminum concentrations were grown over a semi-insulating substrate. The upper layer was etched to form the loading ridge, but the optical signal propagates in the middle layer. This configuration concentrates the light away from the etched edges of the loading ridge, reducing the intensity of light scattered by the edges and thereby reducing the propa-

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gation losses. To prevent additional losses, the first layer above the semi-insulating GaAs is made thick enough to prevent the extension of the signal into the substrate, where it would otherwise be absorbed by the GaAs.

The dimensions and placement of the metal electrodes are chosen in combination with the dielectric properties of the GaAs substrate to provide the required modulating microwave field and the characteristic impedance of 50 Ω. Because there is no doping, the substrate and the three GaAlAs layers are semi-insulating, there is no significant ohmic or rectifying behavior in the waveguides, and all the layers can be considered to be dielectrics.

The $Ga_{1-x}Al_xAs$ layers were grown on the GaAs, substrate by molecular-beam epitaxy. The structures on the surface were formed by standard photolithography using a mask generated by an electron beam. The wave-guiding ridges were defined by wet chemical etching to a height of about 1,400 Å. The electrodes were made by lift-off techniques, using metals evaporated by an electron beam.

Modulators performed as intended in tests with light from a GaAlAs diode. Direct-current measurements showed that the turn-off voltage of a modulator is about 30 V. Theoretical calculations indicate a 3-dB bandwidth•length product of 11.95 GHz for 100-percent modulation depth.

This work was done by Kul B. Bhasin of **Lewis Research Center** *and Christopher M. Chorey and Altan Ferendeci of Case Western Reserve University. Further information may be found in NASA TM-100970 [N88-28240], "A High Frequency GaAlAs Traveling Wave Electro-optic Modulator at 0.82 μm."*

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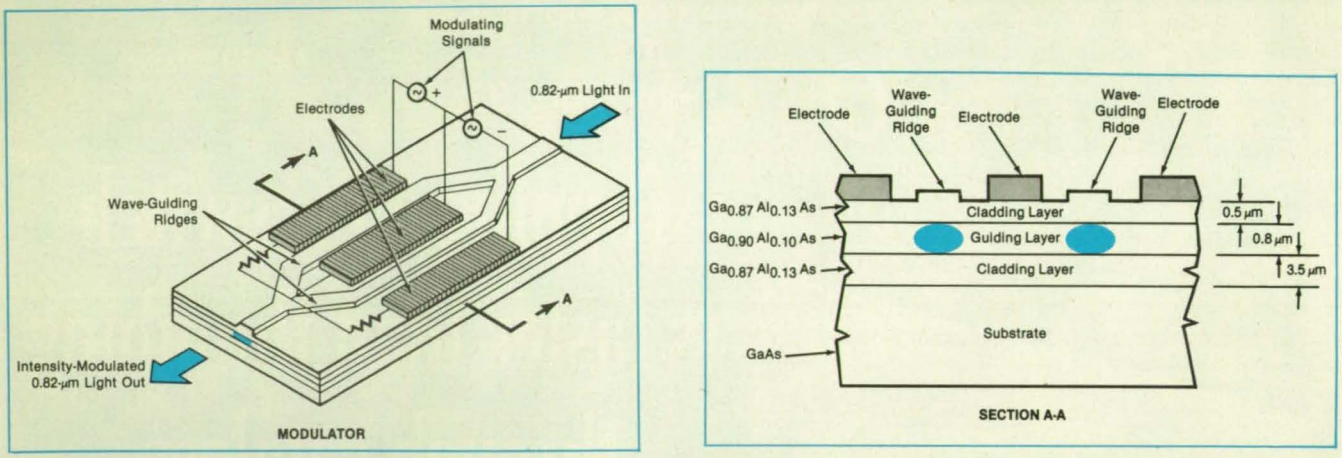

Integrated Optical and Microwave Waveguides in electro-optical materials **constitute a** traveling-wave electro-optical modulator in the configuration of a Mach-Zehnder interferometer.

Tunable Quantum-Well Submillimeter-Wave Oscillators

Frequencies would be adjusted via applied voltages.

NASA's Jet Propulsion Laboratory, Pasadena, California

Tunable (Al/Ga)As electronic devices of the proposed type would oscillate at frequencies from 300 to 3,000 GHz. Heretofore, it has been necessary to operate relatively inefficiently in that frequency range by generating harmonics from devices that oscillate at lower frequencies; and, to obtain higher powers, it has been necessary to use arrays of such harmonic generators. The new device concept offers the potential to make relatively compact, efficient local oscillators for heterodyne mixers in submillimeter radar and imaging systems, nondestructive testing, diagnosis of plasmas, airborne spectroscopy of the atmosphere, detection of weapons and other contraband, and communications.

A representative device would have the layered structure shown in Figure 1. The layers could be deposited by molecular-beam epitaxy, with appropriate grading of the Al composition of (Al/Ga)As to produce the energy-band structure with two partially-exponentially-shaped quantum wells illustrated in Figure 2. Near the bottom of each well, electron-energy levels would be

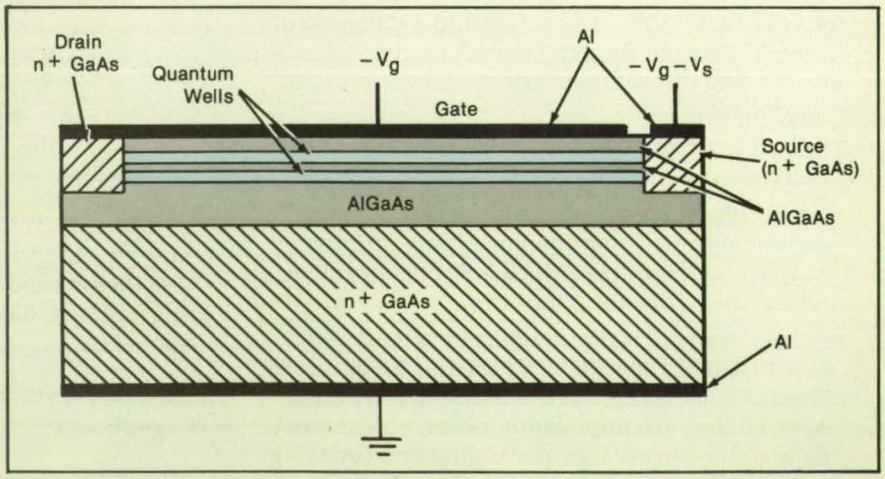

Figure 1. The **Tunable Submillimeter-Wave Generator** would be a layered (Al/Ga)As device.

like those of the well-known harmonic oscillator, separated by an interval (the photon energy) proportional to the square root of the curvature of the well at the bottom.

An electron current would be introduced along the wells (parallel to the layers) from the source contact. Electrons would be accelerated to higher quantum levels above the bottoms of the wells, then return to lower levels, emitting monochromatic radiation at the energies of the transitions between levels. The particular shape of the wells shown in Figure 2 is chosen so that the locations of the bottoms of the wells

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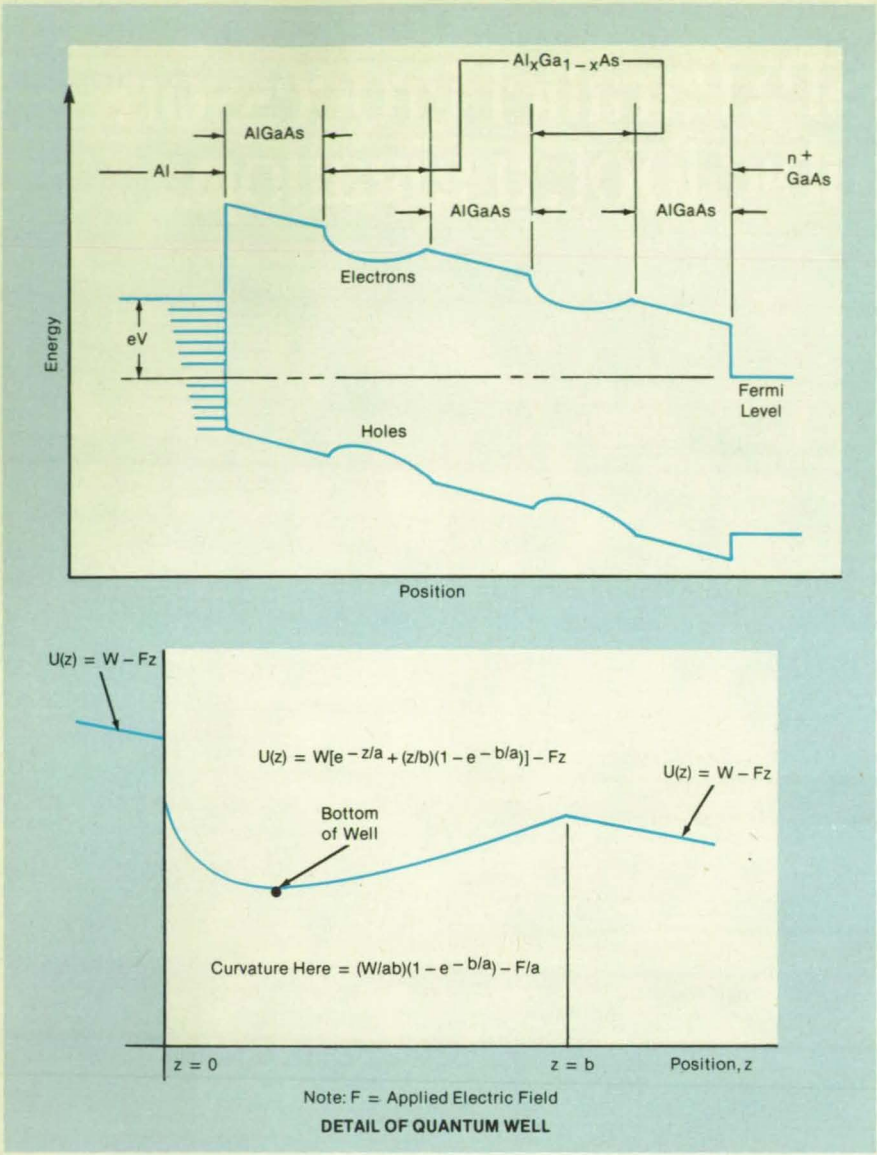

and the curvatures of the wells at those locations depend on the electric field. Thus, a change in the electric field would change the photon energy; that is, the frequency of the output could be tuned by adjusting the electric field.

To generate the frequency-controlling electric field, the voltage $-V_g$ would be applied between the common gate/drain contact and the ground (substrate) terminal. The voltage $-V_g - V_s$ would be applied at the source contact to inject electrons into the wells.

The radiation would travel outward along the planes of the quantum wells (perpendicular to the plane of Figure 1). The radiation could be collected or focused with conventional quasi-optical antennas or reflectors. If the device were placed in a cavity with appropriate reflectors and if there were sufficient gain through stimulated emission, the device might act as a laser that could be tuned through numerous cavity modes over a wide spectral range.

This concept was proposed by Joseph Maserjian of Caltech and Arthur C. Gossard of the University of California for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 143 on the TSP Request Card.*

NPO-17754

Figure 2. The **Energy-Band Structure** of the device of Figure 1 could include two (or more) quantum wells that could be adjusted via the applied electric field to adjust the frequency of radiation emitted by excited electrons.

Circuit Regulates Speed of dc Motor

Two nested feedback loops maintain speed within 1 percent of a constant value.

Lyndon B. Johnson Space Center, Houston, Texas

A driving circuit regulates the speed of a small dc permanent-magnet motor in a tape recorder. The circuit (see Figure 1), intended for use where the motor is not equipped with a tachometer and more-elaborate speed-controlling measures are not justified, maintains the speed of the motor within 1 percent of a constant value.

As shown in more detail in Figure 2, analog circuits in feedback loops 1 and 2 calculate the speed of the motor and compare it with the desired speed,to obtain the speed error. The error signal is then used to

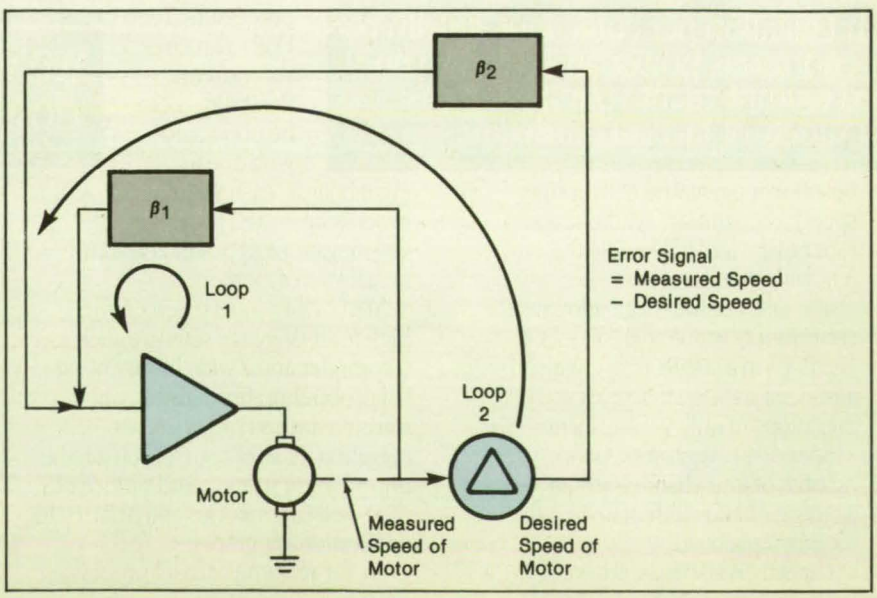

Figure 1. **Two Nested Feedback Loops** regulate the speed of a motor. The inner loop provides coarse regulation, while the outer loop removes most of the variation in speed that remains in the presence of regulation by the inner loop.

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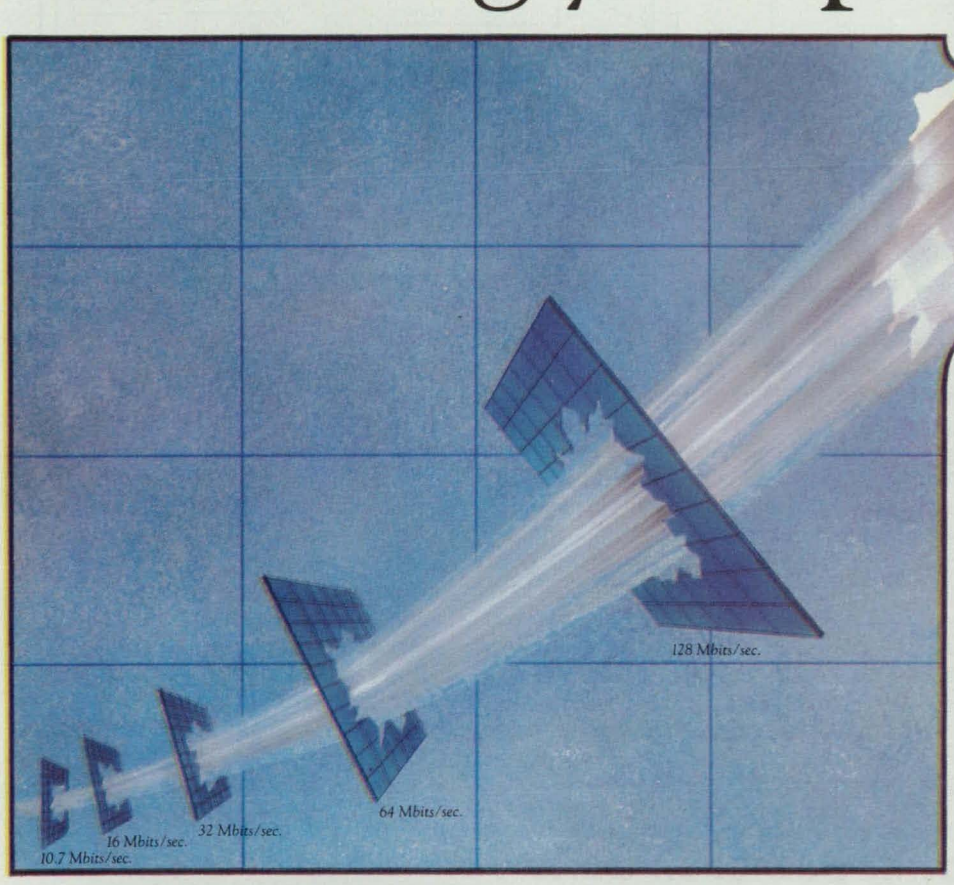

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adjust the current fed to the motor. In loop 1, R_1 and R_2 constitute a voltage divider between V_{in} and V_{out}, and the resulting divided voltage is applied to the positive input of the operational amplifier. Similarly, R_3 and R_m constitute a voltage divider between V_{emf} (the counterelectromotive force of the motor) and V_{out}, and the resulting divided voltage is applied to the negative input of the operational amplifier. When R_2 is properly adjusted, $R_1/R_2 = R_3/R_m$, and V_{emf} is forced to equal V_{in}. However, V_{emf} is directly proportional to the speed of the motor. Therefore, the speed is made directly proportional to V_{in}. Furthermore, the circuit would be expected to smooth out variations in the speed by negative feedback from the motor through R_m and R_3 to the negative input of the operational amplifier.

In practice, the circuit of inner loop permits some residual variation in speed, necessitating the addition of loop 2. In this loop, the voltage at A is proportional to the current through the 1-Ω resistor, and the constant of proportionality is chosen so that this voltage is numerically equal to the instantaneous voltage drop across the motor resistance, R_m, when the motor is running. The voltage at B is proportional to the difference between the motor-terminal voltage and the voltage computed at A. This difference equals V_{emf}, which is directly proportional to the instantaneous speed of the motor. Thus, the voltage at B is proportional to the speed of the motor. Because, in practice, the voltage at B has large negative spikes that increase the variations in speed, a peak-holding circuit is added. This makes the voltage at C a smooth analog of the speed.

This voltage is applied as input to an integrator and summer. "$-V_{speed}$" is proportional to the commanded speed and has to be negative because the voltage at point C is positive and the loop acts to null out the voltage at the summing point.

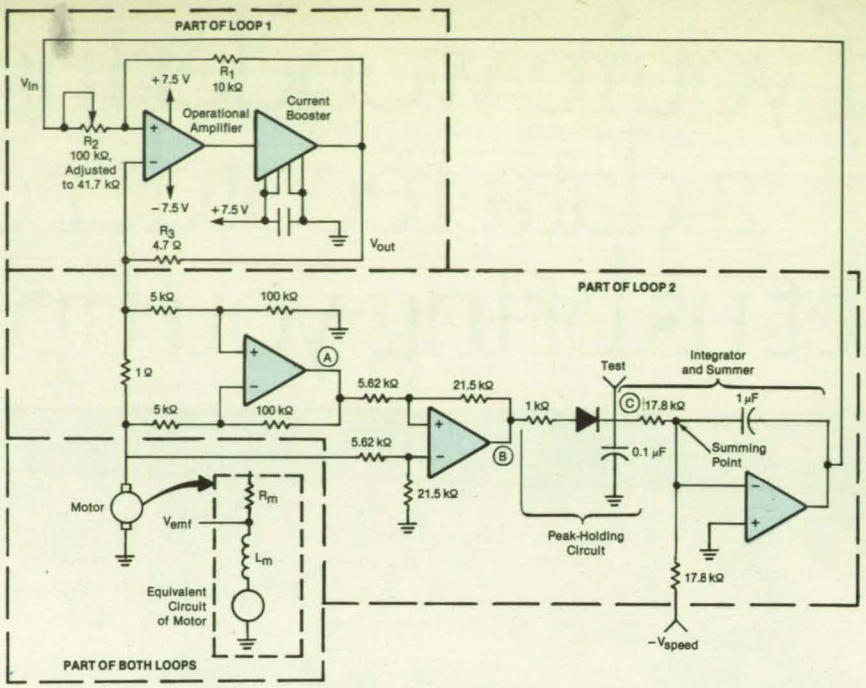


Figure 2. The **Motor-Driving Circuit** compares the speed of the motor (as manifested in a voltage) with a commanded speed (as expressed in a command voltage, $-V_{speed}$) and adjusts the current supplied to the motor accordingly.

It is necessary to set the 100-kΩ potentiometer for the best stability of the loops. This is done by monitoring the "test" point while adjusting this potentiometer. The optimum setting is on the edge between stability and instability, but it should be set a little into the range of stability away from the edge to protect against drift in the values of components.

It is necessary to pick the exact value of the series current-sampling resistor labeled as 1 Ω. This resistor is wound from copper wire and is picked to be as close as practical to one-twentieth of the stalled-motor resistance, R_m. This special resistor compensates for variations in R_m caused by changes in temperature.

This work was done by Charles Weaver, Robin Padden, and Floyd A. Brown, Jr., of SRI International for **Johnson Space Center**. *For further information, Circle 53 on the TSP Request Card.* *MSC-21345*

AlAs Diffusion/Schottky Barrier on GaAs

Epitaxial semiconductor and metal contact films are deposited without interruption of vacuum.

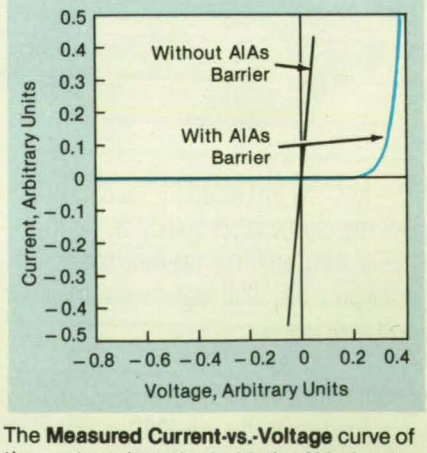
NASA's Jet Propulsion Laboratory, Pasadena, California

An ultrathin epitaxial film of AlAs can be deposited on a GaAs substrate to serve as a Schottky barrier and/or as a barrier to diffusion. This barrier film is deposited without interrupting the processing vacuum in which the substrate was deposited and in which any subsequent layers are to be deposited.

Rectifying metal/semiconductor contacts, which are Schottky barriers, are essential to most electronic devices based on GaAs. Because such devices are sensitive to contamination and handling during fabrication, epitaxial growth techniques (e.g., molecular-beam epitaxy) compatible with ultrahigh vacuum are preferred. Unfortunately, when gold (the contact metal of choice) is deposited directly on an epitaxial GaAs film, the gold and GaAs interdiffuse, causing the contact to become ohmic instead of rectifying. Diffusion can be prevented by exposing the substrate to air before depositing the gold, but this subjects the substrate to corrosion, contamination, and the risk of breakage.

In the new technique, the epitaxial film of AlAs is deposited directly on the GaAs substrate to a depth of only two atomic layers — less than 1 nm thick. The film is thin enough so that it does not constitute an electronic barrier, but thick enough so that it is expected to act as a barrier to the interdiffusion of gold and GaAs. Such a film might also be used as a barrier to the interdiffusion of dopants at heterojunctions.

In a demonstration, a substrate of GaAs 1 μm thick was grown by molecular-beam epitaxy. Without interruption of the vacuum, the two-monolayer AlAs film was deposited on the GaAs. The specimen was



The **Measured Current-vs.-Voltage** curve of the contact deposited with the AlAs barrier indicates the presence of a Schottky barrier 0.85 V high. The straight current-vs.-voltage line of a similar contact deposited without the AlAs barrier indicates that this contact is ohmic.

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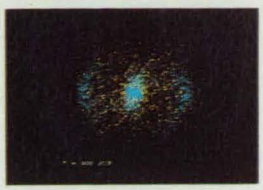

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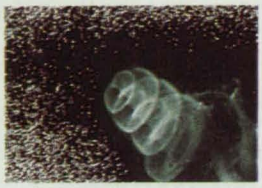

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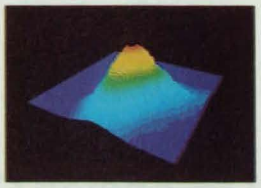

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Sharath Girimaji,
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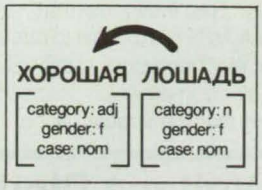

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transferred under ultrahigh vacuum to a metallization chamber, where a gold dot 10 nm thick was deposited from a filament. The specimen was then removed from the chamber.

The current-vs.-voltage curve of the contact showed the desired rectifying behavior (see figure). The height of the barrier, as deduced from this curve, is characteristic of GaAs. This indicates that, as expected, the AlAs film is too thin to affect the transport of electrons significantly. By use of ballistic-electron-emission microscopy, it was found that the spatial uniformity of this diode is better than that of a Schottky barrier formed on material exposed to air, where the contaminated, oxidized surface layer constitutes a nonuniform barrier to diffusion and a barrier to electronic conduction.

This work was done by William J. Kaiser, Frank J. Grunthaner, L. Douglas Bell, and Michael H. Hecht of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 127 on the TSP Request Card.*

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Refer to NPO-17796, volume and number of this NASA Tech Briefs *issue, and the page number.*

High-Voltage Digital-to-Analog Converter

Resistors in series are bypassed by optically isolated switches.

Marshall Space Flight Center, Alabama

A high-voltage 10-bit digital-to-analog converter operates under computer control to put out voltages up to 500 V at currents up to 35 mA. The circuit includes a high-voltage power supply which is used to generate a high-voltage square wave at a frequency set by the computer at a value between 0.2 Hz and 10 Hz (see Figure 1). The circuit is used to drive a 0.02-μF, 1-kV capacitor at a slewing rate of 1 V/μs to provide a signal for a robotic imaging system.

The circuit (see Figure 2) includes a series string of resistors that controls the regulated high-voltage supply. The high-voltage-regulator section evolved from a design in the National Semiconductor Linear Applications Databook LB47. To set the output voltage, the resistors are bypassed as needed by ten optically isolated electronic switches (photovoltaic relays) controlled by the computer.

The power supply is protected against short circuits by switching circuitry (not shown in the figures) that turns it off when the output current exceeds 35 mA. In addition, the circuit includes a "kill" switch to deliberately blow the dc power fuse, if necessary.

This work was done by Steven W. Huston of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available. MFS-29605*

Figure 2. The **High-Voltage Digital-to-Analog Converter,** shown here in more detail, corresponds to the portion of Figure 1 bounded by the dashed lines.

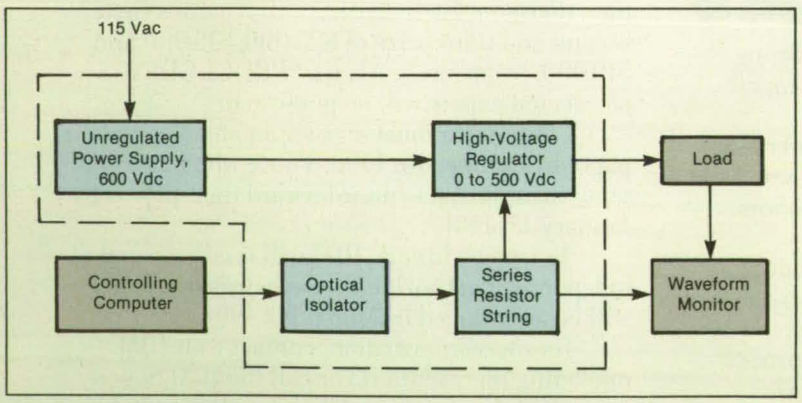
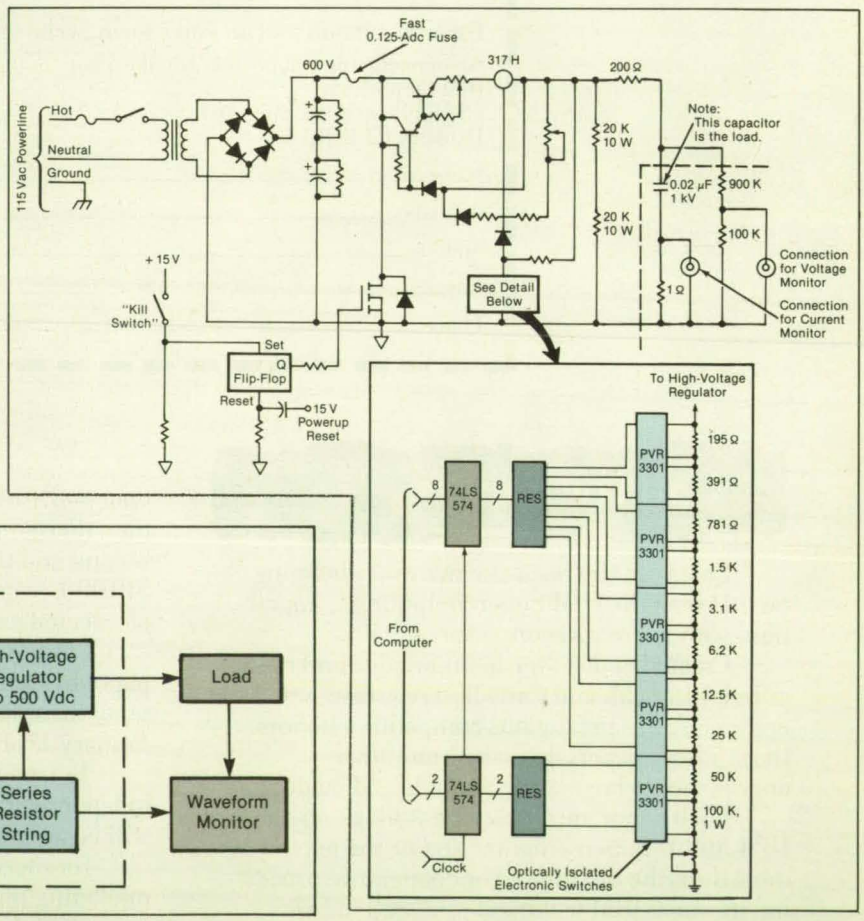


Figure 1. This **Block Diagram** illustrates the use of the fast high-voltage regulator to generate waveforms.

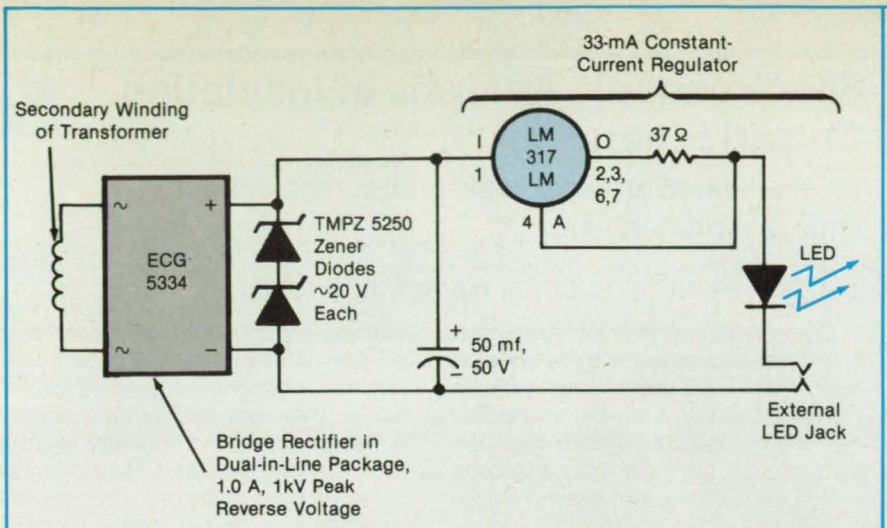


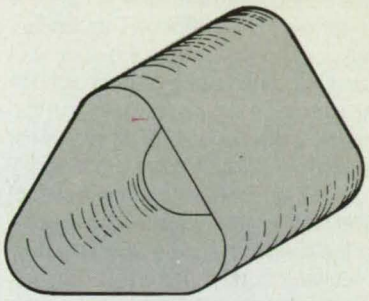
Small, Lightweight Welding-Current Indicator

A circuit is wrapped around a transformer core.

Marshall Space Flight Center, Alabama

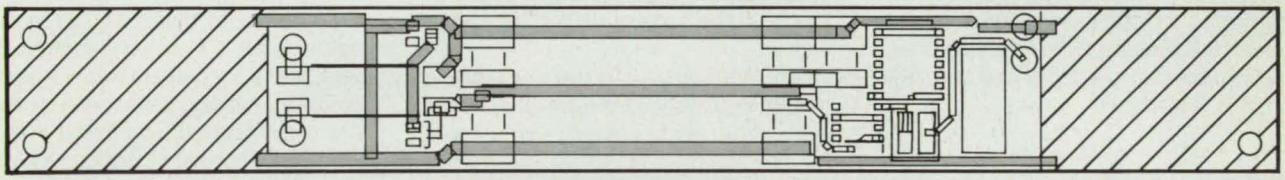
A welding-current indicator will be made of surface-mounted components on a flexible circuit board. The surface-mounted devices make it unnecessary to drill holes in the circuit board to accommodate component leads. The use of small surface-mounted devices will result in a lightweight, compact indicator circuit. To make the circuit even more compact, the flexible circuit board will be wrapped around the trans-





TRANSFORMER CORE

LAYOUT OF FLEXIBLE CIRCUIT BOARD



The **Flexible Circuit Board** will hold a variety of components on its surface. After assembly, the flexible circuit will be wrapped to fit around the transformer core.

former core used to sense the welding current.

The surface-mounted devices are to be bonded to the flexible board with solder and/or epoxy. After the assembled circuit (see figure) will have been tested, it is to be wrapped on the transformer core and potted in a medium-viscosity room-temperature-vulcanizing compound.

This work was done by Steven W. Huston of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*
MFS-29622

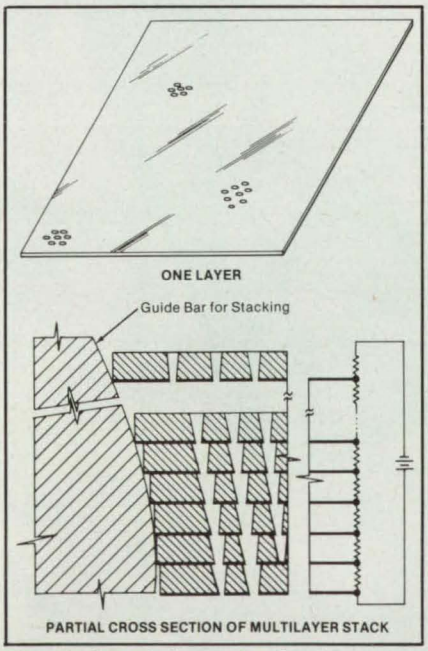
Multiple-Dynode-Layer Microchannel Plate

Improvements include better performance and easier manufacture.

Goddard Space Flight Center, Greenbelt, Maryland

An improved microchannel-plate electron image amplifier is made of a stack of discrete microchannel-plate layers. In comparison with conventional microchannel plates, the new plates are easier to manufacture because there is no need to etch long, narrow holes, to draw and bundle thin glass tubes, or to shear the plates to give the microchannels the curvatures necessary for reduction of undesired emission of ions. Furthermore, whereas the high electrical resistance of a conventional microchannel slows the rate of recharging after each signal pulse so that a typical photon counter in which it is used is limited to a few tens of counts per second, the new design provides for relatively fast recharging of the microchannel dynodes, with consequent enhancement of performance.

Each layer consists of an insulating plate perforated with a complete two-dimensional array of microchannel holes, aligned with a conductive plate containing a matching set of holes. Typically, the holes in the insulating plate taper from larger diameter on the cathode side to smaller diameter on the anode side. The conductive plate is attached to the anode side, and the holes in it are smaller than those in the insulating plate (see figure). The holes in the insulating and conducting plates can be made by well-known photolithographic and etching techniques. Alternatively, the conductive layer can be made by depositing metal on the anode surface of the insulating plate. In that case, deposition can be performed at a shallow angle while the plate is rotated so that the conductive material is deposited part way into the holes to the optimum depth for acceleration of electrons.



Discrete Dynode Layers Are Stacked with a slight offset from layer to layer to form a microchannel plate with curved channels.

A secondary-emitting surface is formed in the holes by deposition either before or after stacking the layers. If the insulating layer is made of glass, gradients of electrostatic potential and secondary-emission characteristics can be modified by treatment in a hydrogen furnace before, or instead of, coating with a secondary-emitting layer.

The layers are stacked in staggered fashion to effect the required curvature (see figure). This can be done easily; for example, by aligning the edges of the layers with a

guide bar. The layers can be simply clamped together, fused together by hot pressing, or perhaps bonded with adhesive to form the multilayer microchannel plate. The conductive layers are connected to the source of accelerating potential by a resistive voltage divider, with the most-negative voltage tap connected to the conductive layer nearest the input (cathode) side and the most-positive voltage tap connected to the conductive layer nearest the output side. The resistors in the divider can be chosen to allow rapid recharging after each signal pulse.

This work was done by Bruce E. Woodgate of **Goddard Space Flight Center**. *For further information, Circle 114 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Goddard Space Flight Center [see page16]. Refer to GSC-13203.

Spectroscopic Analysis of Insulating Crystal Fibers

A new method provides rapid characterization of optical properties.

Langley Research Center, Hampton, Virginia

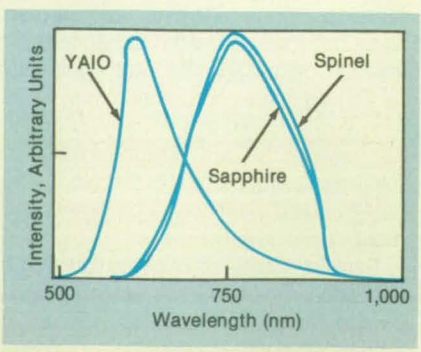
Crystal fibers can be grown more rapidly and less expensively than can crystals produced by more conventional methods. However, because they are smaller and less uniform, measurements of their optical properties are more difficult. Accordingly, a new technique for determining the optical properties of insulating single-crystal fibers has been developed and applied to sapphire, spinel, and YAlO crystalline host fibers doped with triply ionized titanium.

The fibers, grown by use of a pedestal heated by a laser, were about 1 mm in diameter and 5 cm long. Two faces were polished parallel to the axis of each fiber studied. Laser light was injected perpendicular to the axis, and the laser-induced fluorescence emerging from the ends of each fiber was measured. Measurements were also made of the absorption spectra and of the fluorescence lifetimes of these fibers. Typical fluorescence spectra are shown in the figure.

The variety of defects found in large single crystals is also found in the crystal fibers, wherein the effect on the transmission of light is exaggerated because of the sizes of the fibers. Furthermore, these fibers are large enough to support the propagation of multiple modes. Thus, significant scattering may be expected. One would also expect interference and conversion of modes, both caused by defects and nonuniformities in the cross sections of the fibers, to complicate the measurements of absorption.

A statistical treatment of the transport of radiation through fibers was performed to account for multiple scattering and interference. In this analysis, the effects of multiple scattering were treated as those of a length-dependent reflection from the bulk and combined with Fresnel surface reflection to enable the prediction of absorption and emission characteristics. Analysis of the data indicated that this new technique can provide rapid characterization of the optical properties of single-crystal insulating fibers.

This work was done by A. M. Buoncristiani of Christopher Newport College and Addison T. Inge and C. E. Byvik of **Langley Research Center**. *For further information, Circle 5 on the TSP Request Card.*
LAR-13831



These are **Typical Fluorescence Spectra** of single-crystal fibers of the indicated materials. The fibers are doped with triply ionized titanium.

Electronic Systems

Hardware, Techniques, and Processes

Neural-Network Computer Transforms Coordinates

Complicated transformations can be learned from few examples.

NASA's Jet Propulsion Laboratory, Pasadena, California

A numerical simulation has demonstrated the ability of a conceptual neural-network computer to generalize what it has "learned" from a few examples. The ability to generalize is achieved with even a simple neural network (relatively few neurons) and after exposure of the network to only a few "training" examples.

One general concept calls for layers of neurons, the collective function of which

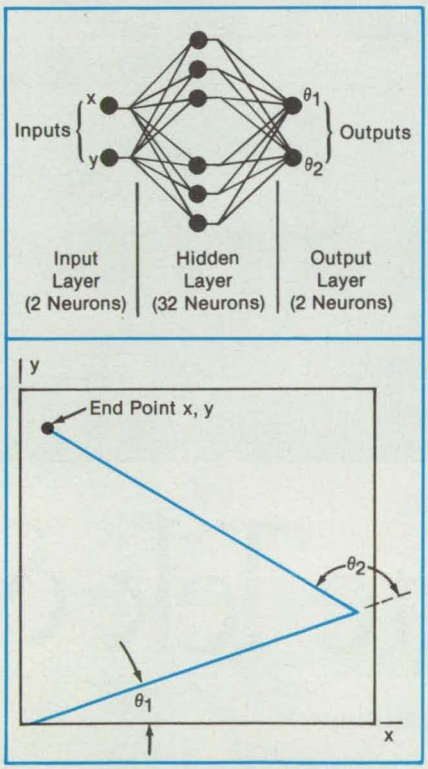


Figure 1. The **Three-Layer Neural-Network Computer** was simulated in a test of its ability to "learn" to transform pairs of Cartesian (x, y) coordinates to corresponding joint-angle (θ_1, θ_2) coordinates.

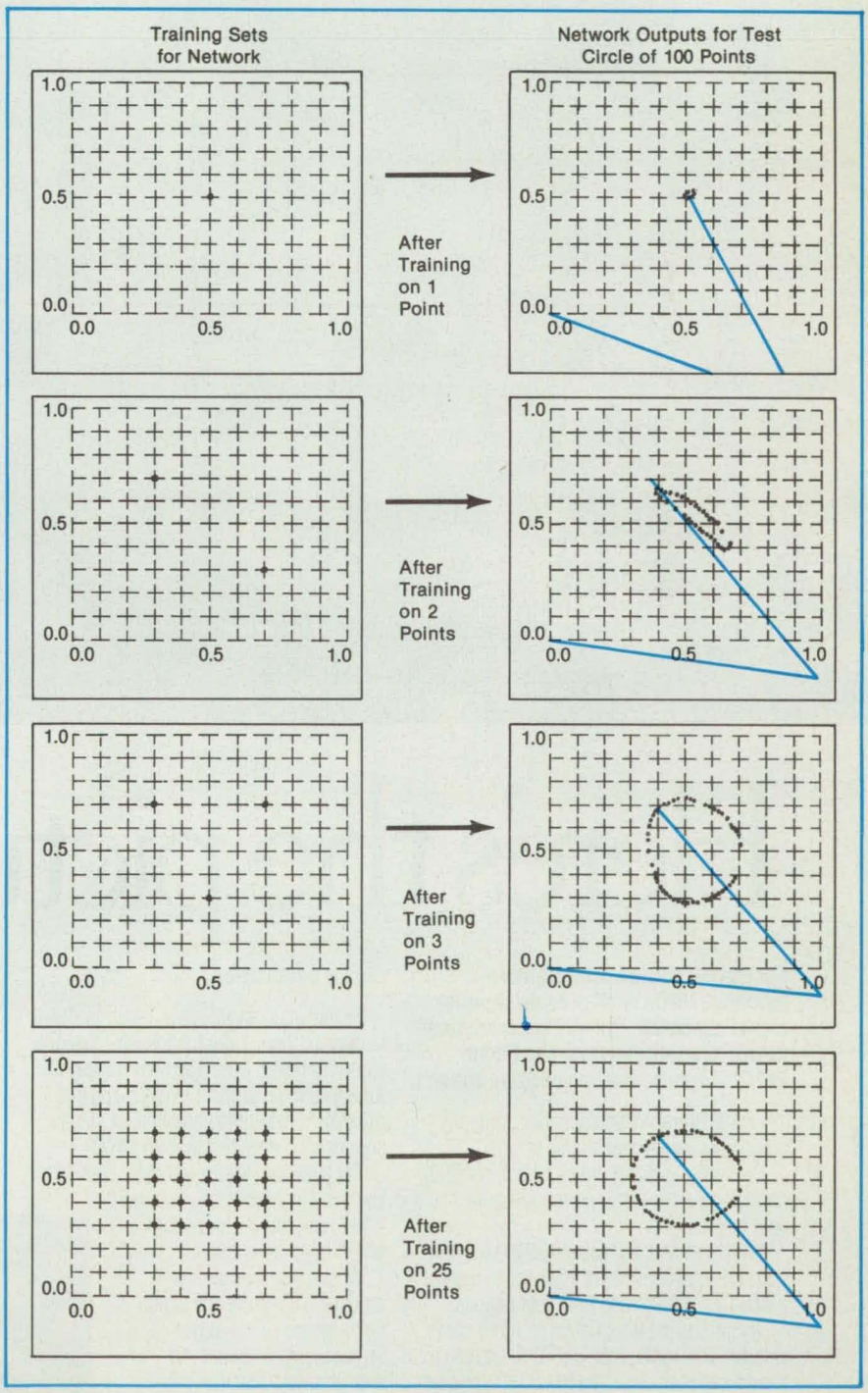
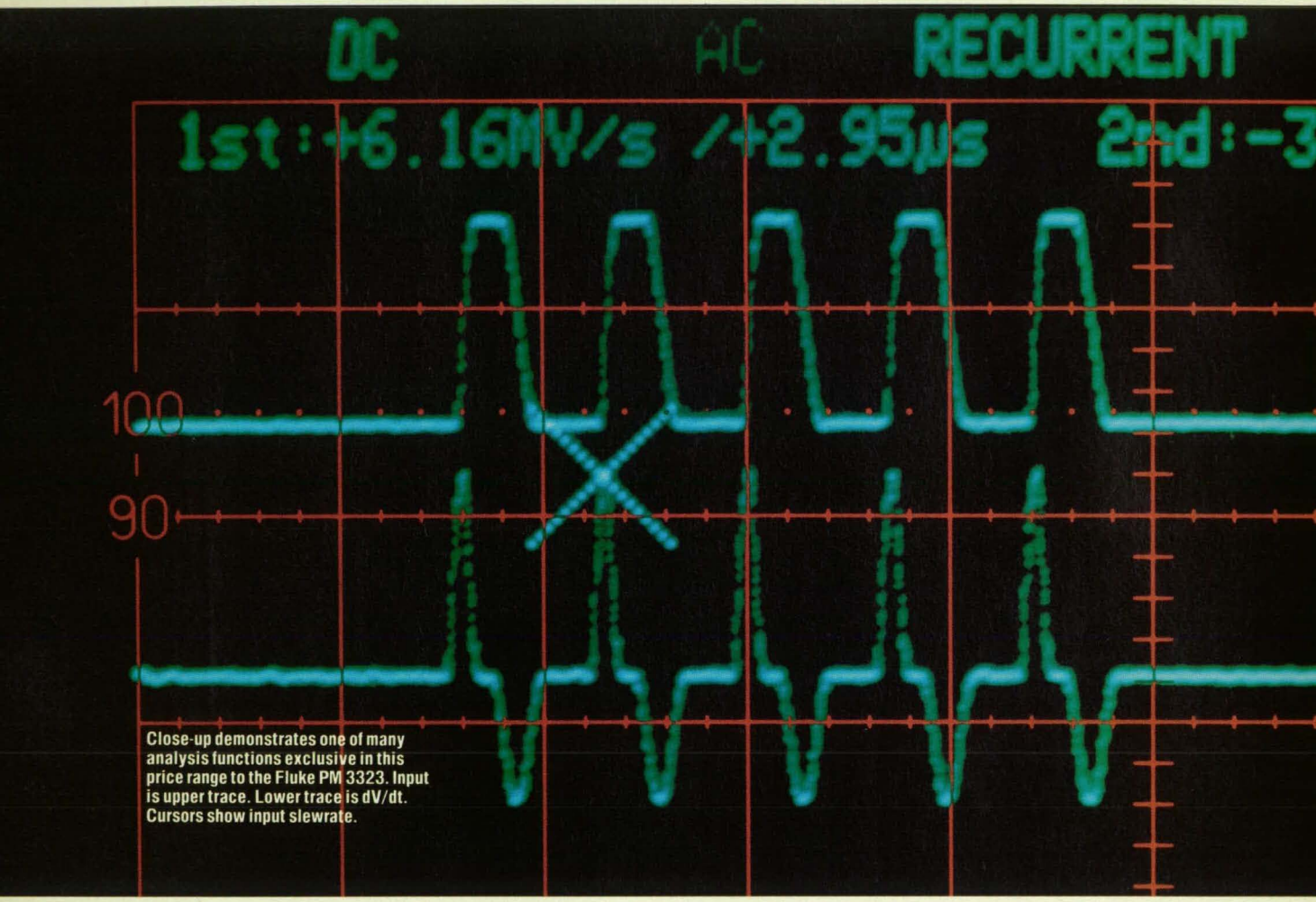


Figure 2. **Random Points on a Circle** in Cartesian coordinates were mapped into joint angles by the simulated neural network of Figure 1 after "training" the network with various numbers of examples of mappings. The ability to obtain fairly accurate mappings after only a few training examples might be used to provide solutions to otherwise intractable mapping problems.

FLUKE



Close-up demonstrates one of many analysis functions exclusive in this price range to the Fluke PM 3323. Input is upper trace. Lower trace is dV/dt. Cursors show input slewrate.

Here's the picture Tek® &

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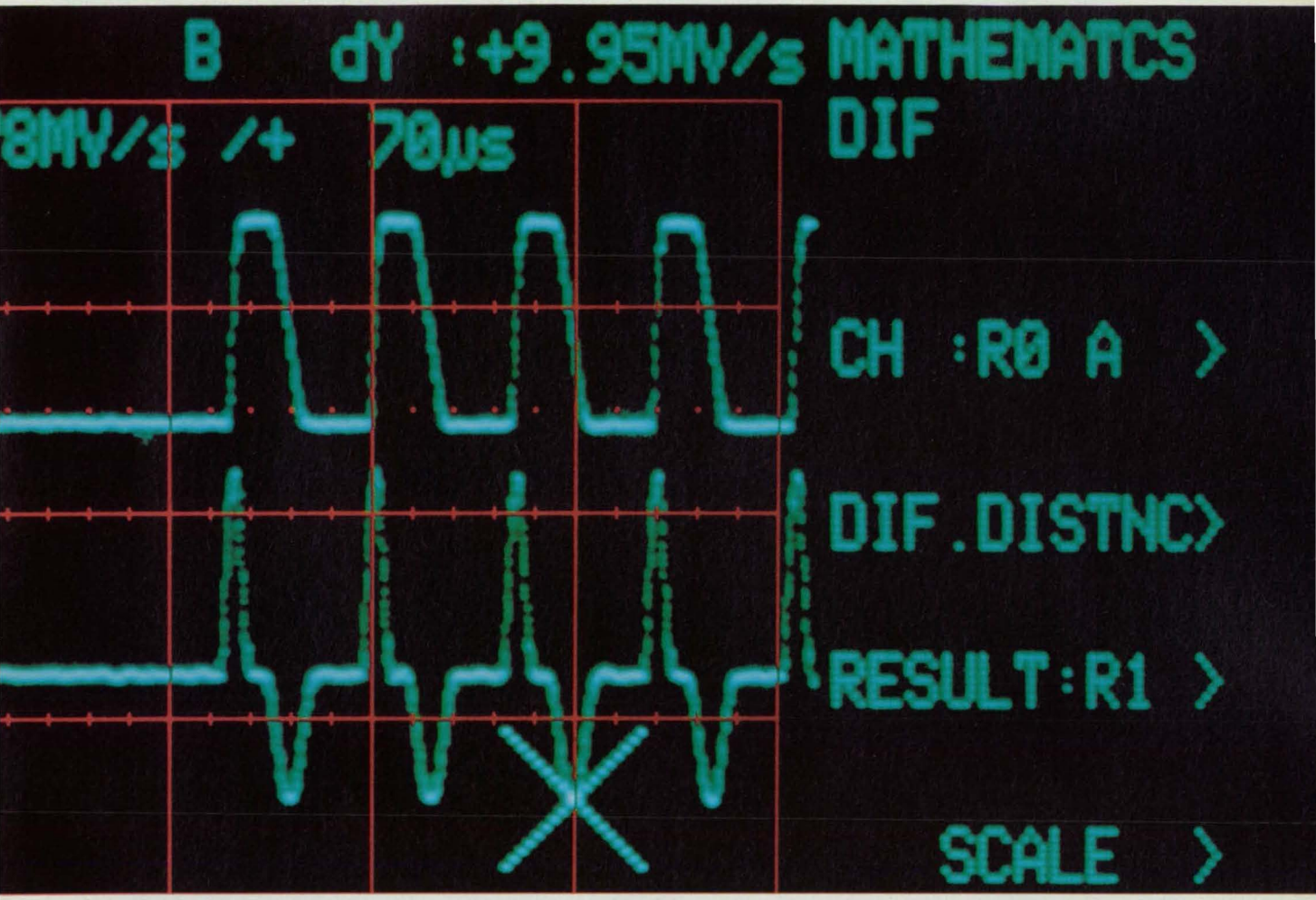

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Speed	300 MHz 500 MS/s	300 MHz 500 MS/s	100 MHz real time, 400 MHz repetitive 400 MS/s
Vertical Resolution	10 bits	8 bits	6 bits
Glitch Capture	Yes	Yes	No
Stop/Save on Difference	Yes	Yes	No
Analysis Functions (Int., Diff., Hist., Filter, FFT)	Yes	No	No
Math Functions (add, subtract, multiply, divide)	Yes	Multiply only	Yes
Measurement Functions (RMS, Freq., etc.)	Yes	Yes	Yes

FLUKE

Circle Reader Action No. 668

exhibits properties typical of real neural systems. The first layer is the input layer, the last layer is the output layer, and the intermediate layers are called "hidden" layers. The total excitation of the ith neuron in the nth layer is given by

$$E_{n,i} = \sum T_{n,i,j} U_{n-1,j}$$

where $U_{n-1,j}$ represents the output of the jth neuron in the $n-1$st layer, and $T_{n,i,j}$ represents the strength of the connection between the ith neuron in the nth layer and the jth neuron in the $n-1$st layer. The output of the ith neuron in the nth layer is given by

$$U_{n,i} = [1 + \exp(-E_{n,i})]^{-1}$$

These equations describe a signal as it "feeds forward" through the network. That is, when the network is given some input, it responds with some output based on the values of its connections.

Many different learning rules have been developed for the self-organization of neural networks. The rule used here is a modification of a back-propagation algorithm. The difference between the desired output and the actual output of a neuron in the output layer for a given input to the network is added to a cumulative error signal that is used to reassign the connections T. During the learning phase, these connections are adjusted so that the differences between the outputs of the network and the desired outputs are eventually minimized in a least-squares sense.

The simulation was conducted to test the ability of the conceptual neural network to generalize to obtain a two-degree-of-freedom topological transformation from the Cartesian coordinates of the end of a two-dimensional, two-rotary-joint robot arm to the joint-angle coordinates of that arm (see Figure 1). The network was given a few "training" examples of sets of corresponding coordinates, then asked to compute the joint angles that corresponded to points not in the original training set. Figure 2 shows how well the simulated network mapped a set of random coordinates on a circle, for various numbers of examples used to train the network.

This work was done by Gary M. Josin of Neural Systems, Inc., for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 142 on the TSP Request Card. NPO-17753*

Multibeam 1.4-GHz Pushbroom Microwave Radiometer

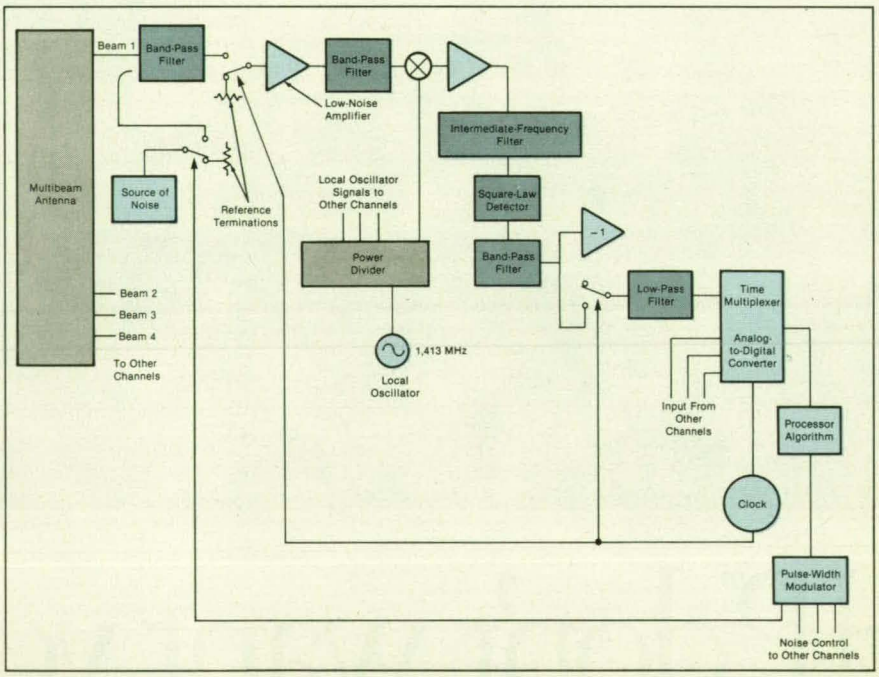
An airborne prototype radiometer exhibits high spatial resolution.

Langley Research Center, Hampton, Virginia

The measurement of multiple geophysical parameters from orbiting spacecraft that achieve high spatial resolution, global coverage, and frequent revisits is very important and useful in agriculture, hydrology, and weather- and climate-forecasting applications. In particular, such geophysical parameters as soil moisture, sea-surface temperature, windspeed, rain rate, amounts and properties of snow and ice, and atmospheric parameters can be measured by use of microwave radiometers. High spatial resolution and wide across-track coverage can be achieved simultaneously by use of multiple narrow beams, which can be either scanned across track or fixed across track in the so-called "pushbroom" configuration. An airborne prototype of a multiple-beam pushbroom microwave radiometer (PBMR) has been developed by the NASA Langley Research Center to advance the radiometric technology necessary for remote sensing of geophysical parameters.

The figure shows a simplified block diagram of the PBMR. The antenna is a 64-element (8 by 8) array of V-dipoles with a stripline feed network for producing multiple beams. The V-dipole was selected as the element of the array because its radiation pattern is nearly circularly symmetrical about the axis of the beam and because its projected length at resonance is shorter than that of a linear dipole, allowing closer physical spacing of the elements.

An L-band front end provides the equipment for injection of noise, input filtering, Dicke modulation, and amplification. The mixer-and-amplifier stage is used to down-convert the desired frequency band to dc (homodyne receiver). A 1.413-GHz local oscillator is used to perform the down-conversion.



The **PBMR Was Developed To Demonstrate Technologies** that may be desirable in pushbroom radiometry and to demonstrate the pushbroom concept in an airborne prototype.

The amplifier/square-law-detector stage provides an output voltage proportional to the input noise power. The analog signal processor then performs band-pass filtering and Dicke correlation of the noise signal, as well as low-pass filtering, before sampling by the digital processor. The digital signal processor provides the appropriate algorithm for optimum loop filtering and estimation of data. The digital signal processor also provides timing for Dicke switching and sampling of data.

The PBMR was designed to conform to requirements developed in conjunction with NASA Goddard Space Flight Center personnel involved in the study of the remote sensing of soil moisture. The instrument has been used in several joint Langley Research Center/Goddard Space Flight Center/United States Department of Agriculture soil-moisture flight experiments in Virginia, Texas, and California. The PBMR data from those experiments are being used to modify, develop, and verify the algorithms used to predict soil moisture from remote-sensing measurements. The image data obtained from those flights may also be useful in the study of the effects of characteristics of beams on radiometer imaging data.

A study using theoretical models and PBMR images to quantitatively link spatial

characteristics of antennas to the accuracy of radiometric soil-moisture-image data would be extremely beneficial and is suggested as a future subject of research. Thus, in addition to the demonstration of possible pushbroom technologies, the PBMR is a useful remote sensing tool and engineering "test bed" for research in radiometry.

This work was done by Roland W. Lawrence, Marion C. Bailey, Richard F. Harrington, Chase P. Hearn, and John G. Wells, Jr., of **Langley Research Center** *and William L. Stanley of Old Dominion Research Foundation. Further information may be found in NASA TM-89005 [N87-11105], "Design and Development of a Multibeam 1.4 GHz Pushbroom Microwave Radiometer."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.
LAR-14023

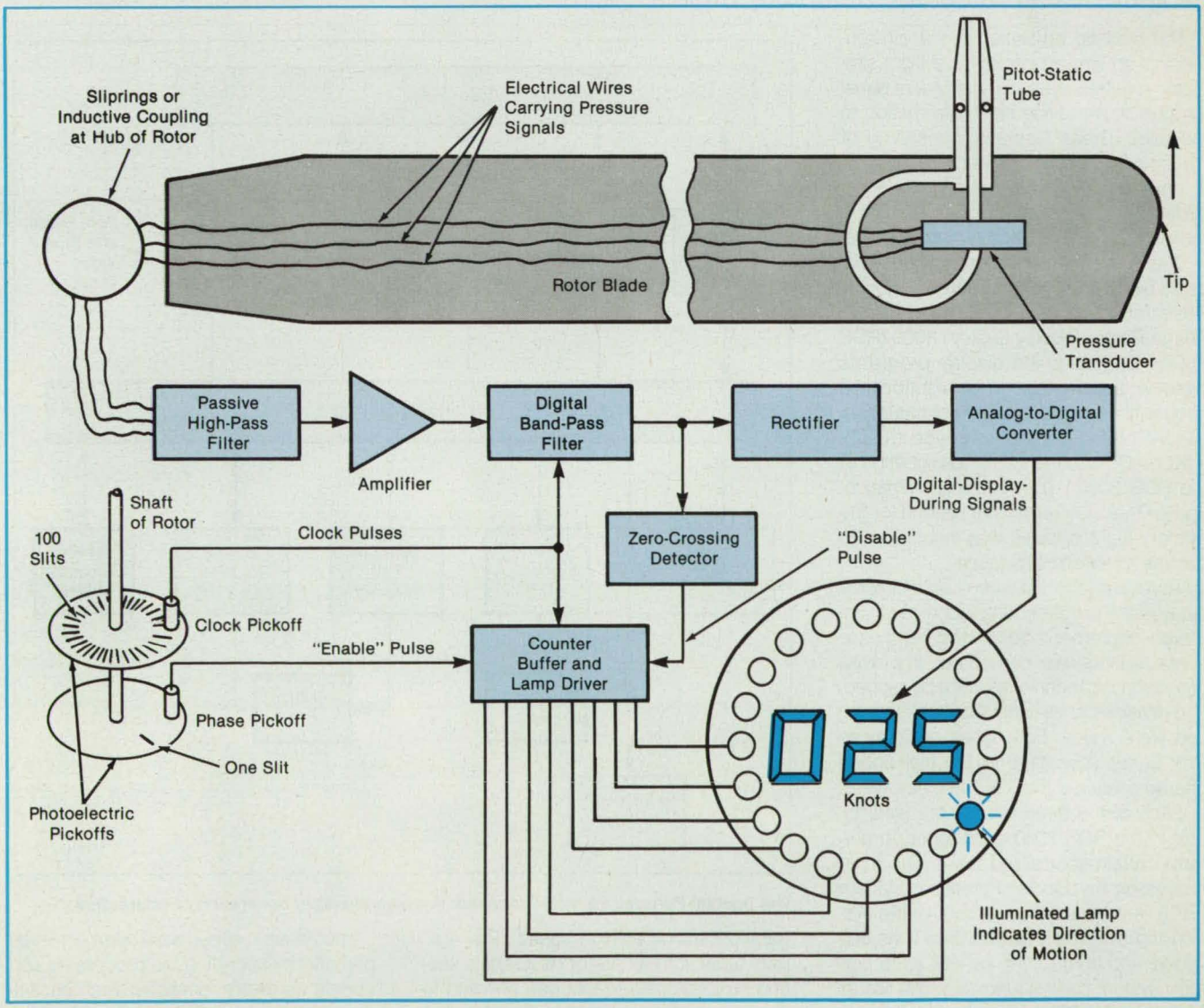
Air-Velocity Sensor for Helicopter

The speed and direction of motion are measured accurately, even when the speed is low.

Langley Research Center, Hampton, Virginia

Because of the multidirectional capability of a helicopter and the invariable presence of the rotor downwash, it is difficult to measure the true airspeed of a helicopter. A typical method involves the use of an airspeed indicator that senses and indicates the difference between impact pressure and static pressure as measured by a pitot-static tube assembly. Because these pressures are extremely low at the low airspeeds at which helicopters often operate, speeds below 40 kn (21 m/s) are difficult to measure accurately. Also, a pitot-static tube assembly is usually installed in the rotor downwash, leading to inaccurate readings; and the airspeed is defined only in the direction in which the tube assembly is pointed, while a helicopter can move sideways and backward as well as forward. Consequently, a new airspeed sensor has been conceived for the accurate measurement of both the airspeed and the direction of flight of a helicopter.

The figure illustrates the concept. A pressure transducer measures the difference between the impact and static pressures at the tip of the rotor blade by use of a conventional pitot-static-tube assembly. This assembly is oriented to face in the direction of the tangential velocity vector of the tip of the blade. The impact pressure sensed by the pitot tube consists of two components: a steady component due to



The **Direction of Motion** of the helicopter is displayed by the lighting of one of a series of lamps that encircle a digital display of the airspeed.

the rotational velocity of the rotor and an alternating component due to the linear velocity of the helicopter, because the linear velocity of the helicopter is added to the velocity of the tip as the tip moves in the direction of helicopter motion and is subtracted as the tip moves in the opposite direction.

The alternating component is extracted from the total-pressure signal and used to drive an indicator that shows the airspeed of the helicopter. The phase of the alternating signal, when compared to the rotational position of the rotor with respect to the frame of the helicopter, is used to drive another indicator that shows the direction of motion of the helicopter. Since the pressure sensed by the pitot-static tube is the sum of the tangential velocity of the tip of the rotor and the horizontal velocity of the helicopter and since this pressure is a squared function of the velocity of the tube, the amplitude of the cyclic pressure component due to the horizontal velocity of the helicopter is several orders of magnitude greater than the steady pressure that would be obtained from a pitot-static tube fixed to the airframe. This feature greatly improves the sensitivity of the instrument to very low airspeeds.

In the system shown in the figure, the electrical output from the transducer is first passed through a passive high-pass filter to remove the steady component. It is then amplified to a usable level and passed through a digital band-pass filter to remove noise and clean up the signal. The center frequency of the digital band-pass filter is set by its clock frequency, which is a large multiple, typically 100, of the desired center frequency. The clock frequency is generated by a digital pickoff on the shaft of the rotor so that the center frequency of the filter is always set at the rotor frequency. The filtered signal is rectified, passed through a linearizing circuit, and presented to the pilot on appropriate displays.

An analog-to-digital converter transforms the dc signal from the rectifier into a digital format that is displayed to the pilot on a conventional light-emitting diode or liquid-crystal display as the airspeed of the helicopter. The direction of motion of the helicopter is displayed by a series of indicator lamps selected by logic that measures the phase angle of the pressure signal with respect to the angular position of the rotor.

This work was done by H. Douglas Garner and Richard F. Hellbaum of **Langley Research Center**. *No further documentation is available.*
LAR-13598

Fast, Real-Time, Animated Displays

A fourfold increase in the update rate is achieved.

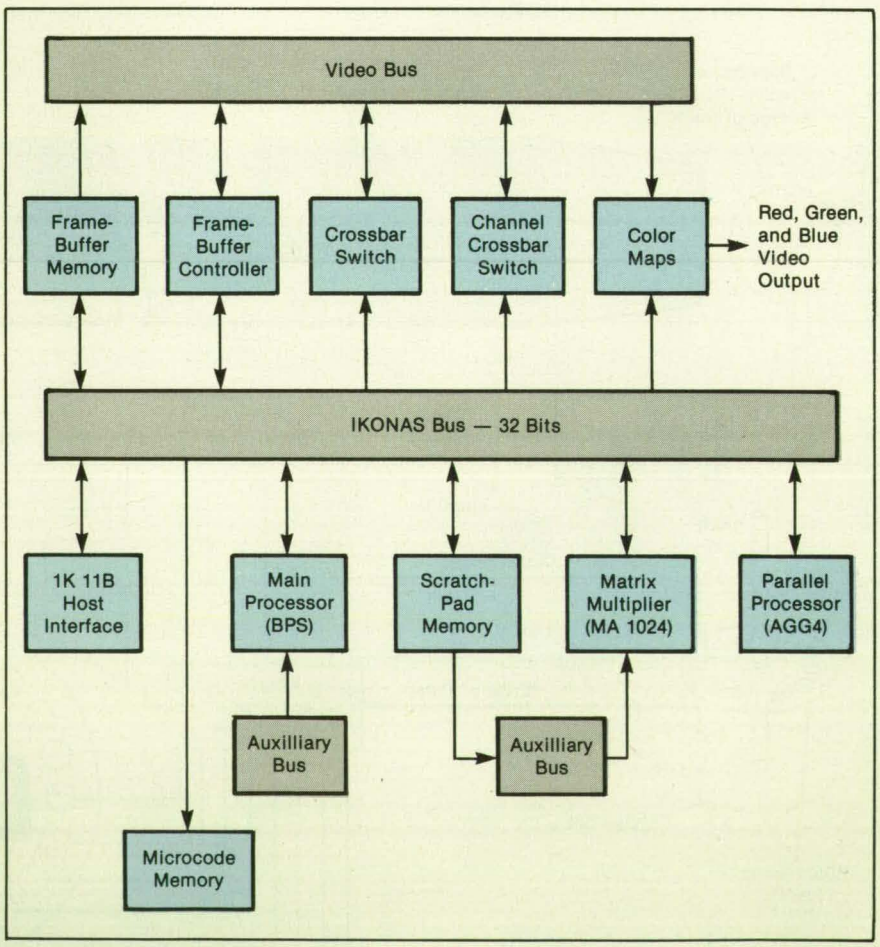
Langley Research Center, Hampton, Virginia

The realistic simulation of the environment of an aircraft cockpit in a flight simulator requires dynamic instrument-panel displays that provide flight information to the pilot. These displays, consisting of dynamic lines, polygons, and alphanumeric characters, must have an animation-update rate sufficiently high to provide a realistic simulation of actual flight displays.

The displays for the Advanced Concepts Simulator (ACS) at the NASA Langley Research Center are generated on the Adage Raster Display System 3000 (RDS 3000). Originally, the display programs were written by use of straightforward sequential programming techniques in the IKONAS Display Language (IDL2). ("IKONAS" was the former designation of the RDS 3000.) The resulting animation-update rate of 4 frames per second for the primary flight displays was insufficient to provide a realistic simulation.

To remedy this deficiency, an extensive study of the programming techniques, language implementations, and hardware characteristics was carried out. Improved programming techniques were developed, and revisions to the language implementation were made. Both types of changes took better advantage of the high-speed characteristics of the RDS 3000 hardware.

Each of the three processors (see figure) in the RDS 3000 is designed to perform certain specialized tasks. The main processor, the Bipolar Processor System (BPS), is the master processor of the system and is normally used to draw lines, polygons, and characters, as well as to perform system-control functions. The Matrix Multiplier (MA1024) is a slave processor that is designed to perform coordinate-axis transformations at high speed. The Auxiliary Graphics Generator (AGG4) is a second slave processor that can be used to draw characters at a rate higher than that of the BPS.



The **Special-Purpose Parallel Processor** enables the rapid generation of characters.

Increases in speed have been achieved primarily by operating the processors and certain hardware functions, such as "bit-map erase," in parallel with each other whenever possible and by revising the mi-

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crocode of the system. The revisions of the microcode focused mainly on increasing the speed of generation of characters. The increases in speed resulted from (1) utilization of the parallel-processing capabilities of the AGG4 and (2) use of the AGG4 to take advantage of certain high-speed characteristics of the display memory that were not previously used. The result was a fourfold increase in the animation-update rate to 16 frames per second.

This work was done by William M. Kahlbaum and Katrina Ownbey of **Langley Research Center**. *Further information may be found in NASA TM-4095, [N89-19899], "High-Speed, Real-Time, Animated Displays on the ADAGE® RDS 3000 Raster Graphics System."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. LAR-14140

Programmable Cadence Timer

An electronic metronome would pace the users through a wide range of exercise routines.

Lyndon B. Johnson Space Center, Houston, Texas

A conceptual programmable cadence timer would provide rhythmic aural and visual cues for exercisers. The timer would automatically change its cadence according to a program entered by the user. It could also function as a clock, stopwatch, or alarm.

The timer would have a variety of uses in rehabilitative medicine, experimental medicine, sports, and gymnastics. In physical therapy, for example, it would give patients flexible pacing for repetitive range-of-motion exercises. It could also be used in intermittent positive-pressure breathing treatment, in which a patient must rhythmically inhale and retain medication delivered under positive pressure; and in incentive spirometer treatment, in which a patient must inhale maximally at regular intervals.

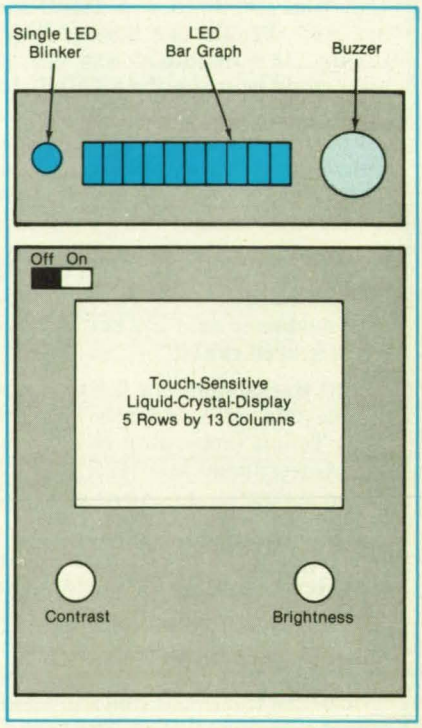
The timer would consist of two modules that could be joined as a unit or separated for remote control (see figure). When joined, the modules would be connected by a single thin electrical cable. When separated, the modules might be connected by the cable or by a line-of-sight infrared data link. With the infrared data link, the exercise area could be kept free of wiring. The modules would contain their own rechargeable-battery power supplies, and the base module could also operate on external direct current or rectified alternating current.

The base module would contain a control microcomputer, a touch-sensitive liquid-crystal display (LCD) for programming, a real-time clock, optical and audio drivers, timers, memory, and hard-wire and wireless transmitting circuitry. It would have controls for adjusting the brightness and contrast of the display and an on/off switch for power.

The audio-visual module would contain a beeper for audio cues and a light-emitting-diode (LED) blinker and an LED bar graph for visual cues. The blinker and beeper could be activated simultaneously, signaling the user to perform a prescribed movement. (The beeper could be silenced if the user prefers.) The 10 segments of the bar graph would light up in sequence to prepare the user for a cue. For example, if the cue cadence were set at a rate of 60 beats per minute, one LED segment would light up every 6 seconds so that, at the end of a 1-minute cycle, all segments would be lit and the blinker would flash. The bar graph would then be reset, and the sequence would be repeated. (The bar graph would not function unless the cable were used to connect the two modules. Like the beeper, the bar graph could be deactivated if the user wants.)

A user could program a block of up to 30 cadence regimes by entering the rate and duration of each regime on the touch-sensitive LCD. The timer could store up to 25 such blocks in its nonvolatile memory. When the user selected a block, the timer would execute each regime in the block in the order entered and display on the LCD the elapsed time for the regime and the current clock time.

This work was done by William A. Hall and John Gilbert of KRUG International for **Johnson Space Center**. *For further information, Circle 45 on the TSP Request Card. MSC-21551*



The **Modular Pacer** could be operated as a single unit or as two units. With the audiovisual module moved away from the base module, the user could concentrate on exercise cues without distraction from information appearing on the liquid-crystal display.

General-Purpose Data-Formatting Input/Output System

Standardized modules connect a host computer to sources and sinks of data.

Langley Research Center, Hampton, Virginia

A multiplexable input/output (I/O) system has been developed as an interface between a host computer and a real-time, fixed-base simulator cockpit. However, the unit was designed to be a general-purpose interface and can be operated through virtually any 8- or 16-bit, transistor/transistor-logic-level, parallel-I/O port with or without handshaking. It accepts byte-coded data in the form of data blocks from a host computer and routes the data to various system I/O modules like discrete outputs, lamp drivers, and seven-segment-display drivers. It also formats and routes data from input modules back to the host computer.

The total system comprises a main central-processing-unit (CPU) board, an interface board, and the I/O modules (see figure). The printed-circuit modules are standard 5 by 7 inches (12.7 by 17.8 cm) in size and fit into a standard 44-pin edge-connector-card cage. The two main modules, the CPU and the interface board, carry out the data formatting and data transfer between the I/O system modules and the host computer.

The CPU module is based on an 8085 8-bit microprocessor with a bidirectional data bus. It is served by 32K of read-only memory for the operating system — so it

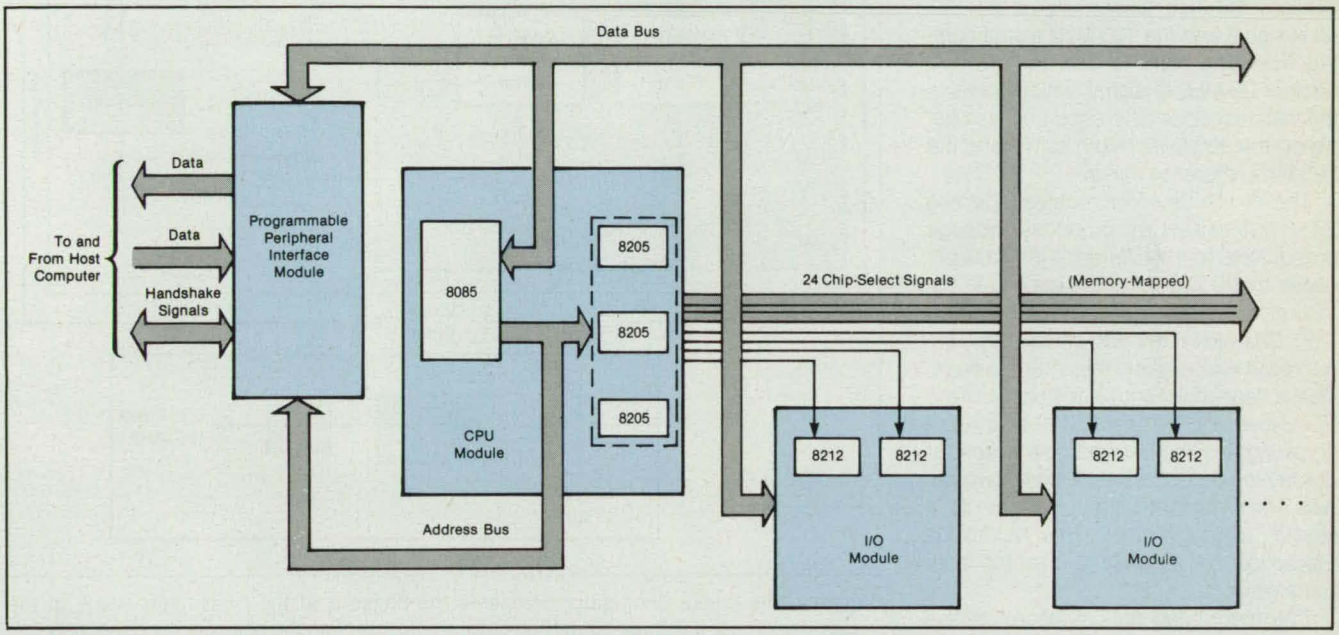
can be expanded — and 128K of random-access memory with an address-decoding mechanism for memory mapping of the system I/O modules. This addressing mechanism consists of three 8205 1-of-8 binary decoders that generate 24 chip-enable signals corresponding to 24 preset memory addresses. Each chip-enable signal selects an 8212 8-bit I/O port (there are two per I/O module), providing a maximum capability of 12 I/O modules per system.

The interface module is based on an 8255 programmable peripheral interface configured for tristated outputs and serves as an interface between the I/O system and any host computer with a parallel port. This module also generates both pulse and logic-level handshaking as well as microprocessor interupts.

The I/O modules plug into a memory-mapped bus structure that accommodates up to 12 modules, in addition to the CPU and interface modules, in any configuration. Each I/O module takes up 2 memory locations out of the 24 provided by the addressing circuitry. Several individual I/O modules have already been designed and implemented for this system, including a discrete output or lamp-driver module, a seven-segment-display-driver module, and a discrete input module with switch-debouncing circuitry that reads in such external inputs as those from switches, and encodes the data for transmission back to the host computer. Other modules are being designed to drive alphanumeric displays and communications interfaces and to serve as analog-to-digital and digital-to-analog converter modules.

This work was done by Anthony M. Busquets and Thomas W. Hogge of **Langley Research Center**. *No further information is available.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 16]. Refer to LAR-13529.



Input/Output Modules Form a Multiplexor with a standard interface to the host computer.

Fiber-Optic Frequency-Transfer Link

Frequency is stabilized by phase conjugation.

NASA's Jet Propulsion Laboratory, Pasadena, California

A system for the distribution of a 100-MHz reference signal features transmission through optical fiber to a station 22 km away and stabilization of frequency by the radiofrequency phase-conjugation method. The system compensates for variations in phase (caused mostly by changes in temperature along the optical fiber) of the signal arriving at the remote station. In preliminary tests, a "breadboard" version reduced the phase variations caused by temperature changes of 20 °C by a factor of 45. The goal for the fully developed system is to maintain a stability of 1 part in 10^{17} during a 1,000-second averaging time.

In this system, the 100-MHz signal is transmitted as modulation of an optical signal. Part of the signal arriving at the remote station is reflected back to the reference station (see Figure 1). The 100-MHz signal undergoes a phase delay θ_1 during transmission through the cable. The problem is to make the phase θ_m of the 100-MHz signal at the remote station equal the phase θ_0 of the reference 100-MHz signal by advancing the phase of the transmitted signal to compensate for the phase delay in the fiber. In the phase-conjugation method, this is done by measuring the phase θ_t of the transmitted 100-MHz signal and θ_r of the return 100-MHz signal and adjusting θ_t until $(\theta_t + \theta_r)/2 = \theta_0$.

The system is shown schematically in Figure 2. The reference station includes a phase conjugator, a fiber-optical transmitter, a fiber-optical receiver, a phase-locked

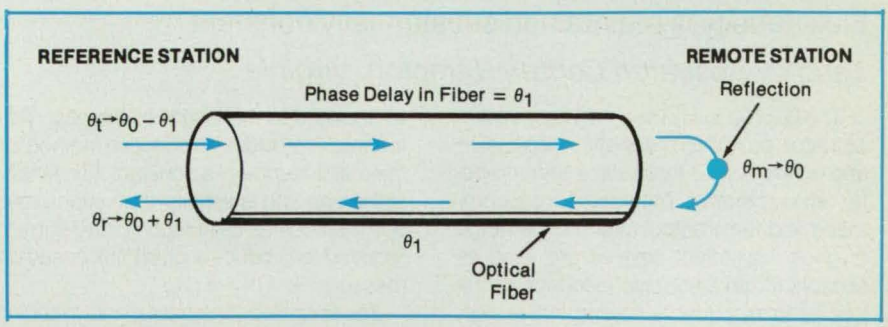


Figure 1. **Stabilization by Phase Conjugation** involves the measurement and control of the phases of the transmitted and reflected signals at the reference station to obtain the reference phase at the remote station.

loop (PLL), and a fiber-optical coupler. A synthesizer supplies a 100-MHz signal and a 20-MHz signal to the first mixer, which multiplies these signals to produce 80-MHz and 120-MHz signals. The first power splitter separates the signal out of the mixer into two signal paths. A filter in each signal path passes only one frequency so that 120 MHz is the output from one signal path and 80 MHz is the output from the other signal path.

The second mixer multiplies the 80-MHz signal and the 100-MHz signal from the voltage-controlled oscillator (VCO) to produce a 20-MHz intermediate-frequency (IF) signal, which contains the instantaneous difference in phase between the VCO signal and the 80-MHz reference. Similarly, the third mixer multiples the 120-MHz signal and the 100-MHz signal coming from the remote unit to produce another 20-MHz IF signal, which contains the instantaneous difference in phase between the 100-MHz return signal and the 120-MHz reference signal.

The phase detector receives the two 20-MHz IF signals and produces a voltage proportional to the difference in phase between them. The voltage is applied to the VCO error input through the inner loop filter (ILF). Changes in the delay in the optical fiber result in changes in the control voltage. This voltage thus controls the phase of the VCO relative to the original 100-MHz reference signal. The second power splitter divides the output of the VCO into two signals. The second mixer receives one of the signals, while the other signal modulates the optical carrier emitted from the laser transmitter.

The modulated optical signal passes through a two-way optical coupler into the fiber. A 50/50 mirror at the remote station reflects half of the optical signal back toward the reference unit. The other half of the optical signal passes through the mirror to the receiver, which demodulates the optical signal and amplifies the resulting 100-MHz radio-frequency signal. A PLL filters the signal, which is used as the remote reference frequency. The reflected optical signal returns to the reference station, where it passes through the optical coupler and is detected by its optical receiver and filtered by its PLL. The third mixer receives the resulting 100-MHz signal, and this closes the phase-control loop of the system.

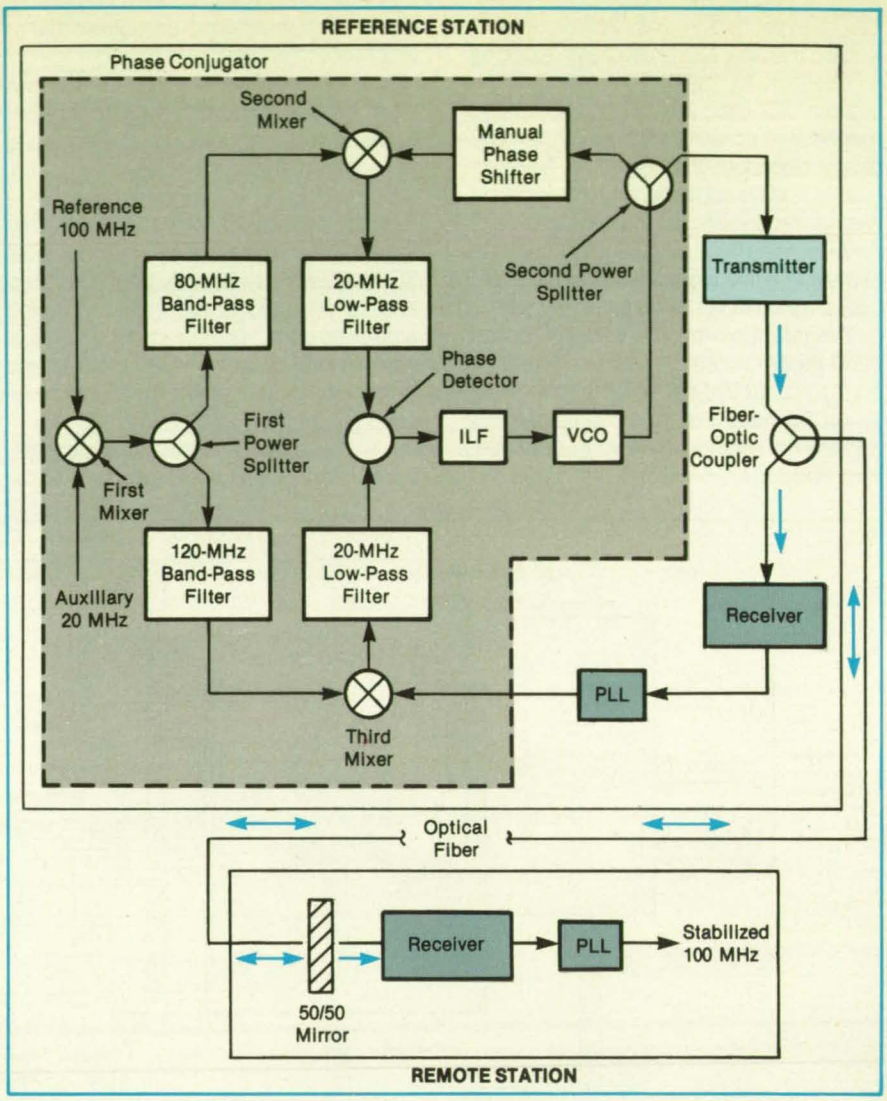


Figure 2. The **Phase Conjugator** compares the phase θ_t at the transmitter and θ_r at the receiver and uses a voltage-controlled oscillator to maintain the phase at the remote station as close as possible to the reference phase θ_0.

This work was done by L. E. Primas, R. L. Sydnor, and G. F. Lutes of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 93 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's Resident Office-JPL [see page 16]. Refer to NPO-17703

Flux-Feedback Magnetic-Suspension Actuator

Flux density is maintained substantially constant.

Langley Research Center, Hampton, Virginia

The flux-feedback magnetic-suspension actuator provides magnetic suspension and control forces that have a linear transfer characteristic between force command and force output over a large range of gaps. Hall-effect devices are used as sensors for an electronic feedback circuit that controls currents flowing in the electromagnetic windings to maintain the flux linking the suspended element at a substantially constant value independent of changes in the length of the gap. This technique provides an effective method for the maintenance of a constant flux density in the gap and is simpler than such previous methods as calculation of the current required to produce a given flux based on measurement of the gap.

The simplified schematic diagram shown in the figure can be used to describe the basic approach. Upper and lower electromagnets with currents I_U and I_L produce forces F_U and F_L on an element suspended in the middle between the electromagnets at a gap distance G_0 from the pole at the face of the upper electromagnet. Because this type of electromagnet produces an attractive force only, two such magnets are required to produce a bidirectional force. A position sensor measures the displacement G of the suspended element with respect to the centered position. Information on this position is required for active

control of the suspended element.

Under the customary simplifying assumptions, the flux, Φ, in an electromagnet is directly proportional to the current in the coil of the electromagnet. The force produced by the upper and lower elements can then be expressed as

$$F_U = K\Phi_U^2$$
$$F_L = K\Phi_L^2$$

Using these equations, the equations for the flux-feedback approach can then be developed. For a bearing-element pair of electromagnets with differential control of flux, the total force is expressed by

$$F_T = F_U - F_L$$

which can be rewritten as

$$F_T = K(\Phi_U^2 - \Phi_L^2)$$

With differential control about a bias flux Φ_0, the fluxes in the upper and lower gaps become

$$\Phi_U = \Phi_0 + \Phi_C$$
$$\Phi_L = \Phi_0 - \Phi_C$$

where Φ_C is the commanded change in flux. The substitution of these expressions into the equation for the total force yields

$$F_T = K\{[\Phi_0^2 + 2\Phi_0\Phi_C + \Phi_C^2] - [\Phi_0^2 - 2\Phi_0\Phi_C + \Phi_C^2]\}$$

which simplifies to

$$F_T = 4K\Phi_0\Phi_C$$

By making the definitions

$$\Phi_C = F_C$$

and

$$4K\Phi_0 = K_F$$

the total actuator-force output, F_T, as a function of the command-force input can be expressed by

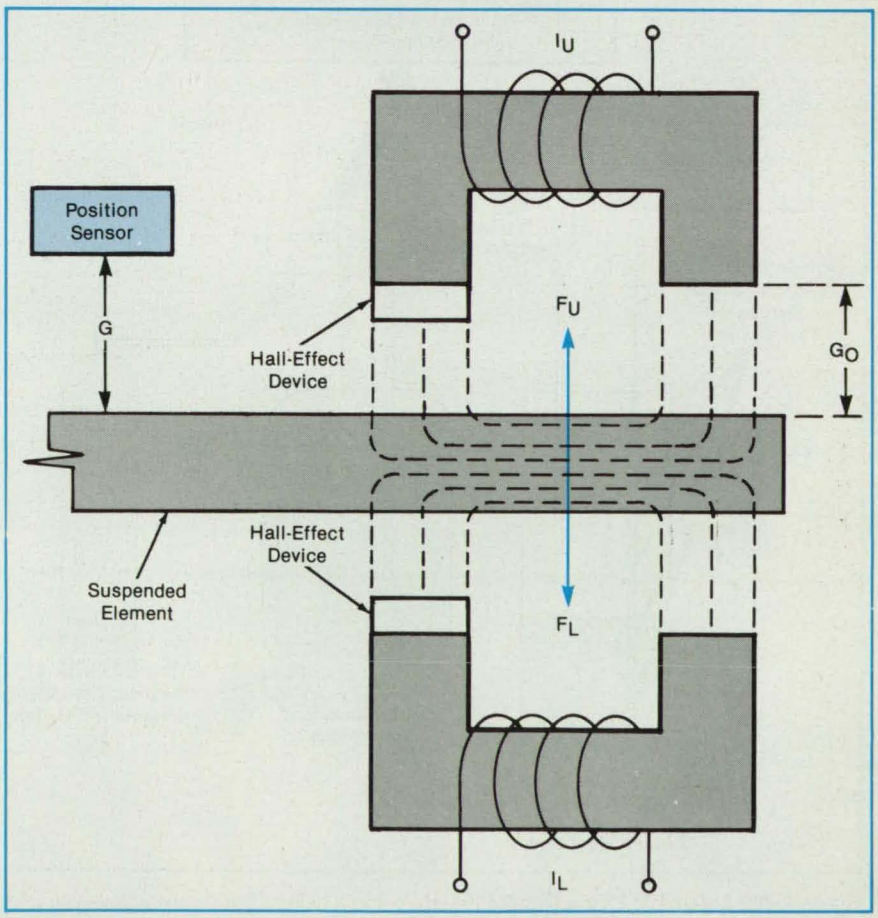
$$F_T = K_F F_C$$

Applications include magnetic actuators for control of the shapes and figures of antennas and of precise segmented reflectors, magnetic suspensions in devices for the storage of angular momentum and/or kinetic energy, and systems for the control, pointing, and isolation of instruments.

This work was done by Nelson J. Groom of **Langley Research Center**. *Further information may be found in NASA TM-100672 [N89-21135], "A Magnetic Bearing Control Approach Using Flux Feedback."*

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

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 16]. Refer to LAR-13785



Hall-Effect Devices Are Used as Sensors in an electronic feedback circuit that controls the suspension of a ferromagnetic element between two magnets.

Automatic Refilling System for Liquid Helium

Cryogenic experiments can be left unattended for days.

Goddard Space Flight Center, Greenbelt, Maryland

A system automatically replenishes liquid helium in a cryogenic experimental apparatus as the liquid evaporates. With the apparatus, experiments can run unattended — during weekends, for example — with less risk that the temperature will rise above the 4.2-K boiling point of helium for lack of coolant.

A microcomputer monitors the level of helium in the Dewar vessel in the experimental apparatus (see Figure 1). When the liquid helium falls to a preset level, the computer commands the transfer of liquid from a storage Dewar to the experimental Dewar by commanding the pressurization of the storage vessel with helium gas from a cylinder. When the level of the liquid helium in the experimental Dewar rises to a preset maximum, the computer commands the flow of gas to the storage Dewar to stop and thus stops the transfer of liquid to the experiment.

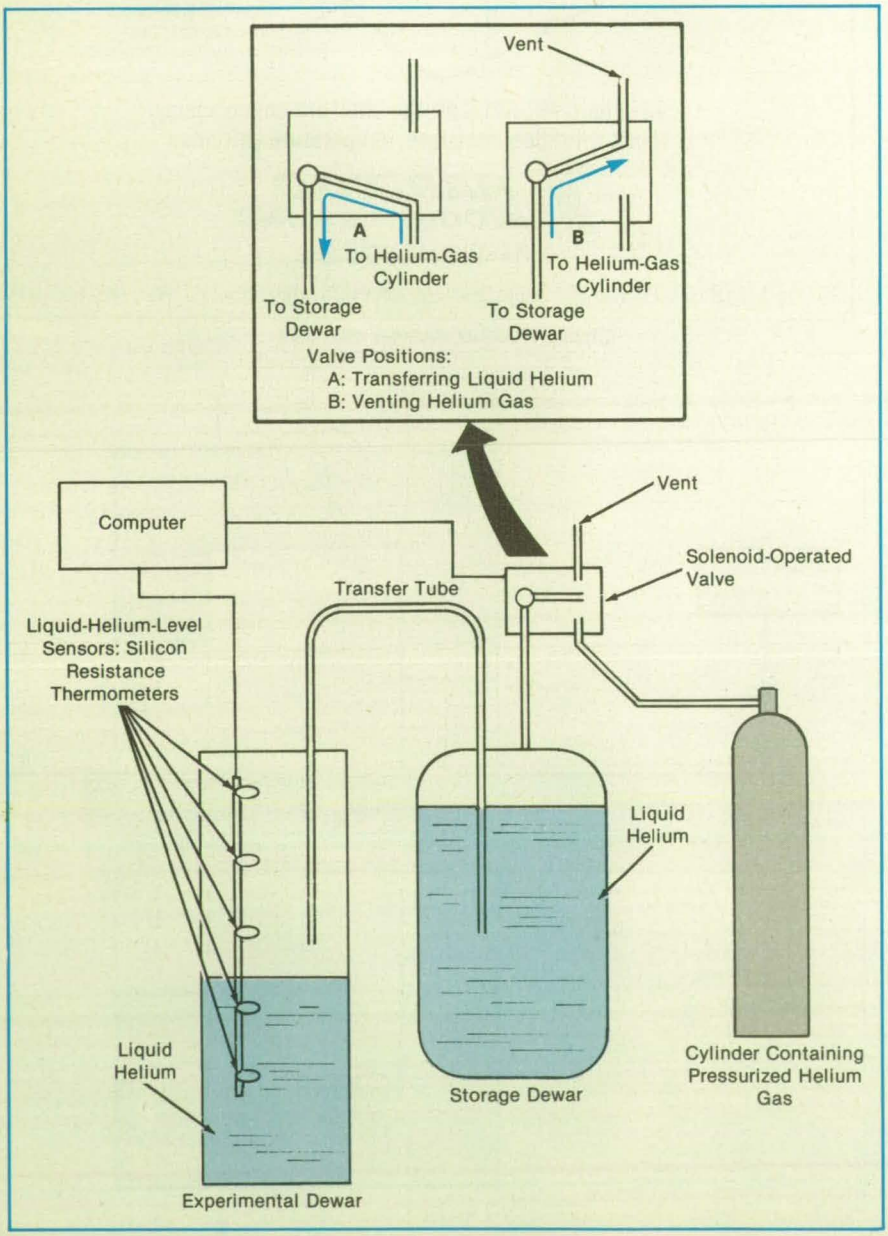


Figure 1. The **Automatic Filling System** transfers liquid helium from a storage vessel to an experimental apparatus under computer control. Gaseous helium from a cylinder supplies the pumping pressure.

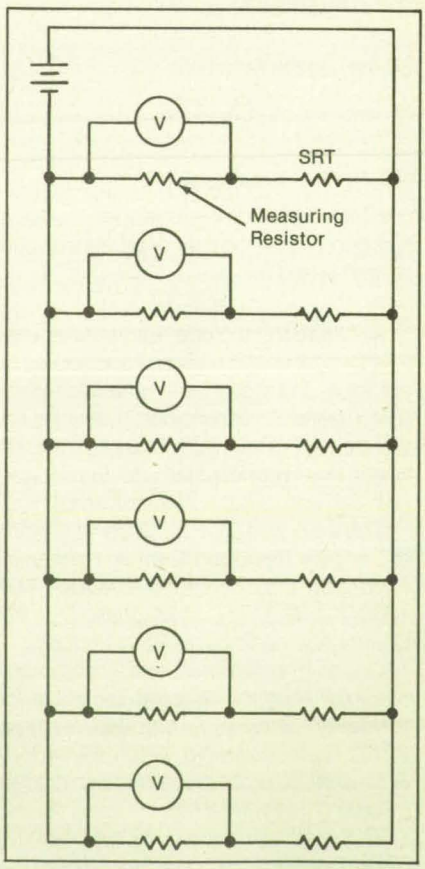


Figure 2. This **Circuit Senses the Level of Liquid Helium** by sensing the voltage across measuring resistors in series with silicon resistance thermometers (SRT's). A low voltage indicates that an SRT is covered, while a high voltage indicates that it is uncovered.

Six silicon resistance thermometers (SRT's) sense the level of liquid helium for the computer. The SRT's are mounted about 5 in. (12.7 cm) apart on a vertical rod in the experimental Dewar. The SRT's are connected in parallel to a source of voltage, and each is connected in series with a measuring resistor (see Figure 2). The SRT's immersed in liquid helium are colder and, therefore, have resistances higher than those of the SRT's above the liquid. Consequently, the currents through the immersed SRT's and the voltages across their measuring resistors are less than those of the SRT's above the liquid.

The minimum allowable level of liquid is programmed into the computer. When the SRT's signal that the liquid has fallen to that level, the computer activates a solenoid valve through a digital-to-analog interface, which, in turn, activates the solenoid valve that pressurizes the storage Dewar. The pressure of the gas pushes liquid helium out of the storage vessel, through a transfer tube, and into the experimental Dewar.

As the liquid helium fills the experimental Dewar, it covers the SRT's in succession until it reaches the programmed maximum level. At this point, the computer cuts power to the solenoid valve, and a spring returns the valve to its nontransfer position, where it connects the storage Dewar to a vent. The excess helium gas then leaves through the vent, and the flow of liquid helium ceases. The valve remains in the vent position so that vapor evolving from the liquid can escape; because the valve is spring-loaded, the vent stays open even if electrical power fails.

If the storage Dewar runs out of liquid, the computer continues to send warm helium gas into the empty storage vessel. It is, therefore, necessary to be sure that enough liquid is stored for the expected period of unattended operation. Alternatively, the computer can be programmed to stop the flow of pressurizing gas if the SRT's indicate that the level of liquid in the experimental Dewar is falling during an attempted refill.

This work was done by Aristides Serlemitsos, Mark SanSebastian, Jay Geagen, and Brent Warner of **Goddard Space Flight Center**. *For further information, Circle 80 on the TSP Request Card.*
GSC-13270

Improved Radiography of Wooden Parts

Low-toxicity liquid penetrant increases absorption in defect regions.

Langley Research Center, Hampton, Virginia

A technique has been developed to increase the radiographic contrasts of inherent latent defects in wood. Radiographic inspection of items fabricated of wood has been traditionally very difficult because of the basic inhomogeneity of this material. Local discrete changes in density in the form of earlywood and latewood growth bands selectively attenuate the penetrating radiation and cause corresponding variations in density on radiographic films. When delaminations, cracks, or other latent defects transcend the inspection areas, their images are superimposed on the already-confusing radiographic images, making interpretation of the images very difficult.

The new technique involves the introduction of a radiopaque substance into the defect site and subjecting the site to penetrating radiation. Radiopaque penetrants have been used for many years to increase the contrasts of internal defects. However, most of the penetrants used are severely restricted in application because of two basic disadvantages: toxicity, which can make the penetrant extremely hazardous for handling, and residual contamination, which causes local staining and could hinder any repair scheme. The radiopaque penetrant that has been used successfully for this technique is a commercially available fluorocarbon cleaning solvent, trichlorotrifluoroethane, which has a favorable toxicity-threshold-limit value of 1,000 parts per million.

In the improved technique, an x radiograph is first made of the area of interest. Then the low-toxicity penetrant is introduced by the flooding, gravity-feed, capillary action, or forced flow. The defect strata are filled with the radiopaque penetrant, increasing the absorption of radiation only in the defect region. The area is again radiographed, and the "before" and "after" images are interpreted.

This technique has been successful in depicting interlaminar shear cracks in a large laminated spruce wind-tunnel fan blade. These cracks, which were radiographically invisible before the penetrant was introduced, were detected through a section thickness of up to 28 in. (71 cm). The technique could be applicable in the inspection of wooden aircraft components, fan and wind-turbine blades, marine parts, insulators, and other wooden components, assemblies, and structures.

This work was done by Maggie L. Berry and Robert F. Berry, Jr., of **Langley Research Center**. *For further information, Circle 49 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 16]. Refer to LAR-13724

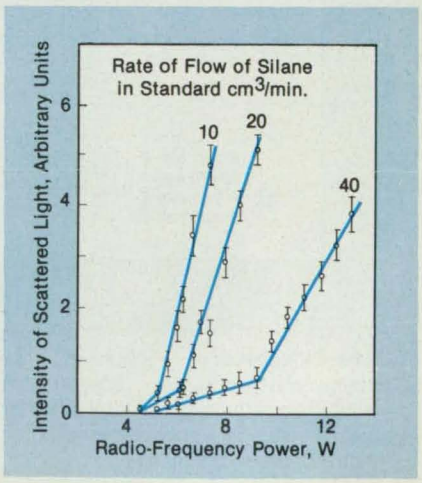
Detection of Gas-Phase Polymerization in SiH_4 and GeH_4

Inelastic scattering of light reveals conditions unfavorable for the deposition of amorphous SiGe:H.

NASA's Jet Propulsion Laboratory, Pasadena, California

Inelastic scattering of laser light has been found to indicate the onset of gas-phase polymerization in the plasma-enhanced chemical-vapor deposition (PECVD) of photoconductive amorphous hydrogenated silicon/germanium alloy (*a*-SiGe:H) film. In this PECVD process, the film is deposited from a radio-frequency glow-discharge plasma of silane (SiH_4) and germane (GeH_4) diluted with hydrogen. Gas-phase polymerization is undesirable because it causes the formation of particulates and defective films.

The inelastic scattering of laser light was first observed as a spurious broadband signal during in situ coherent anti-Stokes Raman spectroscopy (CARS) meas-



The Abrupt Changes in the Intensity of scattered light on each plot indicate the onset of formation of particles at the indicated power levels. The formation of particles can be prevented by keeping the power low.

urements that were being performed to determine closed-chamber disappearance kinetics and steady-state (in flowing gas) depletions of SiH_4 and GeH_4 in plasmas of pure and mixed gases. Although the exact scattering mechanism was not established, it was nevertheless observed that the scattering signal gives a sensitive indication of the formation of particles in the radio-frequency plasma. For example, the figure shows the intensity of scattered light as a function of the radio-frequency power for silane plasmas with various rates of flow.

With the help of the CARS and inelastic-scattering diagnostics, the conditions for the deposition of *a*-SiGe:H films have been optimized in the parameter space of radio-frequency power density, rates of flow of gases, and dilution with hydrogen. The optimum conditions include low power density (20 mW/cm^2), high pressure [0.55 torr (70 Pa)], high rates of the flow of SiH_4 and GeH_4 (28 and 5.6 standard cm^3/min), and a rate of flow of hydrogen sufficient to provide high dilution (100 standard cm^3/min).

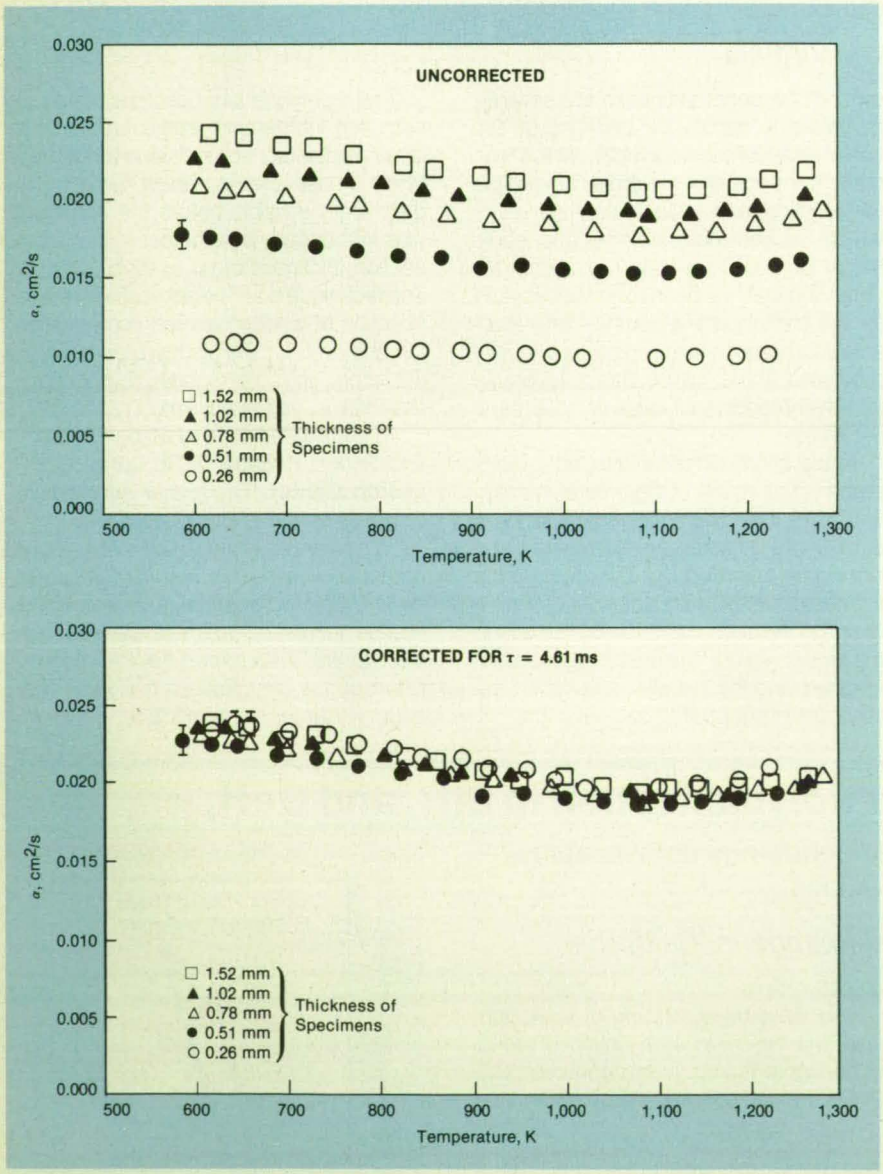
This work was done by Yuh-Han Shing, Joseph W. Perry, and Camillo E. Allevato of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 4 on the TSP Request Card.*
NPO-17779

Improved Analysis of Heat-Pulse Data

Calculations of thermal diffusivity and heat capacity take account of exponential pulses and losses of heat.

NASA's Jet Propulsion Laboratory, Pasadena, California

Equations have been derived to improve the analysis of experimental data in the flash method for the measurement of thermal diffusivity and heat capacity. In the flash method, a pulse of radiant energy from a flashlamp or other source is deposited on the front face of a small, thin specimen, and the temperature of the rear face is monitored as a function of time. Previous analyses have accounted for losses of heat from the specimen and for pulses of various shapes and finite durations. The new equations account for both losses and exponentially decaying pulses.



Thermal Diffusivities as functions of temperature were calculated from flash-method measurements on p-type $Si_{0.8}Ge_{0.2}$ specimens of five different thicknesses. The upper curve was calculated from the experimental data under the assumptions of no loss of heat and zero-duration pulse. The upper curve includes the corrections for the loss of heat and the exponential decay of the pulse.

The mathematical model is based on a flat slab specimen of thickness d of infinite lateral extent. The rate of loss of heat to the surroundings is considered to be proportional to a dimensionless heat-loss parameter L and to the difference between the temperature of the surface of the specimen and the ambient temperature. The thermal parameters of the specimen are the thermal diffusivity α and the thermal time constant, $t_c = d^2/\alpha$. The difference between the final temperature that the specimen would attain if there were no loss of heat (if L were zero) and the ambient temperature is represented by T_∞. The pulse on the front face of the specimen begins at time $t = 0$ and decays exponentially with a time constant τ.

For this model, the exact solution of the one-dimensional heat-diffusion equation is

$$T(t)/T_\infty = 2\sum_{n=0}^{\infty} \frac{\beta_n \cos(\beta_n) + L\sin(\beta_n)}{\beta_n^2 + L^2 + 2L}\ \beta_n \left[\frac{\exp(-\beta_n^2 t/t_c) - \exp(-t/\tau)}{1-\beta_n^2\tau/t_c}\right]$$

where $T(t)$ is the difference between the temperature on the rear surface of the specimen at time t and the ambient temperature, and the β_n are the positive roots of

$$(\beta^2 - L^2)\tan(\beta) = 2L\beta$$

If τ/t_c is small and when t/τ is sufficiently large, the exact equation can be used to derive the following equations for the approximate thermal diffusivity α_a and for the approximate value T_{ma} of the maximum temperature rise T_m.

$$\alpha_a/d^2 = 0.13875[1 - \exp(1.8078 - 1.2407x)]/y$$

and

$$T_{ma}/T_\infty = 1 - \exp(2.608 - 1.2841x)$$

where $x = (t_m - \tau)/(t_{1/2} - \tau)$, $y = t_{1/2} - \tau$, t_m is the time at which $T = T_m$, and $t_{1/2}$ is the time at which $T = T_m/2$. The heat capacity of the specimen can be calculated exactly from $C = Q/T_\infty$ or estimated from $C \approx (T_{ma}/T_\infty)Q/T_m$, where Q is the amount of heat deposited in the specimen.

The figure shows the results of measurements taken on five specimens of p-type $Si_{0.8}Ge_{0.2}$. In the lower curve, where the data are corrected for the loss of heat and the finite duration and decay in the pulses, the scatter in the calculated values of thermal diffusivity is only 2 percent.

This work was done by C. B. Vining, A. Zoltan, and J. W. Vandersande of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 139 on the TSP Request Card.*
NPO-17729

Programmable Multizone Furnace

Moving thermal gradients are created without mechanical motion.

Marshall Space Flight Center, Alabama

A furnace that has multiple, individually programmable heating zones is being developed for use in experiments on directional solidification. The furnace holds a rod specimen and generates thermal gradients (see Figure 1) that move along the specimen. Unlike in prior directional-solidification equipment, the specimen and furnace remain in fixed positions relative to each other during the experiment. The elimination of the translation mechanism makes the furnace more compact and reduces vibrations, which can disturb the experiment.

The furnace, shown schematically in Figure 2, includes a cylindrical stack of ring-shaped heating assemblies that include electrical heating elements, supports, and thermal insulation. The inner diameter of the rings is 1.125 in. (28.6 mm) and is intended to accommodate a specimen with a diameter up to 0.5 in. (12.7 mm). Pairs of adjacent heating assemblies are connected in series electrically and physically, each pair constituting a programmable temperature-control zone. The working core of the furnace [the electrodynamic gradient (EDG) section] consists of the middle 16 time-programmable zones. The eight constant-temperature programmable zones on the ends (four at each end) serve as buffers. Eight water cooling tubes connect all the heating assemblies.

The furnace creates a moving temperature gradient by the coordinated control of the temperatures in the heating zones. This coordination is accomplished by use of a commercially available process controller executing a proportional/integral/derivative control algorithm, using the temperature measured in each zone by a thermocouple as feedback. The temperature in each zone can be programmed to ramp linearly to or from a set value in a specified time or to remain at a set value.

Tests of a prototype revealed the advantages and some disadvantages of this type of furnace. Its flexibility is unquestionably an advantage; that is, the availability of many different temperature profiles through programming makes it a versatile tool for research at low thermal gradients [6 to 75 °C/in. (2.4 to 30 °C/cm)] that travel at moderate speeds [up to 10 in./h (25 cm/h)]. The principal disadvantages are high power consumption (typically > 3 kW) and the high dependence of the gradient and its motion on the control system.

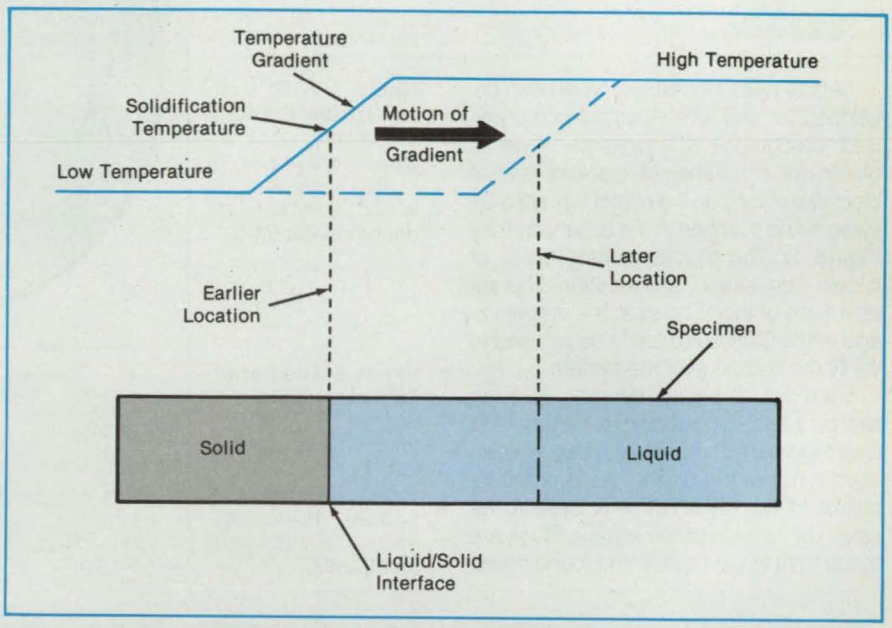


Figure 1. This **Moving Solidification Front** is only one of many simple or complicated moving temperature profiles that can be generated in the programmable multizone furnace.

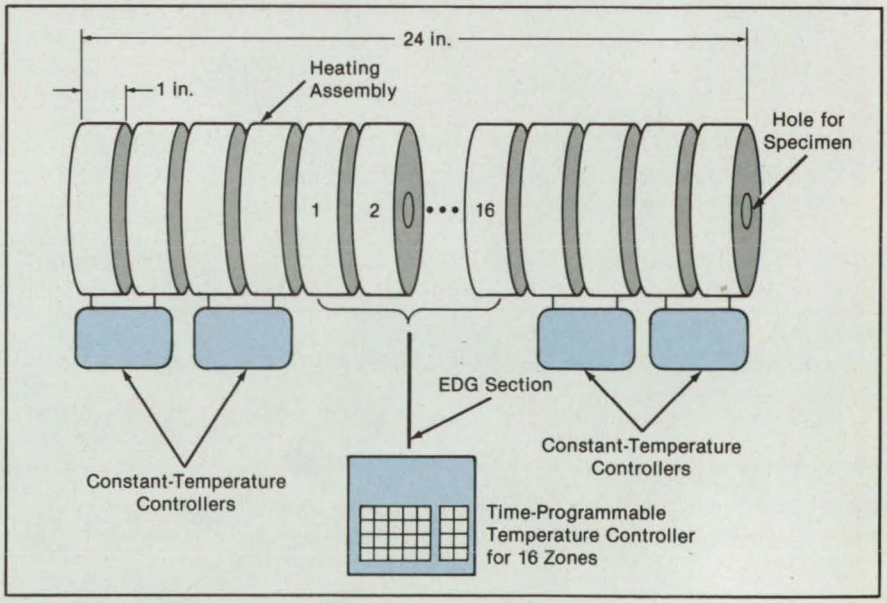


Figure 2. The **Time-Programmable Temperature Controller** regulates the temperature in each of the middle 16 heating assemblies as a function of time to generate a moving temperature profile.

This work was done by Edmund Y. Ting and David J. Larson, Jr., of Grumman Corporate Research Center for **Marshall Space Flight Center**. *For further information, Circle 161 on the TSP Request Card.*
MFS-28375

Calibrator Blocks for Computerized Tomography (CT)

Holes of known size and location enable calibration of CT systems.

John F. Kennedy Space Center, Florida

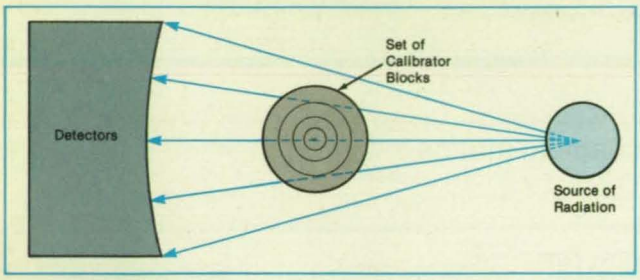


Figure 1. **A CT System Scans** the calibrator blocks (e.g., with x rays or γ rays) in the same way in which it scans an unknown object.

Sets of calibrator blocks have been developed for use with industrial computerized tomography (CT) systems. A set of blocks (or a number of stacked sets of blocks) is placed on the object table of a CT system and scanned in the usual way (see Figure 1). The blocks include holes of known size, shape, and location. The appearance of these holes in the output image of the CT system can thus be used to verify the operation of the system.

Each set of blocks consists of three nested rings surrounding a central disk (see Figure 2). The rings and disk contain square holes. In addition, each ring contains a round hole of diameter equal to the length of the side of the square. Plugs are made to fit in the square and round holes.

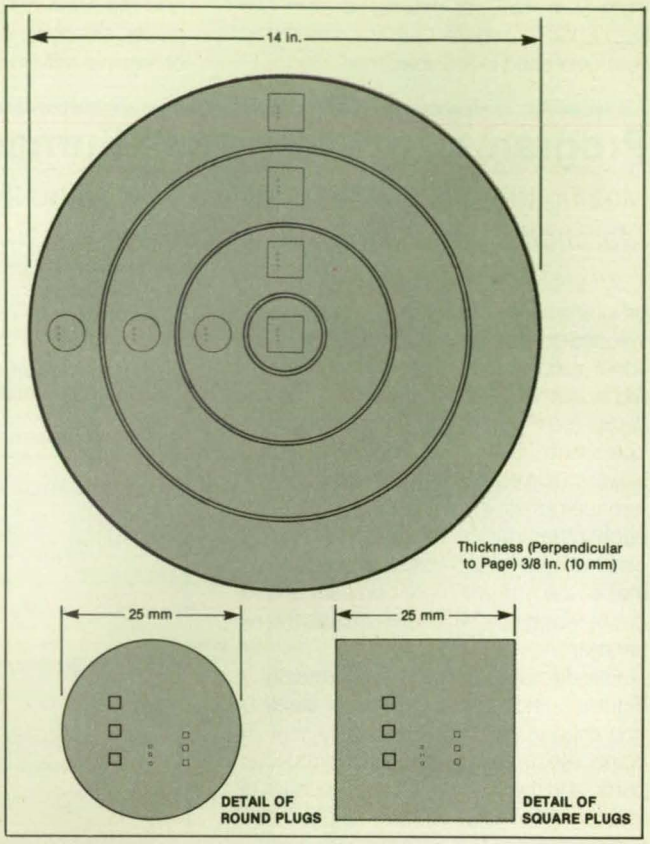


Figure 2. The **Set of Calibrator Blocks** includes plugs and smaller inserts that can be removed to make round or square holes of known sizes and locations.

Each plug contains smaller square holes of three different sizes. Smaller plugs are also made to fit in the smaller square holes. Thus, by removing and inserting rings and plugs, one can provide tomographic features over a range of sizes to test and calibrate an industrial CT system. One can also test axial resolution (the thickness of the tomographic "slice" — typically, 1 mm) by scanning between two stacked blocks with (or without) inserts at partial fill from the interface.

The blocks, plugs, and inserts can be made of any of a variety of materials — for example, various metals and plastics. It is desirable to have sets made of different materials to cover the range of densities that the CT system is expected to scan.

This work was done by H. Peter Engel of EG&G Florida, Inc., for **Kennedy Space Center**. *For further information, Circle 39 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Kennedy Space Center [see page 16]. Refer to KSC-11397

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.

Temperature Rises in Pumps for Superfluid Helium

The characteristics of centrifugal and fountain-effect pumps are compared.

A report discusses the increases in the temperature of superfluid helium in centrifugal and fountain-effect pumps. Such pumps are intended for use in transfers of superfluid helium in outer space. The increases in temperature significantly affect losses during transfers and are, therefore, important in the selection of the temperatures of supply tanks.

For the purpose of this study, the increase in temperature in the fountain-effect pump is calculated on the basis of thermodynamic considerations, starting from the assumption of an ideal pump. The results of recent tests of the ceramic material intended for use in such pumps support this assumption.

The basic equations that describe the thermodynamic characteristics of the ideal fountain-effect pump are those of the thermomechanical effect. The mode of operation is assumed to be that of a constant rate of input of heat. The combination of the two basic equations for this mode yields a new pair of equations that express the operating characteristics of the pump: (1) an equation for the increase in pressure as a function of the rate of input of heat, rate of flow of mass, and the temperature at the inlet to the pump and (2) an equation for the increase in temperature as a function of the increase in pressure and the temperature at the inlet.

The increase in temperature in the centrifugal pump is also calculated on the basis of thermodynamic considerations, but ideal behavior is not assumed. Instead, the measured operating characteristics of a prototype centrifugal pump are inserted in the equations to obtain an estimate. The product of this analysis is three equations: one for the increase in temperature as a function of the increase in pressure, the measured efficiency of the pump, and the temperature at the inlet; one for the efficiency as a function of the rate of flow of mass and the speed of rotation of the pump; and one for the speed of rotation of the pump as a function of the rate of flow of mass and the increase in pressure.

The comparison of the equations for the two pumps reveals four principal differences. First, the increase in temperature in the centrifugal pump is less than that in the fountain-effect pump except at very low flows and high increases in pressure. Second, the temperature at the outlet of the fountain-effect pump depends only slightly on the temperature at the inlet. Third, under the conditions expected during the cooling of a warm receiving tank, the centrifugal pump has an operating characteristic better than that of a fountain-effect pump. Fourth, the centrifugal pump has an optimum operating curve, near the curve of maximum thermodynamic efficiency, for which the increase in temperature is minimized. Overall, the centrifugal pump is more effective because it produces a smaller rise in temperature.

This work was done by Peter Kittel of **Ames Research Center**. *Further information may be found in NASA TM-100997 [N88-27507], "Temperature Rise in Superfluid Helium Pumps."*

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-12264

Equations for Isocaloric Fountain-Effect Pumps

Operating characteristics of leaky pumps are derived.

A report presents equations for the thermodynamical characteristics of leaky fountain-effect pumps operating at constant rates of input heating. The equations differ from those developed previously for fountain-effect pumps operating at constant differences of temperature, in which the pressure heads and rates of flow are independent of each other.

The fountain effect, also known as the thermomechanical effect, is the tendency of superfluid helium to flow through a capillary tube in the direction of increasing temperature. One stage of a fountain-effect pump contains a porous plug, which separates a source of superfluid helium at a lower temperature, T_0, from a region at a higher temperature, T_1, into which the fluid is to be pumped.

The analysis begins with the basic equations of the thermomechanical effect. Assuming that the rate of input heating is constant, that the flow through the pump is subcritical (below the onset of quantized vorticity), that the temperatures vary slowly, and that the viscosity and the ratio of specific heat at constant chemical potential to entropy are independent of temperature, the author derives the equations for the mass-flow rate and pumping pressure of an ideal single-stage pump. This line of analysis is then extended to describe an ideal pump in which multiple stages are connected by partially-heat-sunk vortex tubes and the flows in the tubes are highly turbulent.

Next, an effective thermal conductivity is introduced to account for the heat carried by the viscous leakage of normal (nonsuperfluid) helium backward through the pores of the plug(s). The equations of the ideal single- and multiple-stage pumps are modified to include this effect. The resulting equations can be used to calculate various measures of performance of a leaky fountain-effect pump; e.g., pressure head as a function of mass-flow rate, hydrothermodynamic efficiency, and transfer effectiveness (the fraction of pumped mass remaining after a portion has been evaporated to keep the process at constant temperature). The following conclusions can be drawn from the equations:

- The pressure head decreases monotonically with increasing rate of flow.
- The pressure head and rate of flow of a leaky pump are always less than those of an ideal pump.
- At low rates of flow, multistage pumps give higher pressure heads than do single-stage pumps. At high rates of flow, single-stage pumps give higher pressure heads.
- The performance of a fountain-effect pump improves dramatically as its temperatures decrease.

This work was done by Peter Kittel of **Ames Research Center**. *To obtain a copy of the report, "Operating Characteristics of Isocaloric Fountain-Effect Pumps," Circle 159 on the TSP Request Card.*
ARC-11850

Astrometric Telescope Facility for the Space Station

The telescope would be used to detect planets outside the solar system.

A paper discusses the proposed Astrometric Telescope Facility, which would be installed on the Space Station to study the motions of stars other than the Sun and thereby possibly detect planets around them. The measurements are expected to verify, modify, or refute current theories about accretion of interplanetary clouds into stars and planets. They may also help to answer the question "Are we unique, alone?"

In addition, the Astrometric Telescope would measure motions and distances between stars and star clusters in nearby galaxies and in our own galaxy.

The facility would be constructed in three parts that could be placed in orbit by a single Space Shuttle mission. It could be assembled in the service bay of the Space Station, then moved and attached to the coarse pointing system or assembled directly on the coarse pointing system. It would be controlled from the Earth, requiring only maintenance and repairs by the Space Station crew.

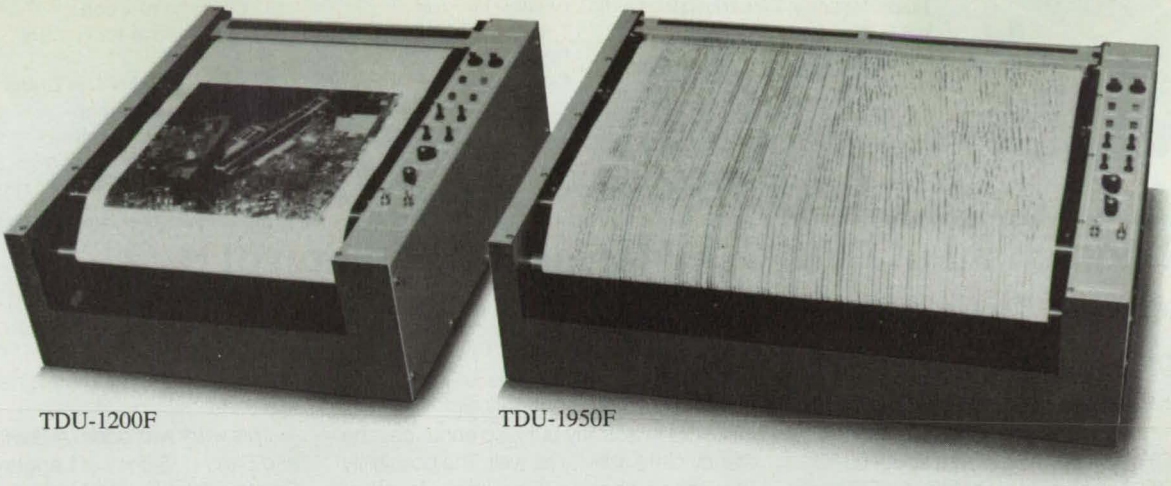
The system would consist of six subsystems (optics, structure, thermal control, command and data, pointing and control, and power and harness) in addition to the focal-plane instrument composed of a Ronchi ruling and drive assembly, folding and field optics, multichannel astrometric photometer, and visible imager. These elements would be able to measure the relative motions of stars with an accuracy of 10 microarcseconds.

Raw data from the system would normally be transmitted to the ground for processing. However, there may be intervals of several weeks when the Space Station would not provide the necessary data-transmission capacity of 1.75 megabits per second. When this happens, a computer on the Space Station would reduce the data.

The image of a star field would be focused on the Ronchi ruling by the paraboloidal primary mirror of the telescope. The ruling would modulate the image. A diagonal mirror would direct the modulated light to the side of the telescope tube, where a relay-lens assembly would magnify the image from 5 to 12.5 cm, to make it large enough for the 32 movable pickups of the multichannel astrometric photometer.

According to a preliminary analysis, the viewing required for the detection of planets can be accomplished in about two-thirds the total time available for viewing. This would leave about 2,000 hours per year for other astrophysical investigations. The system would be designed for a lifetime of 20 years, with maintenance by the Space Station crew at intervals of 5 years.

This work was done by K. Nishioka, J. Scargle, and J. Givens of **Ames Research Center**. *To obtain a copy of the report, "An Astrometric Facility for Planetary Detection on the Space Station," Circle 158 on the TSP Request Card.* *ARC-11842*



TDU-1200F TDU-1950F

We're widening the scope of hard copy recording.

TDU-1200

TDU-850

Raytheon has added a series of wide "flatbed" models to its quality line of thermal hard copy recorders. The new TDU-1950F and TDU-1200F units, in 19.5 inch (49.5 cm) and 12 inch (30 cm) configurations, respectively, provide enhanced vertical integration of data for a broad range of specialized applications.

The flatbed models join Raytheon's established family of "free fall" thermal recorders – the TDU-850, with an 8.5 inch (21 cm) printing width, and the TDU-1200, with a 12 inch (30 cm) printing width.

Raytheon's thermal recorders produce high resolution copy at high speeds and can generate full tonal images up to 256 multi-shade levels of true grey. Alternately, they can display digital data in crisp graphic or alphanumeric form using an optional IEEE 488 interface.

Traditional uses include CRT hard copy, military surveillance, spectrum analysis, LOFAR gram displays, ultrasonic production control, and facsimile transmissions. New and evolving applications include support for computer assembly testing and chromosome analysis in genetic research.

TDU's print on paper, plastics or transparencies. They feature clean, odor-free, maintenance-free operation.

Make hard copy easy with today's most versatile and reasonably priced thermal recorders. Call or write Marketing Manager, Production Components, Raytheon Company, Submarine Signal Division, 1847 West Main Road, Portsmouth, RI, USA 02871-1087. Phone 401 847-8000.

Raytheon

Circle Reader Action No. 512

Materials

Enhancement of Pt/SnO_2 Catalysts by Addition of H_2O

Water vapor in pretreatment gas restores essential hydroxyl groups.

Langley Research Center, Hampton, Virginia

Platinum on tin oxide (Pt/SnO_2) is a good catalyst for the oxidation of carbon monoxide (CO) at temperatures from about 25 °C to 100 °C. The activity of Pt/SnO_2 for CO oxidation is significantly enhanced by pretreating it at approximately 225 °C with a reducing gas such as CO. However, such pretreatment frequently causes an initial dip in the activity of the catalyst before the enhanced steady-state activity is achieved, as shown in the figure.

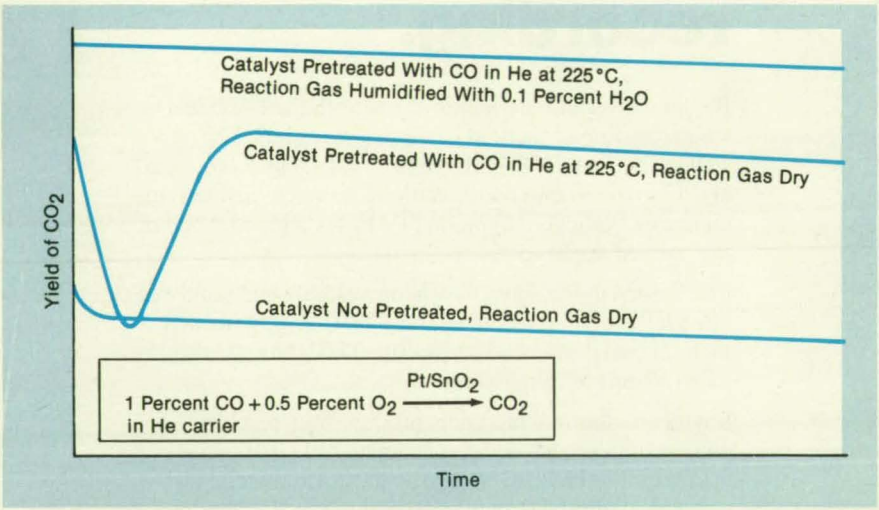
The initial dip in the activity of the catalyst is caused by dehydration of the surface of the catalyst during the pretreatment. Dehydration converts reactive hydroxyl (OH) groups on the surface to less reactive doubly-bonded oxygen atoms. The downward portion of the dip shows the initial loss in catalyst activity as the few remaining hydroxyl groups are used up. The ensuing upward portion results from rehydration of the surface by migration of H_2O (or OH) from the bulk of the catalyst.

The dip in the activity of the catalyst can be eliminated by rehydrating the catalyst prior to use. The rehydration is accomplished by exposing the catalyst to a humidified inert gas between pretreatment and exposure to the CO/O_2 reaction mixture or by humidifying the reaction mixture itself.

As the figure also shows, the humidification of the catalyst not only eliminates the initial dip in activitiy but also enhances the steady-state activity as well. The possibility that these observations apply to other noble-metal/reducible-oxide catalysts is currently being investigated. Such catalysts are needed to maintain high output in CO_2 lasers and are, therefore, of great technological importance. This technique would be useful in the manufacture of high-power CO_2 lasers for industrial and scientific uses.

This work was done by David R. Schryer and Barry D. Sidney of **Langley Research Center**; *John D. Van Norman, Kenneth G. Brown, and Jacqueline Schryer of Old Dominion Research Foundation and Billy T. Upchurch of Science and Technology Corp. No further documentation is available.*

LAR-14084



Pretreatment of a Pt/SnO_2 Catalyst with humidified gas results in an improvement in the activity of the catalyst, as manifested in the yield of CO_2 in the catalyzed reaction between CO and O_2.

High-Temperature Polyimide Resin

This material combines thermo-oxidative stability with autoclave processability.

Lewis Research Center, Cleveland, Ohio

An improved polyimide resin can be used at continuous temperatures up to 700 °F (371 °C) — 100 °F (56 °C) higher than previously possible with autoclavable resins. The material, PMR-II-50, serves as a matrix for fiber-reinforced composites.

With its high temperature rating, the material can be used in such turbine engine components as air-bypass ducts, vanes, bearings, and nozzle flaps. Other potential applications include wing and fuselage skins on high-mach-number aircraft and automotive engine blocks and pistons.

PMR-II-50 is based on PMR-II resin, which was introduced in 1976. In the older material, thermo-oxidative stability was sacrificed for processability so that parts could be formed from the material in an autoclave. In the new material, a high-molecular-weight prepolymer is used to ensure thermo-oxidative stability in the finished product. Moreover, the prepolymer cures by an addition reaction and thus readily yields void-free parts after processing in an autoclave.

The new resin is available from two commercial suppliers. At $400 per pound (1988 prices), it costs about three times as much as do PMR-15 resins.

This work was done by Raymond D. Vanucci and Diane C. Malarik of **Lewis Research Center**. *For further information, Circle 65 on the TSP Request Card.*

LEW-14923

LARC-I-TPI: a New Thermoplastic Polyimide

Improved properties enhance usability as an adhesive or in composite matrices.

Langley Research Center, Hampton, Virginia

"LARC-I-TPI" denotes an improved version of the LARC-TPI class of thermoplastic polyimides, which are high-performance polymers developed for the manufacture of strong, lightweight aircraft structures. The melt-flow and adhesive properties of the new polymers make them attractive for use as matrix resins for composites, molding powders, adhesives, and coating films. The new polymers are also less toxic: unlike the polymers of the original version, the improved LARC-I-TPI polymers are formulated without 3,3′-diaminobenzophenone, which is mutagenic and commercially unavailable.

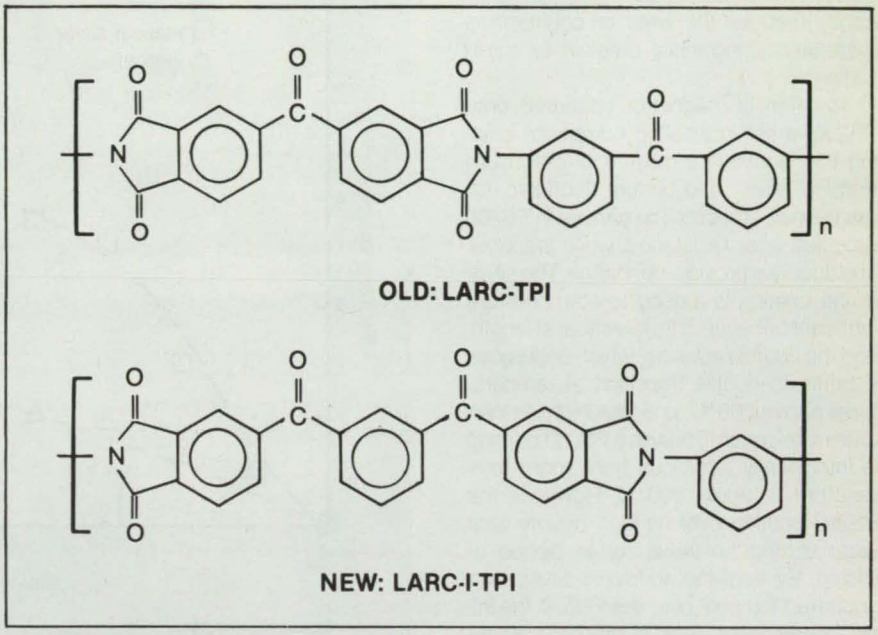
The original LARC-TPI polymers have undersirably broad distributions of molecular weights and contain amine and anhydride functional end groups; these features result in poor molding properties and low melt stability. The LARC-I-TPI polymers (see figure) are high-molecular-weight 4,4′-isopthaloyldiphthalic anhydride-metaphenylenediamine polymides, the molecular weights of which are controlled through selective end-capping to improve their adhesive and melt-flow properties. An LARC-I-TPI polymer is readily synthesized from the isopthaloyldiphthalic anhydride monomer (which is, itself, readily synthesized and inexpensive) and metaphenylenediamine (which is commercially available, nonmutagenic, and only slightly toxic).

The LARC-I-TPI polyimides have glass-transition temperatures, film-forming abilities, solubilities, and isothermal thermogravimetric weight losses similar to those of the original LARC-TPI. However, by preparing LARC-I-TPI polyimides with suitable end-capped and non-end-capped components, one can obtain composite-matrix resins, neat-resin moldings, and coating films that have properties identical or superior to those of the original LARC-TPI polyimides.

In experiments LARC-I-TPI polyimides of both end-capped and non-end-capped versions were dissolved in dimethyl acetamide, and the resulting solutions used to coat graphite fibers. After drying at a temperature of 175 °C, the coated fibers were consolidated into fiber/matrix composites at 350 °C under a pressure of 300 psi (2 MPa). The end-capped version exhibited superior melt flow. In other experiments, films, adhesives, and adhesive tapes were prepared.

This work was done by Terry L. St. Clair and Donald J. Progar of **Langley Research Center** *and J. Richard Pratt of PRC, Inc. For further information, Circle 163 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 16]. Refer to LAR-14101.



The **LARC-I-TPI Polyimides** are isomers of the original LARC-TPI polyimides. The newer LARC-I-TPI polyimides are made from less-toxic ingredients and have better and more controllable processing properties.

Reducing Run-in Wear of Ceramic-Based Coatings

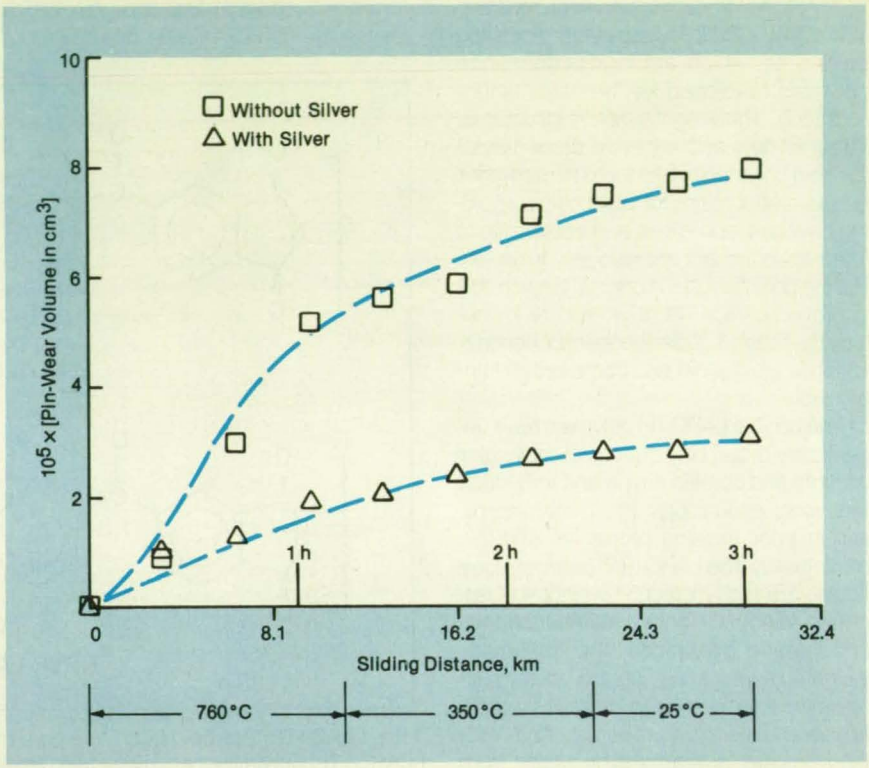
A silver surface layer helps a rough ceramic slide smoothly.

Lewis Research Center, Cleveland, Ohio

A thin film of silver applied over the finish ground surface of a plasma-sprayed, metal/ceramic solid lubricant coating significantly reduces the wear of counterface materials during initial break-in or run-in sliding.

The film is magnetron-sputtered onto PS200, a self-lubricating composite coating that contains a mixture of chromium carbide, silver, and barium fluoride/calcium fluoride eutectic. The carbide in PS200 provides wear resistance, while the silver and fluorides provide lubrication. The silver in the coating is a good low-temperature lubricant because of its low shear strength, and the fluoride eutectic, which undergoes a brittle to ductile transition at temperatures above 500 °C, provides high-temperature lubrication. Thus, the PS200 coating is intrinsically lubricious from room temperature to about 900 °C. However, the PS200 coating exhibits high counterface wear during an initial run-in period of sliding. By applying additional silver as a sputtered top coat over the PS200, the initial counterface wear is dramatically reduced. Also, because both the silver top coat and PS200 are thermally and chemically stable in oxidizing and reducing environments to 900 °C, the combination is appropriate as lubrication for cylinder-wall/piston-ring contacts in Stirling engines and for backup lubrication for gas lubricated journal bearings. These two applications have been successfully tested at Lewis Research Center.

In the current research program, silver films of various thicknesses were sputtered onto PS200-coated test disks. The disks were tested in a pin-on-disk tribometer. Friction and wear were measured at temperatures of 760, 350, and 25 °C in a helium atmosphere. Films between 1,000 and 1,500 Å thick were found to provide the best lubrication of the counterface (pin) material (see figure). In this application, the additional silver film acts as a break-in lubricant, reducing the initial abrasivity of the finish gound coating to the metallic counterface (pin) material.



The **Pin-Wear Volume** is reduced by more than half when the disk is lubricated with a layer of silver 1,000 Å thick. These data were taken at a sliding speed of 2.7 m/s and a force of 4.9 N between the pin and the disk.

This work was done by Christopher DellaCorte, Harold E. Sliney, and Daniel L. Deadmore of **Lewis Research Center.**

Further information may be found in NASA TM-100783 [N88-15885], "Sputtered Silver Films To Improve Chromium Carbide Based Solid Lubricant Coatings for Use Up to 900 °C."

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-14834

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.

Polymeric Additives for Graphite/Epoxy Composites

Brominated additives can improve mechanical properties.

A report describes experimental studies of the properties of several graphite/epoxy composites that contain polymeric additives as flexibilizing or toughening agents. It emphasizes the effects of brominated polymeric additives (BPA's) with or without carboxy-terminated butadiene acrylonitrile rubber. (BPA's are of interest because bromine introduces flame retardancy.) The report reviews the effects of individual and combined additives on the fracture toughnesses, environmental stabilities, hot/wet strengths, thermomechanical behaviors, and other mechanical properties of the composites.

The experimental data lead to the following conclusions, among others:

- With or without rubber added, the higher the molecular weight of the BPA, the more deterioration of mechanical properties is observed.
- The lower the molecular weight of a BPA, the lower is its thermal stability in the uncured state. However, once a BPA is combined in an expoxy polymeric matrix, the molecular structure of the epoxy and the ratios between the aromatic and aliphatic constituents of the three-dimensional cured polymer network dominate the thermal stability.
- BPA's that have been prereacted with carboxy-terminated butadiene acrylonitrile (CTBN) rubber increase the impact strengths of composites.
- The introduction of BPA's into composites that contain CTBN seems to increase shear strengths. An optimum formulation for this purpose contains 8 to 19 percent CTBN and 19 percent bromine.
- Although BPA's increase the flexural moduli of composites, they seem to decrease slightly the flexural strengths and

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Circle Reader Action No. 419

fracture energies of the composites in comparison with those of composites that contain only CTBN rubber additives.

This work was done by D. A. Kourtides of **Ames Research Center** *and Z. Nir of Makhteshim Chemical Works. To obtain a copy of the report, "A Review of Polymeric Additives Used for Toughening of Graphite Composites," Circle 110 on the TSP Request Card.*

This invention has been patented by NASA (U.S. Patent No. 4,550,129). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Ames Research Center [see page 16]. Refer to ARC-11427.

Fiber-Reinforced Superalloys for Rocket Engines

Features include increased service lives and higher allowable operating temperatures.

A report discusses experimental studies of fiber-reinforced superalloy (FRS) composite materials for use in turbine blades in rocket engines. The FRS composites are intended to withstand extreme conditions of high temperature, thermal shock, atmospheres that contain hydrogen, high cycle fatigue loading, and thermal fatigue, all of which tax the capabilities of even the most-advanced current blade material — directionally-solidified, hafnium-modified MAR M-246 [MAR M-246 (Hf) (DS)].

Tungsten-alloy wire was selected as the reinforcing fiber for the composites. Three iron-base alloys (Incoloy* 903, FeCrAlY, and 316L stainless steel) and the nickel-base superalloy Waspaloy were chosen as matrix materials. Monofilament tapes of 40 volume percent fibers were made by arc spraying. The tapes were hot-pressed into composite panels 50 mm wide, 150 mm long, and 1.5 mm thick, with the fibers parallel to the length.

The composite panels were subjected to tensile, thermal-shock, thermal-fatigue, low- and high-cycle-fatigue, and embrittlement-by-hydrogen tests. The estimated and measured behaviors of the composites were contrasted with that of MAR M-246 (Hf) (DS) at a temperature of 870 °C. In addition, the properties of the composites intended for use in advanced rocket engines (which are slightly different from the composites tested here) were projected for 1,100 °C from the results of these tests.

On the basis of the projections it was concluded that FRS turbine blades offer the potential of operating lives of the order of 1,000 times those of MAR M-246 (Hf) (DS) blades, as well as the capability to operate 200 °C hotter. In addition, the FRS blades are expected to undergo smaller strains induced by thermal transients during the starting and stopping of engines.

The following other conclusions were also drawn:

- The resistances of FRS composites to thermal shocks are two to nine times that of MAR M-246 (Hf) (DS).
- The resistances of FRS composites to thermal fatigue equal or exceed that of MAR M-246 (Hf) (DS).
- The tensile and cycle fatigue strengths of the FRS composites equal or exceed those previously estimated.
- Prior damage by thermal shock has negligible influence on the cycle fatigue behavior of FRS composites.
- The FRS composites exhibit negligible embrittlement when exposed to hydrogen at a pressure of 6.9 MPa.
- No ductile-to-brittle transition is observed in FRS composites at temperatures from −196 to 1,100 °C.

Thus, the FRS composites have an attractive combination of properties for use in the turbopump blades of advanced rocket engines at temperatures from 870 to 1,100 °C.

*"Incoloy" is a registered trademark of the Inco family of companies.

This work was done by Jack R. Lewis and Jim L. Yuen of Rockwell International in cooperation with Donald W. Petrasek and Joseph R. Stephens of **Lewis Research Center**. *Further information may be found in NASA TM-100880 [N89-15990], "Fiber Reinforced Superalloys for Rocket Engines."*

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-14871

High-Temperature Creep Behavior of Fiber-Reinforced Niobium

Tungsten fibers reduce creep and mass in advanced power systems.

Reinforcing niobium alloys with tungsten fibers increases their resistances to creep by factors of as much as 10, a study has found. The study, conducted to determine the feasibility of using the composite materials in advanced space power systems, is described in a 22-page report. Such systems require a service life of greater than 7 years in the presence of liquid alkali metals at temperatures above 1,350 K. Under these conditions, long-term resistance to creep is a prime concern.

The materials tested were niobium and niobium with 1 percent zirconium, both reinforced with unidirectional tungsten fibers. Specimens of these composites were made by arc spraying the niobium alloys onto a single row of fibers to produce a tape, followed by hot isostatic pressing of several layers of tape to produce a panel. Microscopic examinations showed that there was little or no adverse chemical reaction between the tungsten fiber and niobium matrix.

The composite specimens were tested in vacuum at 1,400 and 1,500 K, in tension along the fiber axes. When each specimen ruptured, it triggered a switch, and the time to rupture was recorded automatically. (Tungsten fibers were also tested in this manner.) The creep strain of each composite specimen was determined by using a cathetometer to measure the increase in distance between two marks.

The creep behavior of the composite materials could be described by an empirical power-law equation, in which the rate of creep is proportional to the nth power of the stress on the reinforcing fibers and is inversely proportional to the nth power of the fiber content, where n typically ranges from 5 to 6. The minimum rate of creep is inversely proportional to the time to rupture of the composite.

The composites are heavier than are unreinforced niobium or niobium with 1 percent zirconium. However, the high-temperature creep strengths per unit density of the composites are greater than those of

the unreinforced alloys by an order of magnitude. Thus, thinner sections of the composites can be substituted for unreinforced material in power systems, with significant decreases in mass and creep at high temperatures. Alternately, the potential for increased service temperature of components can be considered.

This work was done by Donald W. Petrasek and Robert H. Titran of **Lewis Research Center**. *Further information may be found in NASA TM-100804 [N88-18707], "Creep Behavior of Tungsten/Niobium and Tungsten/Niobium-1 Percent Zirconium Composites."*

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-14831

Stability of a Carbon-Dioxide-Removing Resin

Trimethylamine, which is toxic, is emitted in small amounts during desorption.

A report describes experiments to determine the long-term chemical stability of IRA-45, a commercial ion-exchange resin that is a candidate for use in removing CO_2 from the atmosphere of the Space Station. In the proposed system, the cabin air would be passed through the resin, and the acidic CO_2 would be absorbed by weakly-basic hydrated diethylenetriamine bonded to the porous resin substrate. When the resin had adsorbed all the CO_2 that it could, it would be disconnected from the airstream and heated with steam to desorb the CO_2. The resin could than be reused.

The experiments were conducted in an automated laboratory flow-test facility designed to simulate the conditions in the cabin of the Space Station. Packed columns of the resin were tested for 569 absorption/desorption cycles to determine the decrease in capacity for the absorption of CO_2 and the amounts and kinds of volatile organic compounds released from the resin during heating by steam, both as functions of the number of cycles. The capacity for CO_2 was measured in real time during each cycle. Organic volatiles in the CO_2 desorbed from the resin were trapped on graphitic carbon adsorbents. The trapped volatiles were analyzed by gas chromatography and mass spectrometry.

The capacity of the resin for absorption of CO_2 decreased gradually with time, but the rate of decrease also decreased significantly. After a 43-percent loss of capacity during the first ten or so cycles, the additional loss during the remaining cycles was only 2.7 percent.

A total of 36 organic chemicals were found in the desorbed CO_2, and seven of these were found in the process air. Those emitted during the early cycles were presumed to be contaminants, while those emitted during the later cycles were assumed to result from breakdown of the resin. During the first 80 cycles, trimethylamine was present in the process air downstream of the resin bed in concentrations at or above the maximum allowable for the spacecraft. Because trimethylamine was still present after 569 cycles, it is believed to be a principal product of the breakdown of the resin. It could be removed by post-treating the process air with phosphoric acid on charcoal. The other chemicals could be removed by the trace-contaminant-control subsystem of the Space Station.

This work was done by Theodore Wydeven of **Ames Research Center** *and Peter Wood of San Jose State University. To obtain a copy of the report, "Stability of IRA-45 Solid Amine Resin as a Function of Carbon Dioxide Absorption and Steam Desorption Cycling," Circle 152 on the TSP Request Card.*
ARC-12129

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

Birefringent-Filter Model

An interactive computer program aids in the design of solid-state lasers.

Birefringent filters are often used to narrow spectral lines (that is, as band-pass filters) in solid-state lasers. The Birefringent Filter Model computer program implements a stand-alone mathematical model of a birefringent filter for use in the design and analysis of a birefringent filter. It was originally developed to aid in the design of solid-state lasers to be used on aircraft or spacecraft in remote sensing of the atmosphere. The model is general enough to enable the user to address such problems as temperature-stability requirements, manufacturing tolerances, and alignment tolerances.

The input parameters for the program are divided into seven groups: (1) general parameters that refer to all elements of the filter; (2) parameters related to wavelength; (3) filter, coating, and orientation parameters; (4) parameters of input rays; (5) specifications of output devices; (6) parameters related to components; and (7) parameters of transmission profiles. The program can analyze a birefringent filter with as many as 12 different components, which may include polarizers and Brewster-angle plates, and can calculate the transmission and summary parameters for multiple passes as well as for a single pass through the filter.

The Jones matrix, which is calculated from the input parameters of groups 1 through 4, is used to calculate the transmission. Output files containing the calculated transmission or the calculated Jones matrix as a function of wavelength can be created. These output files can then be used as inputs for programs written by the user. For example, to plot the transmission or to calculate the eigentransmittances and the corresponding eigenpolarizations for the Jones matrix, the appropriate data are written to a file.

The Birefringent Filter Model program is

written in Microsoft FORTRAN 2.0. The format of the program is interactive. It was developed on an IBM PC XT equipped with an 8087 math coprocessor and has a central-memory requirement of approximately 154K. Since Microsoft FORTRAN 2.0 does not support complex arithmetic, matrix routines for addition, subtraction, and multiplication of complex, double-precision variables are included. The Birefringent Filter Model program was written in 1987.

This program was written by Patricia L. Cross and Clayton H. Bair of **Langley Research Center**. *For further information, Circle 106 on the TSP Request Card.*
LAR-13945

Mathematics and Information Sciences

Managing Information on Costs

A mathematical model of costs incorporates flexibility and many capabilities.

The Cost Management Model, CMM, is a software tool for planning, tracking, and reporting costs and information related to costs. The model is capable of estimating costs, comparing estimated costs to actual costs, reporting costs, performing "what-if" analyses on estimates of costs, and providing a mechanism to maintain data on costs in a format oriented to management. A number of supportive cost methods are built in: escalation rates, production-learning curves, activity/event schedules, unit production schedules, a set of spread distributions, tables of rates and factors defined by the user, and a full arithmetic capability. Import/export capability is also possible with the 20/20 Spreadsheet available on Data General equipment.

The user provides names to files, cost elements, cases, and reports. The user must also determine the structures of files, reports, and cost-element hierarchies. Data and output can be reviewed without having to make printouts to enable focus on the analysis of data.

The user puts data into two modules. One module is the Input Processor, which accepts the rates, factors, and tabular data; the other is the Cost Input Processor, in which the user enters costs and builds the costing structure with algorithms. The main module runs the cases set up by the user with little interaction with the user, and the Report Writer enables the user to gain access to the data files produced during the run and to assemble the data into reports for printing. There are three major categories of reports: cost by time, cost by unit, and cost by unit by time.

CMM is a software tool that requires a competent analyst for effective application. The relationship between cost elements and other elements and the interrelationships between the characteristics of cost elements must be understood for effective use of the model. Incorporation of many capabilities and flexibility for the user has also resulted in a fairly complex model. That complexity has been substantially offset by providing the user with a "user-friendly" screen-input system. CMM provides a "starter set" of case selection, input files, and output reports.

The CMM program requires the AOS/VS operating system available on the Data General MV series computers. The program is written mainly in FORTRAN 77 but uses SGU (Screen Generation Utility). The user must have a Data General package, PRESENT, as the Report Writer module if CMM is used for reports. The user must have at least 10,000 free blocks before attaching CMM to the ID. The host user must have approximately 100,000 blocks free to attach the entire contents of the tape. CMM was developed in 1988.

This program was written by Zoe A. Taulbee of ECON, Inc., for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 66 on the TSP Request Card.*
MFS-28361

Managing Mobile/Satellite Propagation Data

Data from experiments are converted into standard and more useful forms.

The "Data Management System for Mobile Satellite Propagation" software package is a collection of FORTRAN programs and UNIX shell scripts designed to handle the huge amounts of data resulting from mobile/satellite radio-propagation experiments. These experiments are designed to assist in defining channels for mobile/satellite radio-communication systems. By understanding multipath-fading characteristics of a channel, Doppler effects, and blockage due to artificial objects as well as natural surroundings, the channel can be characterized. Experiments in propagation are then performed, using a prototype of the system that simulates the ultimate product environment. After the data from these experiments are generated, the researcher must gain access to these data with a minimum of effort and use the data to derive some standard results.

The programs included in this software package manipulate the data files generated by the NASA/JPL Mobile Satellite propagation experiment on an interactive basis. In the experiment, a transmitter operating at 869 MHz was carried to an altitude of 32 km by a balloon. A vehicle within the line of sight of the transmitter was then driven around, splitting the incoming signal into in-phase and quadrature channels and sampling the strength of the resulting signal 1,000 times per second. The data were collected at various antenna-elevation angles and different times of day. The angles and times of day constitute ancillary data.

This software package contains a program to convert the binary format of the data into standard ASCII format suitable for use with a wide variety of computing-machine architectures. Also included is a UNIX shell script designed to parse this ASCII file into those records of data that match the researcher's desired values for the ancillary-data parameters. In addition, four FORTRAN programs are included to obtain standard quantities from the data. Such quantities as the probability of signal level greater than or equal to a specified signal level, probability densities of the signal levels, frequency of duration of fade, and Fourier transforms of the sampled data can be generated from the data from the experiment on propagation.

All programs in this package are written in either FORTRAN 77 or UNIX shell scripts. The programs were developed in 1987 for use with a UNIX operating system on a DEC MicroVAX computer.

This program was written by Anil V. Kantak of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 11 on the TSP Request Card.*
NPO-17269

Cumulative Poisson Distribution Program

Overflow and underflow in sums is prevented.

The Cumulative Poisson Distribution Program, CUMPOIS, is one of two computer programs that make calculations involving cumulative Poisson distributions. Both programs, CUMPOIS (NPO-17714) and NEWTPOIS (NPO-17715), can be used independently of one another. CUMPOIS determines the cumulative Poisson distribution, which can be used to evaluate the cumulative distribution function (cdf) for Γ distributions with integer shape parameters and the cdf for X^2 distributions with even degrees of freedom. It can be used by statisticians and others concerned with probabilities of independent events occurring over specific units of time, area, or volume.

CUMPOIS calculates the probability that n or fewer events (i.e., cumulative) will occur within any unit when the expected number of events is given as λ. Normally, this probability is calculated by a direct summation, from $i = 0$ to n, of terms that involve the exponential function, λ, and inverse factorials. This approach, however, eventually fails because of underflow for sufficiently large values of n. In addition, when an exponential term is moved outside of the summation for simplification, there is a risk that the terms remaining within the summation, and the summation itself, will overflow for certain values of i and λ. CUMPOIS eliminates these possibilities by multiplying an additional exponential factor into the summation terms and the partial sum whenever there is a threat of overflow or underflow. The reciprocal of this term is then multiplied by the completed sum to obtain the cumulative probability.

The CUMPOIS program is written in C. It was developed on an IBM AT computer with a numeric coprocessor using Microsoft C 5.0. Because the source code is written using standard C structures and functions, it should compile correctly on most C compilers. The program format is interactive, accepting λ and n as inputs. It has been implemented under DOS 3.2 and has a memory requirement of 26K. CUMPOIS was developed in 1988.

This program was written by Paul N. Bowerman, Ernest M. Scheuer, and Robert Nolty of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 151 on the TSP Request Card.*
NPO-17714

Mechanics

Silicon Nitride Balls for Cryogenic Bearings

Resistance to wear is greater than that of 440C steel.

Marshall Space Flight Center, Alabama

Experiments have shown that the lives of ball bearings immersed in liquid nitrogen or liquid oxygen are increased significantly when the 440C steel balls (running on 440C steel races) are replaced by balls of silicon nitride. The silicon nitride ball material was developed previously for use at high temperatures, where lubrication is poor or nonexistent.

The wear lives of ball bearings in cryogenic environments are limited because cryogenic coolants provide little or no lubrication. In this respect, the operating conditions of such bearings are similar to those of bearings in hot environments. The low friction and resistance to wear of ceramics makes them attractive as candidate materials for use in bearings, but the brittleness of most ceramics is a disadvantage in applications in which high reliability is required. The silicon nitride balls are suitable for use in rolling bearings because, unlike many other ceramics, the silicon nitride of the grade used to make the balls (Norton grade NDB-100 or equivalent) fails by spalling rather than by fracturing.

Prior to tests of full-scale ball bearings, the wear of bearing materials in liquid oxygen was evaluated in a subscale testing rig that included a cone and three balls 0.5 in. (12.7 mm) in diameter to simulate the operation of the high-pressure-oxidizer turbopump of the Space Shuttle main engine. The specimens were tested for 6 h at a maximum Hertzian stress of 450 kpsi (3.1 GPa). The silicon nitride balls showed no measurable wear, indicating better resistance to wear than that exhibited by balls of 440C steel.

Silicon nitride balls 0.8125 in. (20.64 mm) in diameter for the thrust bearing of the low-pressure-oxidizer turbopump and 0.5 in. (12.7 mm) in diameter for the turbine-end bearing of the high-pressure-oxidizer turbopump of the Space Shuttle main engine have been acquired. The thrust bearing was tested in liquid nitrogen, which was used because it is nonreactive and because its temperature, density, and viscosity are similar to those of liquid oxygen. The bearing completed 27,000 seconds of operation under conditions representative of the environment in the low-pressure-oxidizer turbopump in 8-minute duty cycles and in steady-state operation at high levels of thrust. The results of the test showed that the combination of the silicon nitride balls running against the 440C steel races had the best wear life of any bearing tested to date and that the ball material spalls without fracturing. Plans for future tests call for the use of liquid oxygen as the working fluid.

This work was done by Myles F. Butner and Lillian W. Ng of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*
MFS-29613

Improved Insert for Variable Mach Number

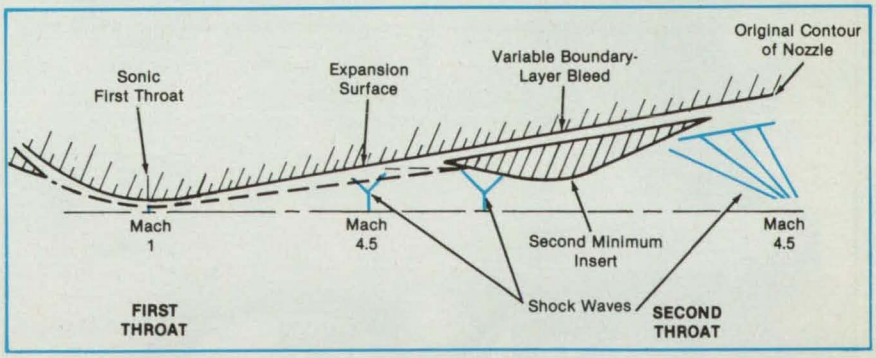
A nozzle insert lowers a wind-tunnel mach number while maintaining excellent flow quality.

Langley Research Center, Hampton, Virginia

The Langley Research Center 8-ft (2.4-m) HTST wind tunnel provides flight-simulation conditions from mach 6 to mach 7 at altitudes of 80 to 130 kft (24.4 to 39.6 km). With its large test section, it can accommodate full-scale, airframe-integrated scramjet engines, missiles, and other components. However, these engines and missiles operate over a large mach-number range beginning at approximately 4. A nozzle insert has been designed to lower the mach number to this level without significant degradation of the uniformity of flow and without excessive loss of total pressure.

This nozzle insert is actually an improvement of a prior design that lowered the operational mach number but degraded the quality of the flow to an unacceptable level. The essential components of the improved design (see figure) include a sonic first throat, an expansion surface, a variable boundary-layer bleed, the insert itself, and the existing, unchanged, contour of the nozzle. The modification involves the creation of the secondary throat and the critical addition of a boundary-layer bleed path between the insert and the original tunnel wall.

With this simple second minimum insert placed in the expansion region down-



The **Second Minimum Insert** lowers the operational mach number without significant degradation of the properties of the flow.

stream of the first throat, wide ranges of decrease in the mach number were easily achieved. The insert has boundary-layer-flow bleeds to stabilize the compression shock wave and to alleviate the strength of the turning shock-wave system at the exit of the insert.

The compression surface of the insert generates very strong shock waves and central mach disks; the reexpansion after the second (supersonic) throat helps to attenuate this shock-wave/mach-disk system. In addition, the exit pressure of the boundary bleed is much higher than the static pressure of the nozzle and thus creates a large region of separated flow that gradually turns the expanding exit flow from the insert.

This design enables a quick change of mach number in an existing facility at relatively low cost (less than one-tenth that of replacing the entire nozzle) and requires no special contouring of the existing nozzle. It represents a simple and cost-effective method of altering the mach number in any supersonic wind tunnel.

This work was done by Richard L. Puster of **Langley Research Center**. *No further documentation is available.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 16]. Refer to LAR-13548

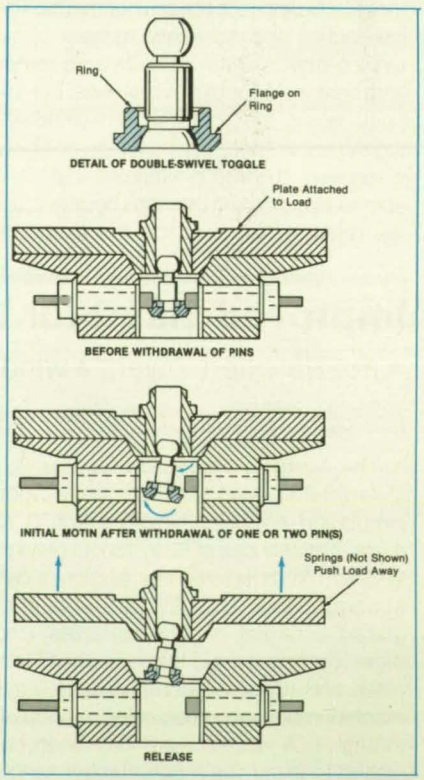
Double-Swivel Mechanism for Reliable Release

This mechanism functions even if two out of three elements fail.

Lyndon B. Johnson Space Center, Houston, Texas

A double-swivel toggle mechanism releases large, heavy objects reliably. The double-swiveling action of the mechanism ensures that it clears restraining pins upon release.

An upper ball on the toggle fits in a ball socket on the object to be released while a lower ball fits in a ball-socket ring. Three pins retain the ring by its flange (see figure). When the time comes to release the ob-



Pins Retain the Toggle and Its Load. If a pin fails to withdraw at the designated time for releasing payload, the toggle swivels about its upper ball, and the ring swivels about the lower ball so that the ring flange clears the failed pin. The double-swiveling action ensures disengagement even if two pins fail to withdraw.

ject, the pins are withdrawn by springs or pyrotechnic devices.

Ordinarily, all three pins are withdrawn simultaneously, and the toggle and object are ejected by springs. If a malfunction occurs, however, and one or two pins remain(s) in place, the toggle action still releases the object. The toggle swivels so that it rotates clear of the unreleased pins. The lower ball cannot transmit a moment to the object that would cause the mechanism to twist on the remaining pins and lock on them in a way that would prevent release.

The pins are straight cylinders. They are not tapered at their tips, where they meet the toggle-ring flange. This provision eliminates forces that would tend to cause inadvertent or premature release.

This work was done by Guy L. King and William C. Schneider of **Johnson Space Center**. *For further information, Circle 60 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center [see page 16]. Refer to MSC-21436

Simulation of Unsteady, Viscous, Incompressible Flow

Results of computations compare favorably with experiments.

Ames Research Center, Moffett Field, California

A method for the numerical solution of the Navier-Stokes equations of viscous, incompressible flow is developed based on the use of a fractional-step procedure. The method is accurate to second order in both space and time.

The Navier-Stokes equations are put in integral form and discretized over finite volumes to yield a fully conservative second-order scheme. Finite-volume discretization is preferred because it usually results in more accurate and stable solutions for generalized coordinate systems, especially for meshes with clustered points and large curvature. Special care is given to satisfy the "geometrical conservation laws" to minimize the errors resulting from the spatial discretization.

The numerical difficulties associated with the absence of a time derivative of the pressure in the equation of conservation of mass are handled by a fractional-step procedure. In each time step, the equations of conservation of momentum are solved for an approximate velocity field that does not satisfy the equation of continuity. In the second stage, the velocity and pressure fields are corrected in such a way that the equation of conservation of mass is satisfied. This step leads to a Poisson equation with Neumann-type boundary conditions that may exhibit very poor convergence properties, especially in generalized coordinate systems. The time consumed in the solution of the Poisson equation may be as high as 80 percent of the total computational time, even in a Cartesian case.

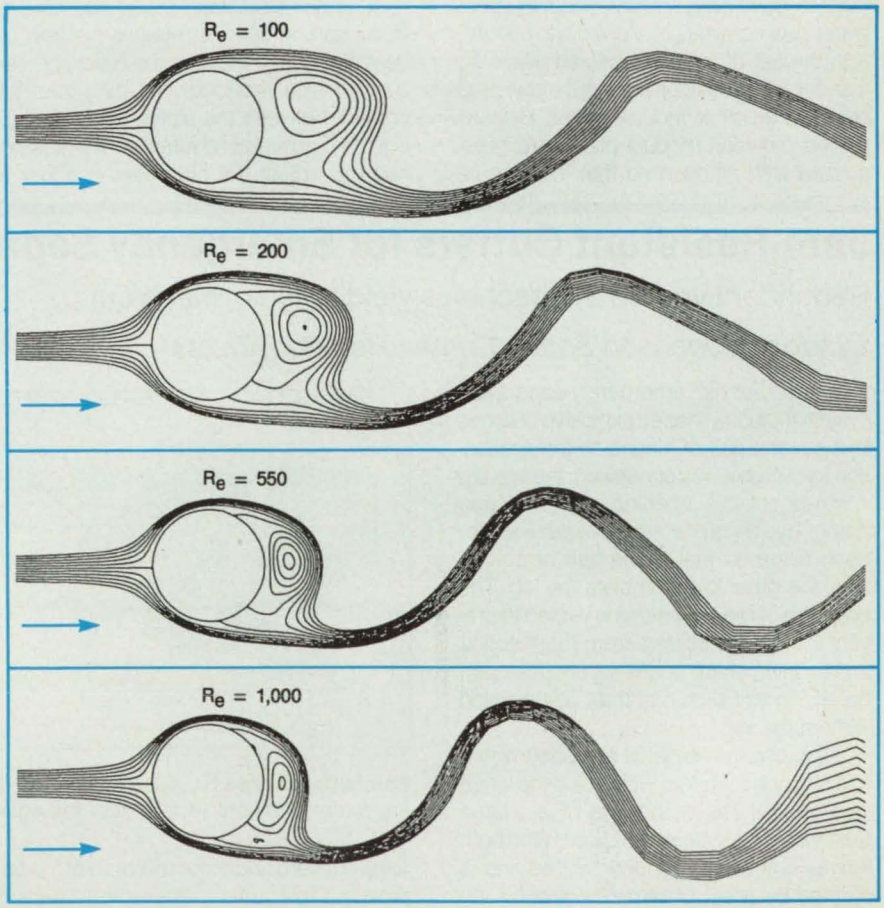
In this method, an attempt is made to minimize the Poisson-equation difficulties by choosing the pressures at the centers and the volume fluxes across the faces of the computational cells as the dependent variables instead of the familiar Cartesian components of the velocity. This choice ensures the satisfaction of the discrete equation of conservation of mass to within round-off errors in any coordinate system and has favorable effects on the convergence properties.

A consistent solution to Poisson's equation is obtained by deriving the Laplacian operator from the discrete equivalent of the operator $\nabla\cdot\nabla$ (where $\nabla\cdot$ and ∇ are the divergence and the gradient operators, respectively), rather than discretizing the Laplacian operator directly. A novel and efficient ZEBRA scheme with four-color ordering has been devised for the efficient solution of the nonorthogonal Poisson equation on vector computers. The solution of the Poisson equation could be converged to within any specified small error in all the cases solved so far.

The method has been applied to a two-dimensional lid-driven flow in a cavity and to a flow around a circular cylinder with shedding of vortices (see figure). The results of the computations have been found to compare favorably with those of other numerical studies and, in the case of the cylinder, with those of experiments.

This work was done by Moshe Rosenfeld and Dochan Kwak of **Ames Research Center**. *Further information may be found in NASA TM-101016 [N88-30085], "Numerical Simulation of Unsteady Incompressible Viscous Flows in Generalized Coordinate Systems."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. ARC-12277



The **Flow Around a Cylinder**, including the shedding of vortexes, is simulated at various Reynolds numbers, Re.

Pressurized-Flat-Interface Heat Exchanger

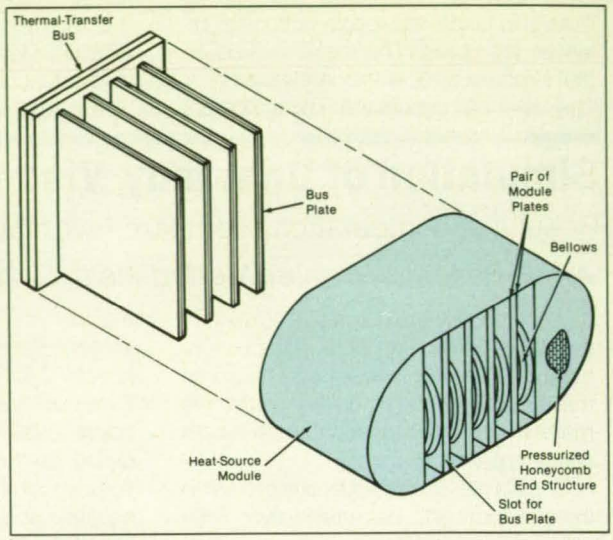
High thermal conductance is obtained without leakage between loops.

Lyndon B. Johnson Space Center, Houston, Texas

A heat-exchanger interface enables the efficient transfer of heat between two working fluids without allowing the fluids to intermingle. The interface is thin, flat, and easy to integrate into a thermal system, unlike interfaces based on concentric cylinders or pressurized fingers. In a prototype version made of aluminum, contact conductances of 652 to 729 Btu/h·ft^2·°F (3.70 to 4.14 kW/m^2°C) were achieved.

A possible application is in chemical or pharmaceutical manufacturing when even trace contamination of the process stream with water or other coolant could ruin the product. It may also reduce costs when highly corrosive fluids must be cooled or heated. The corrosive-fluid side of the exchanger could be made of special corrosion-resistant material while the noncorrosive side could be made of standard, less costly materials. If either side developed leaks or became fouled, it could be removed without disturbing the other side.

At an interface, a set of contact heat-exchanger plates is positioned on the thermal transport bus, through which ammonia or other suitable coolant flows (see figure). A module containing a corresponding set of water-heated plates is slipped into contact with the set of ammonia-cooled plates so that each thermal-bus plate is sandwiched between a pair of module plates. Bellows placed between module plates are pressurized with nitrogen so that the module plates press firmly against the bus plates, ensuring good thermal contact. The faces of the bellows are thin diaphragms that conform to the surfaces of the module plates. The flowing water in the module heats the module plates, which pass their heat to the bus plates, which in turn transfer the heat to the flowing ammonia.



Working Fluids Flow Independently in a heat-transfer module (right) and a thermal transport bus (left). Pairs of plates in the module slip over plates on the bus and are pressed against the bus plates by inflated bellows. Many such modules can be located along a bus.

A further advantage of the interface is that it can be used to regulate the flow of heat. To reduce the flow, the bellows pressure can be reduced, reducing thermal contact between the plates and decreasing the thermal conductance. There is no need to adjust the fluid flow in either a module or the thermal bus with valves or pumps.

This work was done by F. E. Voss, H. R. Howell, and R. V. Winkler of LTV Aerospace and Defense Co. for **Johnson Space Center**. *For further information, Circle 57 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center [see page 16]. Refer to MSC-21271

Jam-Resistant Cutters for Emergency Separation

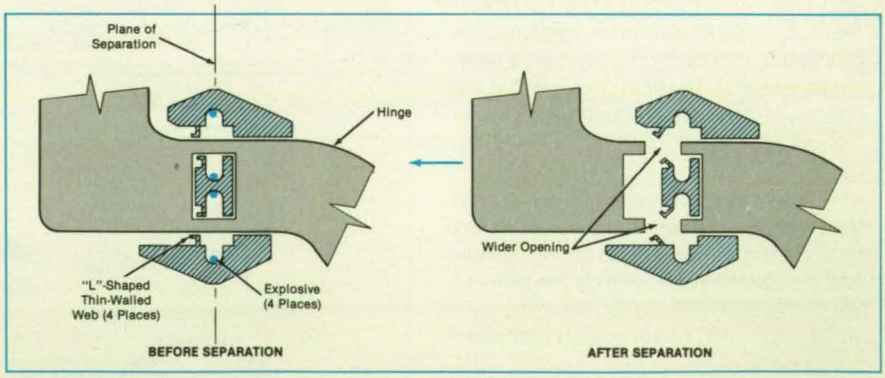
Redundant vented pyrotechnics yield reliable, clean cuts.

Lyndon B. Johnson Space Center, Houston, Texas

A pyrotechnic emergency-separation system includes shaped explosive charges that sever a pair of hinges. In the application for which it was conceived, the system ensures reliable opening of an escape hatch. Two pairs of cutters are provided for each hinge so that if one pair of cutters fails, the other can complete the job. The pressure of the explosions is vented to prevent the charge holders from fragmenting and forming sharp edges around the open hatch. An exit slide can then be deployed without tearing.

Each charge holder is equipped with a thin L-shaped retainer wall facing the hinge (see figure). The detonation of a charge cuts through a web in the hinge. With both hinges cut, the hatch door is free and is ejected by a set of thrustors around the periphery of the hatch.

At detonation, the thin wall of the L-shaped retainer collapses, and the retainer folds outward under the pressure of the explosion. This action widens the opening around the severed hinge so that it can leave without hindrance.



Before Detonation L-shaped retainers bear on the hinge. After detonation, the retainers are folded outward to facilitate the egress of the severed hinges.

This work was done by Arturo C. Ordonez and Ronald N. Yee of Rockwell International Corp. for **Johnson Space Center**. *For further information, Circle 145 on the TSP Request Card.*

MSC-21474

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THE PROGRAM

NASA management has invited space agency researchers and key industry leaders to address **TECHNOLOGY 2000** audiences. **Several concurrent sessions are planned for 8:30 - 11 a.m. and 2:30 - 5:30 p.m. on both Tuesday and Wednesday, November 27 and 28.** The symposia topics include:

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ROBOTICS AND ARTIFICIAL INTELLIGENCE
SOFTWARE ENGINEERING
LASERS/OPTOELECTRONICS
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TELECOMMUNICATIONS
BIO-MEDICINE
MATERIALS SCIENCE
SENSOR TECHNOLOGY

A final list of specific topics and speakers will accompany registration confirmations; attendees may then choose the sessions they wish to attend.

THE LOCATION

All sessions will be held at the Washington Hilton Hotel and Towers, 1919 Connecticut Ave., N.W., Washington D.C. 20036. The hotel is conveniently located near the DuPont Circle stop on the Metro Red Line, and offers indoor parking.

REGISTRATION AND FEES

The full registration fee is $150, and includes symposia and exhibits for both days. For those who can attend for only one day, registration for technical sessions and exhibits is $100. Attendees may visit the exhibit area only at a cost of $20/day.

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3__Eng. Svc.-Tests/Quality
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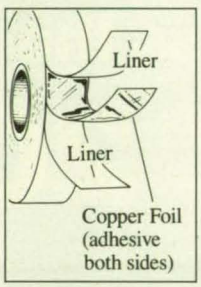
3M Announces Double-Coated Foil Shielding Tape

Copper foil base with electrically-conductive adhesive on both sides for reliable point-to-point grounding.

AUSTIN, Tex. – This new UL Recognized tape has a multitude of uses in electronic design, test, and QC laboratories where good grounding paths are required. Other applications include shielding of PC boards, microwave antennas and display boards; grounding and static charge draining.

Scotch™ Brand Electrical Tape #1182 features a dynamic range over a frequency from 1 MHz to 1 GHz. EMI/RFI shielding effectiveness was measured in the Near Field using a modified Mil Std 285 test procedure.



Scotch Brand Foil Shielding Tape #1182 is supplied on a liner that permits easy handling and dispensing in either random or definite lengths without curling.

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3M

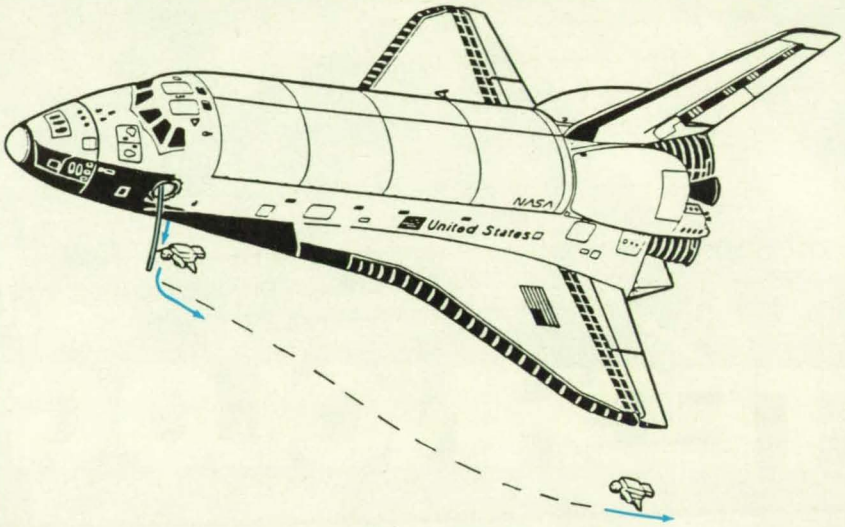
Safe-Egress Pole for Vehicle in Motion

People eject at a safe distance from protruding structures.

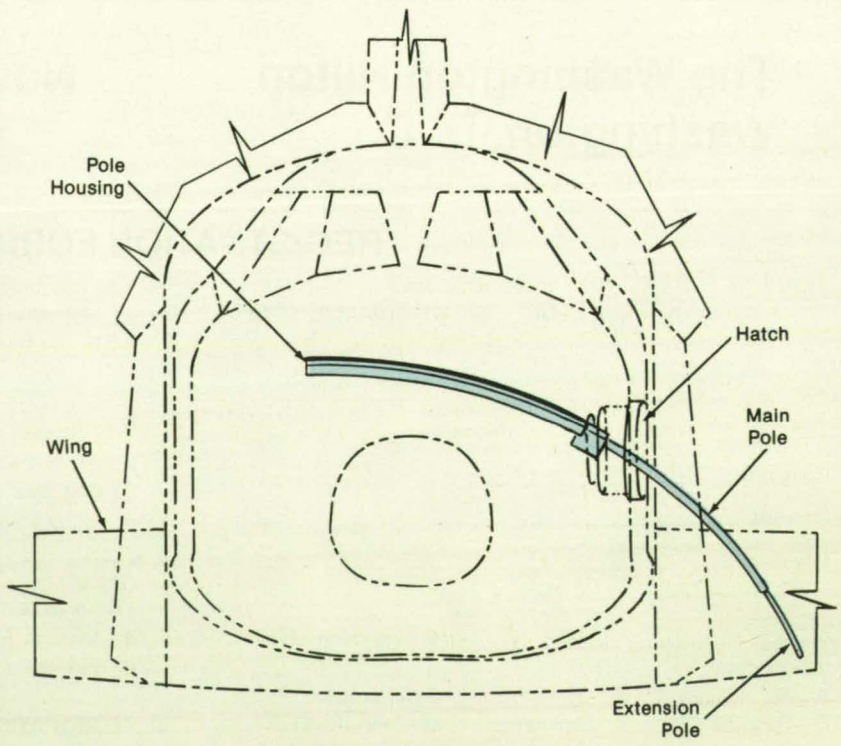
Lyndon B. Johnson Space Center, Houston, Texas

A telescoping pole helps people leave a moving vehicle in an emergency. The pole extends from the vehicle far enough to guide people away from structural features that could strike and injure them. Such a pole could also be used to deliver cargo from aircraft without damage to or by wings or to eject supplies from moving trucks so that they land off the roadway.

The telescoping-pole concept was developed to help crewmembers escape from the Space Shuttle under certain flight conditions. For example, in an aborted launch or before a crash landing, at an altitude of about 20,000 feet (6.1 km) the left-side hatch of the Shuttle would be blown off. The telescoping pole would be extended out through the open hatchway (see



OVERVIEW SHOWING PATH OF EJECTION



FRONT VIEW SHOWING POSITION OF EXTENDED POLE

The **Escape Pole Extends** downward and to the rear so that users can jump clear of the wing, before releasing themselves.

figure). The crew would then leave one by one through the hatch and slide along the pole on lanyards. At the tip of the pole, they would be released from the aircraft.

The retracted pole is compact and lightweight. Unlike other means of emergency egress such as ejection seats or belly tunnels, it does not require drastic structural modification of the Shuttle. Unlike an extraction rocket, which pulls crewmembers through the hatch fast enough to clear the wing, the telescoping pole does not subject the ejecting members of crew to high accelerations and does not require the storage of pyrotechnics in the cabin.

At the beginning of deployment, a main pole extends from the housing, guided by a bearing block. A kicker-spring mechanism pushes the main pole out, and an arrester assembly stops the main pole as it reaches the limit of its movement, absorbing its kinetic energy. An extension spring then pushes the extension pole outward. An energy absorber stops the extension pole as it reaches its limit. An antiretraction lock prevents the extension pole from retracting to the main pole once it has been deployed. A redundant manually operated mechanism is used to deploy the pole if the kicker-spring mechanism fails to operate.

This work was done by Winston D. Goodrich, Clarence J. Wesselski, Timothy E. Pelischek, Bruce H. Becker, Jon Kahn, Margaret E. Grimaldi, John McManamen and Edgar O. Castro of **Johnson Space Center**. *For further information, Circle 71 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center [see page 16]. Refer to MSC-21461

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.

Simulation of Turbulent, Oscillating Boundary Layer

Numerical results support predictions of simplified theories.

A report discusses aspects of algebraic and numerical modeling of the flow in the infinite half space on one side of an infinitely-large, flat plate, with a sinusoidally oscillating free-stream velocity along one axis of the plate. This flow has a rich variety of behaviors, including strong gradients of pressure, points of inflection, and reversal.

The chosen flow is the turbulent version of a classical problem, known as Stokes' second problem, for which the exact solutions of the Navier-Stokes equations of viscous flow are known. The zero mean value of the free-stream velocity gives rise to a natural homogeneity along and across the plate; this justifies the imposition of periodic boundary conditions in a direct simulation and improves the statistical sample considerably. In addition, the Reynolds-averaged quantities are functions only of the time and of the coordinate perpendicular to the plate. This provides a good test of the abilities of mathematical models of turbulence to treat unsteady and inflectional velocity profiles with little numerical effort and with high numerical accuracy. This flow also exhibits reversal of the velocity without the usual difficulties of coupling between viscous and inviscid motions and of singularities encountered in spatially separating flows.

The authors present equations that describe the shear stress and the mean velocity as a function of distance from the plate and phase angle. This theory is based on dimensional analysis, the Reynolds-number-similarity hypothesis, and some plausible assumptions about the forms of

functions that describe various aspects of the flow. The theory is tentative in that these concepts and assumptions are consistent with current thinking but cannot be proved rigorously. The equations are known to be applicable only at high Reynolds numbers and inapplicable near the phase of reversal of the wall shear stress.

The predictions of the theory were compared with the results of a numerical simulation via the Navier-Stokes equations of three-dimensional, viscous, incompressible flow over a narrow range of Reynolds numbers. The simulation showed that the oscillating boundary layer displays a complex behavior, as a function of both the phase angle and the Reynolds number. Although the flow is believed to be linearly stable, it exhibits a first transition to a "preturbulent" state just below a Reynolds number of 600. A second transition, between 600 and 800, allows it to generate well-developed turbulence during at least part of the cycle. During that part of the cycle, it contains a log layer (referring to the proportionality of the velocity to a logarithm of a nondimensionalized distance from the wall) and agrees with other aspects of the high-Reynolds-number theory described above. Also, despite the complexity of the flow, a new algebraic model of turbulence yielded results in satisfactory agreement with those of the numerical simulation and the predictions of the theory.

This work was done by Philippe R. Spalart and Barrett S. Baldwin of **Ames Research Center**. *Further information may be found in NASA TM-89460 [N87-24642], "Direct Simulation of a Turbulent Oscillating Boundary Layer."*

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-11858

Simulated Hypersonic Flows About a Blunt Body

Unsteady and steady flows are compared.

A report describes a computer numerical study of two-dimensional, unsteady, viscous, hypersonic flows of air about a blunt body with an impinging shock. This kind of flow represents many practical phenomena; for example, the interaction of the fluctuating bow shock of a hypersonic airplane with the shocks of the leading edge of a wing or of the lip of the cowl at the inlet to the engine. Such interactions give rise to complicated, moving shock-on-shock patterns.

The two-dimensional body consists of a circular cylinder that caps a planar slab. The flow is represented by the unsteady, thin-layer, Navier-Stokes equations for a perfect gas with laminar boundary layer. The unsteady interaction is represented by the downward motion, at constant speed, of the impinging shock across the bow shock of the body. The Navier-Stokes equations are incorporated into, and solved by, a high-resolution, implicit, second-order-accurate (in time and space), total-variation-diminishing algorithm that was developed for transonic and supersonic flows and was extended recently to hypersonic and equilibrium real-gas flows.

Previous studies have shown that in steady flows, various kinds of shock interactions occur, depending on the freestream conditions and the angles and locations of impingement of shocks. Experimental data on steady supersonic flows have led to the identification of six different types of interactions, denoted as types I through VI. The present numerical simulations of unsteady hypersonic flows predict shock interactions similar to those observed in the steady supersonic flows. However, in these simulations, the peak surface pressures do not seem to occur during the Type-IV interaction as they do in the steady supersonic flows. The significance of this fact is that the Type-III interaction occurs over a range of angles and positions of impingement of shocks much broader than the range for the Type-IV interaction. Also, the details within the shock layer differ appreciably. For example, boundary-layer separation and transient supersonic jets flowing parallel to the surface of the blunt body occur in the unsteady, but not in the steady, shock interactions.

This work was done by P. Kutler and H. C. Yee of **Ames Research Center** *and G. H. Klopfer of NEAR, Inc. Further information may be found in NASA TM-100096 [N88-22650], "Numerical Study of Unsteady Viscous Hypersonic Blunt Body Flows With an Impinging Shock."*

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-12251

Propagation of Pulse Vibrations in Large Structures

Dispersion, damping, and confinement are studied.

A study yields new insights into the propagation of pulse-excited vibrations in large, complicated structures. Special attention is paid to the dispersion, damping, and trapping of pulses. The understanding of these effects can help such endeavors as designing tall, thin buildings to resist high winds and earthquakes.

A conventional finite-dimensional mathematical model of a structure may not represent adequately the high-frequency components of vibrational response. Consequently, in this study, the response to a pulse excitation (which has considerable high-frequency content) is represented by a system of small-amplitude pulses propagating as characteristic waves. The dynamics of these pulses are represented by linear equations with delay arguments, which equations complement the conventional finite-dimensional model.

The dynamical equations are put in the customary matrix form, and the general form of the numerical solution is written in closed form in terms of the excitations. The responses to pulse excitations are also studied analytically with the help of z transforms. Periodic, quasi-periodic, and nonquasi-periodic excitations are represented by sums of pulses with various finite or infinite numbers of terms with various commensurate or incommensurate delays between them.

These techniques of analysis are illustrated by applying them to structures excited by harmonically repeated pulses. It is shown that the vibrational responses of the structures qualitatively resemble the modal responses to sinusoidal excitations. The resemblance disappears and new phenomena emerge in the presence of nonperiodic excitations. For example, when there are certain similarities between the nonperiodic excitations and the nonperiodic properties of the structures, resonances can occur.

The study reaches three main conclusions that are particularly relevant to the design of structures that can resist damage when excited by pulses:

1. Propagating pulses are dispersed by such structural irregularities as joints between members of unequal length. The effect of dispersion is related to the loss of periodicity of pulse motion. A pulse is split irreversibly when it passes such a joint.
2. Pulses can be damped by appropriate combinations of elastic and dissipative properties of joints. There is an optimal relationship between these two properties that provides the most effective damping.
3. The nonsymmetrical properties of joints can be exploited to obtain a pulse-trapping effect that can protect a structure. More specifically, the reflection and transmission coefficients for waves coming from one side of a joint are different from those for waves coming from the other side. An appropriate selection of these coefficients leads to localization of pulses within certain parts of the structure, where they can be damped later.

This work was done by Michail Zak of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Dispersion, Damping and Confinement of Propagating Pulses in Large Space Structures," Circle 144 on the TSP Request Card.*
NPO-17559

Machinery

Testing Bearing Balls for Ignition in Liquid Oxygen

Balls are heated in flowing liquid oxygen to simulate behavior in turbomachinery.

Marshall Space Flight Center, Alabama

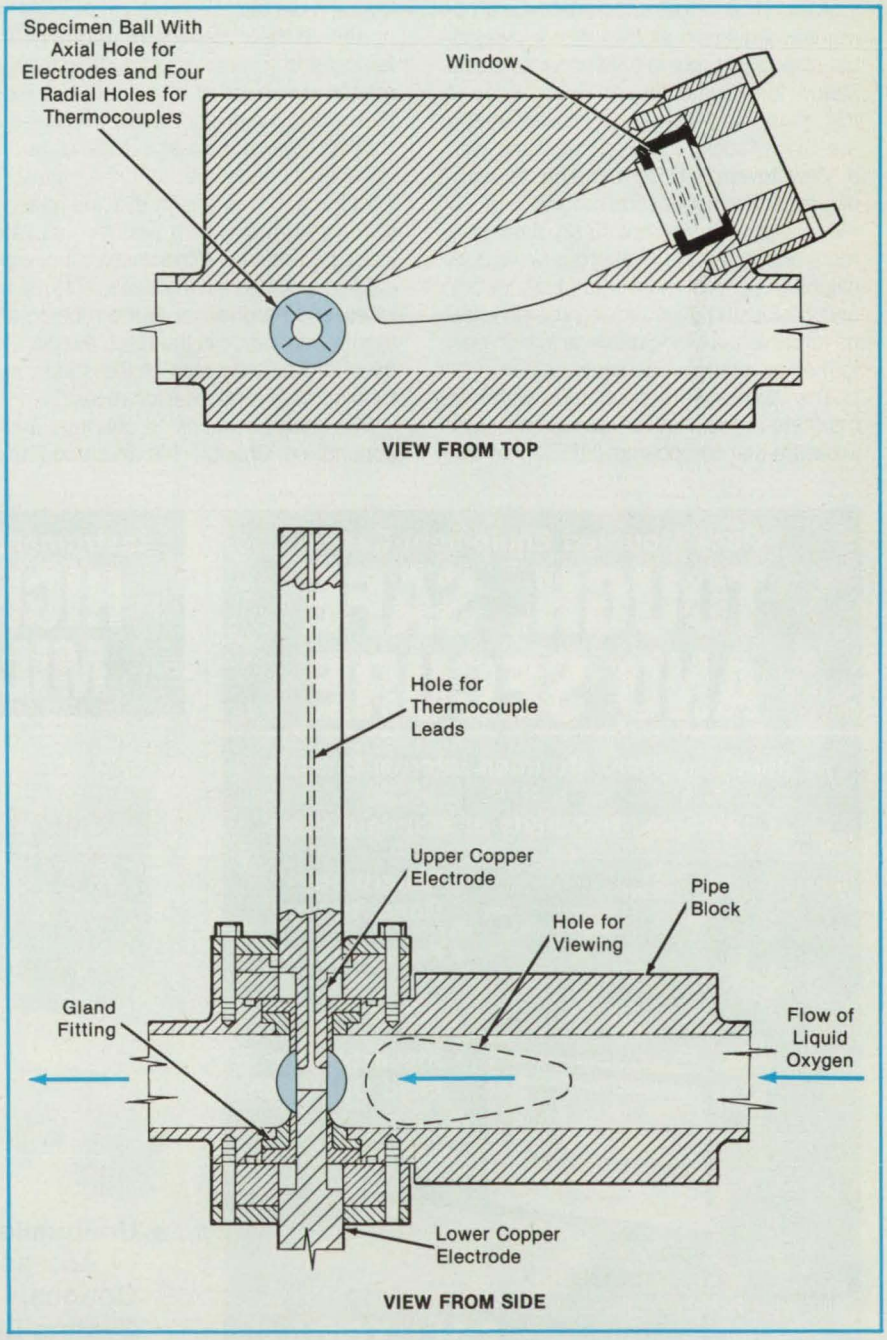
An inexpensive, safe apparatus has been built to test cooling by, ignition in, and nucleate boiling to film boiling of liquid oxygen flowing around ball bearings. The apparatus provides for the heating of bearing specimens, direct observations, and measurements of temperatures and temperature distributions by thermocouples and infrared sensors. It is used to evaluate the suitability of various materials and surface treatments for ball bearings in high-pressure liquid-oxygen turbopumps.

In the apparatus, a specimen ball is held on the axis of a pipe (see figure). A gland fitting seals the pipe during tests and allows access to the fixture for the insertion and removal of specimens. Copper electrodes pass through holes in the gland fitting to make contact with the specimen. Four thermocouples are embedded in the ball, and the thermocouple leads are brought out through an axial hole in the upper electrode.

During a test, liquid oxygen at a pressure up to 800 lb/in.^{2} (5.5 MPa) flows along the pipe and around the specimen while a current of up to 4,000 A in the copper electrodes heats the specimen. A viewer can observe the flow and boiling of the liquid oxygen and the ignition of the ball through a port extending at an angle from the pipe. Alternatively, an infrared-sensing device can be positioned at the port to map the distribution of temperature on the surface of the ball. Meanwhile, the thermocouples provide a record of the temperature at points in the ball before, during, and after boiling and ignition.

By reversing the direction of flow of the liquid oxygen, one can observe either the upstream or downstream side of the ball. The thermocouples can be positioned before the test by rotation of the ball to the desired orientation.

This work was done by William R. Wagner, Constantine Peroulias, and Louis H. Pidcoke of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*
MFS-29410



The **Ball Rests in the Fixture** while liquid oxygen flows around it. The flow can be reversed so that an observer or an infrared sensor can view the phenomena on the trailing or leading side of the ball. The ball shown here is 1 in. (2.54 cm) in diameter and is made of 440C stainless steel.

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.

Rubbing Between Rotors and Stators

Dynamical effects that damage turbomachinery are described.

A report describes experimental and numerical-simulation studies of the dynamical effects of rubbing between rotors and stators in turbomachinery. The purpose of this study was to gain improved understanding of such rubbing phenomena, with a view toward (1) contributing to techniques for the diagnosis of rubbing (e.g., via the analysis of vibrations), (2) predicting more accurately the limiting operating conditions (e.g., maximum rotational speeds and loads), and (3) improving design criteria to prevent rubbing damage in high-performance rotating machinery.

The studies were concerned with two machines: one that simulated the high-pressure-fuel turbopump (HPFTP) of the main engine of the Space Shuttle; and a smaller, simpler, two-bending-mode-rotor rig designed for more generic studies of rubbing. The experiments on these machines produced a wide array of results, confirming the richness of rotor-to-stator-rubbing phenomena. Some of the observed phenomena, such as fluid-induced instabilities and internal-friction instability, were not correlated with rubbing.

The influences of several factors upon the responses of rotating systems were investigated. The main focus was on the lateral vibrational responses modified by rubbing of the rotor against the stator. The emphasis was on the vibrational modes of lowest order because these modes are important in the dynamics of rotors. Of the factors and parameters that affect the rub-related dynamics of rotors, the two most thoroughly investigated were the speed of rotation relative to the spectrum of natural vibrational frequencies, and the radial preload force. It was shown that the patterns of rotor vibrations vary with the values of these parameters. Other factors that were studied included the materials, surface finishes, and hardnesses of the rubbing elements; unbalance in the rotor; the geometry of the rubbing area of the stator; and rubbing at several axial locations.

The report contains 16 chapters and 3 appendixes. Chapter 1 is an introduction. The second chapter reviews the literature on rotor/stator rubbing. The third chapter provides a more specific characterization of rubbing. Chapter 4 describes the initial design assumptions and data for the HPFTP-simulating test rig. Chapter 5 summarizes the results of tests of bearings used to simulate interstage seals. Chapters 6 and 7 describe the HPFTP-simulating rig and some preliminary experimental results from the use of it, respectively.

Chapter 8 presents the results of measurements of dry friction and analysis of the surface-damaging effects of rubbing. Chapters 9 and 10 describe the two-bending-mode test rig and the experimental results obtained with it, respectively. Chapter 11 presents the mathematical model of the rubbing rotator/bearing/seal/stator system. Chapter 12 presents the results of tests on the HPFTP-simulating rig. Chapter 13 describes the results of experiments on rotor-to-stator rubbing contact in the two-bending-mode test rig. Chapter 14 describes the computer code for the simulation of the dynamic responses of the rotor-to-stator rubbing system. Chapter 15 presents some of the computer-generated results.

Chapter 16 presents conclusions — including a discussion of the influence of rubbing on the dynamics of rotating machinery, of the prevention of rubbing, and of the use of vibration-measuring and data-proc-

Space Station Freedom's orbit 240 miles above the Earth, is the perfect place for a power system designed for 30 years of uninterrupted operation.

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Garrett Fluid Systems Division, a member of the NASA-LeRC/Rocketdyne Power System Team. 1300 West Warner Road, Tempe, AZ 85284. (602) 893-4421.

Allied Signal Aerospace

essing instrumentation — and hints on the diagnosis of rubbing. Appendix 1 presents data from HPFTP hot-fire tests. Appendix 2 is a conference paper that includes results of the rotor/stator-rubbing study. Appendix 3 contains information on the electronic instrumentation used in the experiments.

This work was done by Agnes Muszynska, Donald E. Bently, Wesley D. Franklin, Robert D. Hayashida, Lori M. Kingsley, and Arthur E. Curry of Bently Nevada Corp. for **Marshall Space Flight Center**. *To obtain a copy of the report, "Influence of Rubbing on Rotor Dynamics," Circle 8 on the TSP Request Card.* *MFS-27226*

Aerobrakes for a Manned Mars Mission

Aerobrakes will make a round-trip flight to Mars possible.

A paper presents the results of a study of aerobraking in a manned mission to Mars. The paper describes the geometry and aerodynamic characteristics of the aerobraked vehicle. It discusses the computer program, WTRAJ, that was used to simulate trajectories near planets. It analyzes the aerocapture processes for both Mars and Earth. It examines the mass efficiency, or saving in propellant mass, afforded by aerobraking.

Aerobraking would be used instead of retrorocket propulsion to slow the spacecraft for entry into the Martian atmosphere as well as for return to the Earth. The reduction in the amount of fuel required would more than compensate for the added weight of the braking apparatus and its heat-shield system. The mass of fuel saved would be at least 30 percent of the mass of the entering vehicle at both Earth and Mars.

The study was based on an aerobrake design that has been developed over several years and accounts for thermochemical relaxation effects in real gases in both the Martian and Earth atmospheres. The paper suggests that two aerobrakes of different size will yield the best performance in three principal phases of the mission: one aerobrake for aerocapture over Mars and descent of a surface lander and another aerobrake for the return to Earth. The paper concludes that the benefits of aerobraking are so great that they could make the entire mission possible.

This work was done by G. P. Menees of **Ames Research Center**. *Further information may be found in N88-11700, "Aeroassisted-Vehicle Design Studies for a Manned Mars Mission."*

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-12117*

Fabrication Technology

Hardware, Techniques, and Processes

Viewing Welds by Computer Tomography

A computer-aided technique yields images for evaluation of welds.

Marshall Space Flight Center, Alabama

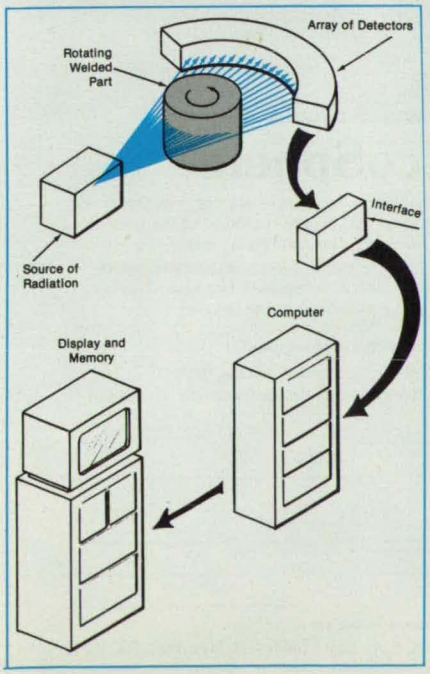
A computer tomography system is used to inspect welds for root penetration. The system offers the only nondestructive way to check penetration from outside when the inner surfaces are inaccessible.

A source illuminates the rotating welded part with a fan-shaped beam of x rays or gamma rays (see figure). Detectors in a circular array on the opposite side of the part intercept the beam and convert it into electrical signals. A computer processes the signals into an image of a cross section of the weld. The image is displayed on a video monitor (see Figure 2).

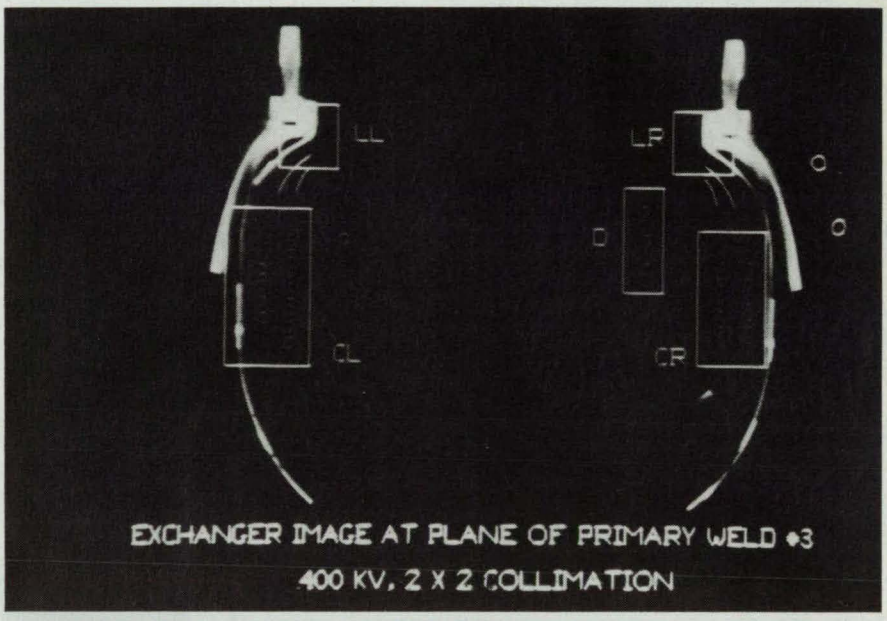
Computer tomography thus provides an image of the interior of a weld similar to the microscopic views provided by metallurgical sectioning. Unlike sectioning, however, tomography does not destroy the specimen and gives results almost instantly.

This work was done by Antonio G. Pascua and Jagatjit Roy of Rockwell International Corp. for **Marshall Space Flight Center**.

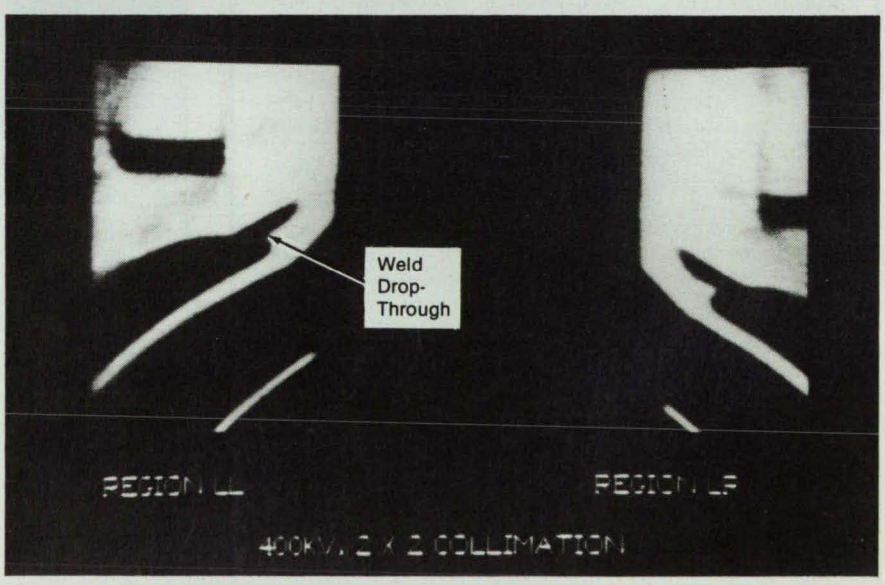
Figure 1. A **Video Image** of the cross section of a weld results from computer processing of signals from detectors.



No further documentation is available.
MFS-29555



OVERVIEW TOMOGRAPH SHOWING REGIONS MARKED FOR ADDITIONAL PROCESSING



TOMOGRAPHS OF REGIONS LL (LINER LEFT) AND LR (LINER RIGHT)

Figure 2. The **Computed Tomographic Image** of a weld in a heat-exchanger assembly includes regions framed for additional processing. The additionally processed images for two of these regions (below) show more detail in scan planes that intercept a mounting bolt in a threaded cavity. A weld drop-through is evident.

Resistance-Welding Test Fixture

Realistic welding conditions produce reliable specimens.

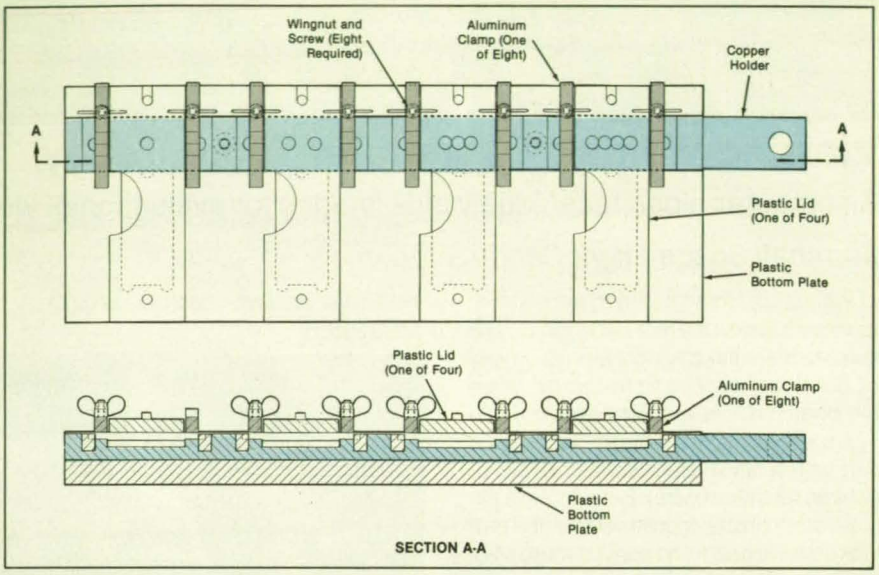
Marshall Space Flight Center, Alabama

A simple fixture holds resistance-welding test specimens. The fixture provides for flows of heat and electrical current similar to those encountered in manufacture.

The fixture (see figure) holds specimens of foil and screen for welding onto stainless-steel plates. A specimen holder and clamps secure the samples while an operator welds each pair by applying a resistance-welding tool through notched openings in lids.

Electrical current and heat flow through the sample, the copper holder, and aluminum clamps. Other parts are made of thermally- and electrically-insulating poly(methylmethacrylate). When the welded specimens are subjected to tensile peel tests, they accurately represent production parts. Microscopic comparisons of specimens assembled in the fixture and production parts have verified the authenticity of the simulated conditions.

This work was done by Andrew D. Brennan of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information, Circle 29 on the TSP Request Card.* *MFS-29426*



The **Specimen Holder** includes a metallic holder and clamps to provide electrical and thermal paths and plastic parts that provide thermal and electrical isolation.

Removing Burrs in Confined Spaces

The right tool makes a normally impossible job easy.

Marshall Space Flight Center, Alabama

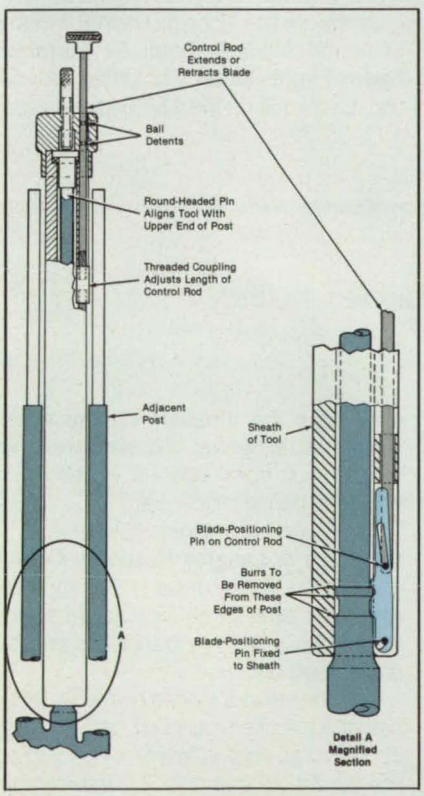
A special tool has been proposed to remove burrs on ring edges left by the operations of a hollow mill near the bases of round posts. The tool was conceived because the posts are placed so closely together that ordinary and makeshift tools can damage the adjacent posts and are difficult or impossible to use in the narrow, deep spaces surrounding the edges to be deburred. Although the tool is designed specifically for use on hollow liquid-oxygen-injector posts of a spacecraft engine, the general tool concept is adaptable to similar deburring problems on otherwise inaccessible parts. The proposed tool is an example of the design of a simple special tool to do a job that cannot be done with commercially-available, general-purpose tools.

The figure shows the tool in the operating position on a post between two adjacent posts. The cylindrical sheath of the tool is aligned at the lower end by contact with part of the outer surface of the post. At the upper end, the tool is aligned by the insertion of a round-headed pin into the axial hole in the post. A long control rod is equipped with a knurled handle at the upper end and is made in two pieces that are joined together by a threaded coupling.

When the control rod is pushed downward toward the position shown, the blade-positioning pin on the control rod slides downward in the long, upper slot in the blade, causing the blade to move inward toward the post. When this pin reaches the bottom of the long slot, it pushes the blade downward against the other blade-positioning pin, which is fixed in the sheath of the tool; this downward motion against the fixed pin also pushes the blade toward the post. Edges of the blade are ground to just the size and shape to meet the edges to be deburred at the end of the downward and inward motion. After the tool is thus placed in the operating position, it is turned around the axis of the post to cut off the burr.

Two ball detents hold the control rod in the operating position; the threaded coupling can be used for fine adjustment of the operating position of the blade when the rod is in this lower detent position. The blade is pulled outward from the post by withdrawing the rod upward to a single-detent position.

This work was done by Friedrich Windbiel of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.* *MFS-29392*



Burrs on Three Milled Edges near the bottom of the middle post are removed by a blade rotated around the post in the specially designed tool.

Preloaded Composite-Strut/End-Fitting Joint

This strong, lightweight joint would resist loosening.

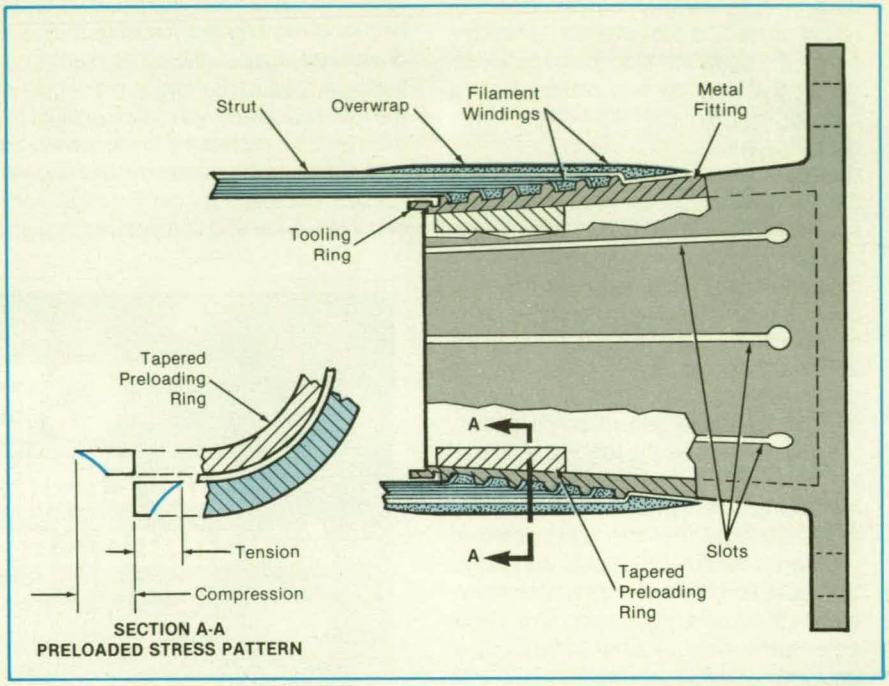
Marshall Space Flight Center, Alabama

A proposed structural joint between a composite (e.g., graphite-fiber/epoxy) strut and a metal end fitting would be strong and light in weight. The joint would be configured to distribute stresses fairly uniformly, with little interlaminar stress. The joint would resist loosening under reversals of loads and changes in temperature.

The joint would be integral with the strut, which is a round composite tube. The metal fitting would be tapered about 6° and would include exterior grooves that would resemble Acme threads except that they would have rounded corners and fillets. The fitting would also have longitudinal slots to allow a small amount of radial deflection for preloading and for relief of thermal stresses (see figure).

The strut and joint would be made simultaneously in a layup process. Starting from the extreme, inner-radius end of the fitting (the left end of the fitting in the figure), the composite tube would be built up in successive layers that would extend into the grooves. Thus, when completed, the joint would transmit loads in almost the same manner as that of a toothed belt and pulley used to transmit power. The joint would be covered by a high-tension-filament overwrap.

The composite material would be cured at 625 °F (329 °C). To provide for a preload and to prevent loosening that would otherwise be caused by differential thermal expansion and contraction between the metal and the composite material, the end of the metal fitting would be compressed before layup by a tooling ring or by part of the mandrel used to form the strut. The tooling ring or mandrel would be coated with a mold-release material so that it would not become bonded during the cure. After the cure, the tooling ring or mandrel would be removed, and the resulting springback of the metal fitting would apply some preload.



The **Composite-Strut/Metal-Fitting Joint** would be built up integrally with the strut in a layup process. The joint would remain tight under reversals of loads and changes in temperature.

The final component of preload would be applied by inserting a tapered ring in the fitting to expand the slotted segments.

This work was done by Dean S. Monitor of Martin Marietta Corp. for **Marshall Space Flight Center**. *For further information, Circle 130 on the TSP Request Card. MFS-28339*

Bonding Elastomers to Metal Substrates

Curing and vulcanization are done simultaneously in specially designed molds.

Langley Research Center, Hampton, Virginia

An improved, economical method for bonding elastomers to metals prevents failures caused by debonding. Previous methods involving prevulcanized elastomers or vulcanization to preheated adhesive surfaces placed additional thermal and physical stresses on the materials and interfaces because of the various heating cycles involved. In the new technique, vulcanization and curing occur simultaneously in a specially designed mold that acts as a form for the desired shape of the elastomer and as a container that positions and supports the metal parts.

The metal substrates are first thoroughly degreased in a suitable solvent using a vapor/liquid/vapor sequence. The bonding surfaces are abraded and cleaned by grit blasting and then again treated with solvent. They are then coated with adhesive and allowed to dry. The metal substrates are assembled in the mold, and the press components are preheated to the curing temperature. The mold is clamped by the press, and the uncured elastomer is loaded into the transfer pot and pressed into the mold sprue. Heat and pressure are applied until the elastomer and adhesive are vulcanized and cured.

This technique increases the interface adhesion between the metal, adhesive, and elastomer because the cure and vulcanization occur simultaneously at equal temperature and pressure. The process eliminates the stresses on the metal substrates, adhesive, and elastomer that would result from separate vulcanization and bond-curing processes.

This work was done by George E. Dickerson of **Langley Research Center** *and Henry L. Kelley of the U.S. Army Aerostructures Directorate located at Langley Research Center. No further documentation is available.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 16]. Refer to LAR-13645.

France: A Leader In Space

Hermes aerodynamic fluxes visualized in hydrodynamic tunnel

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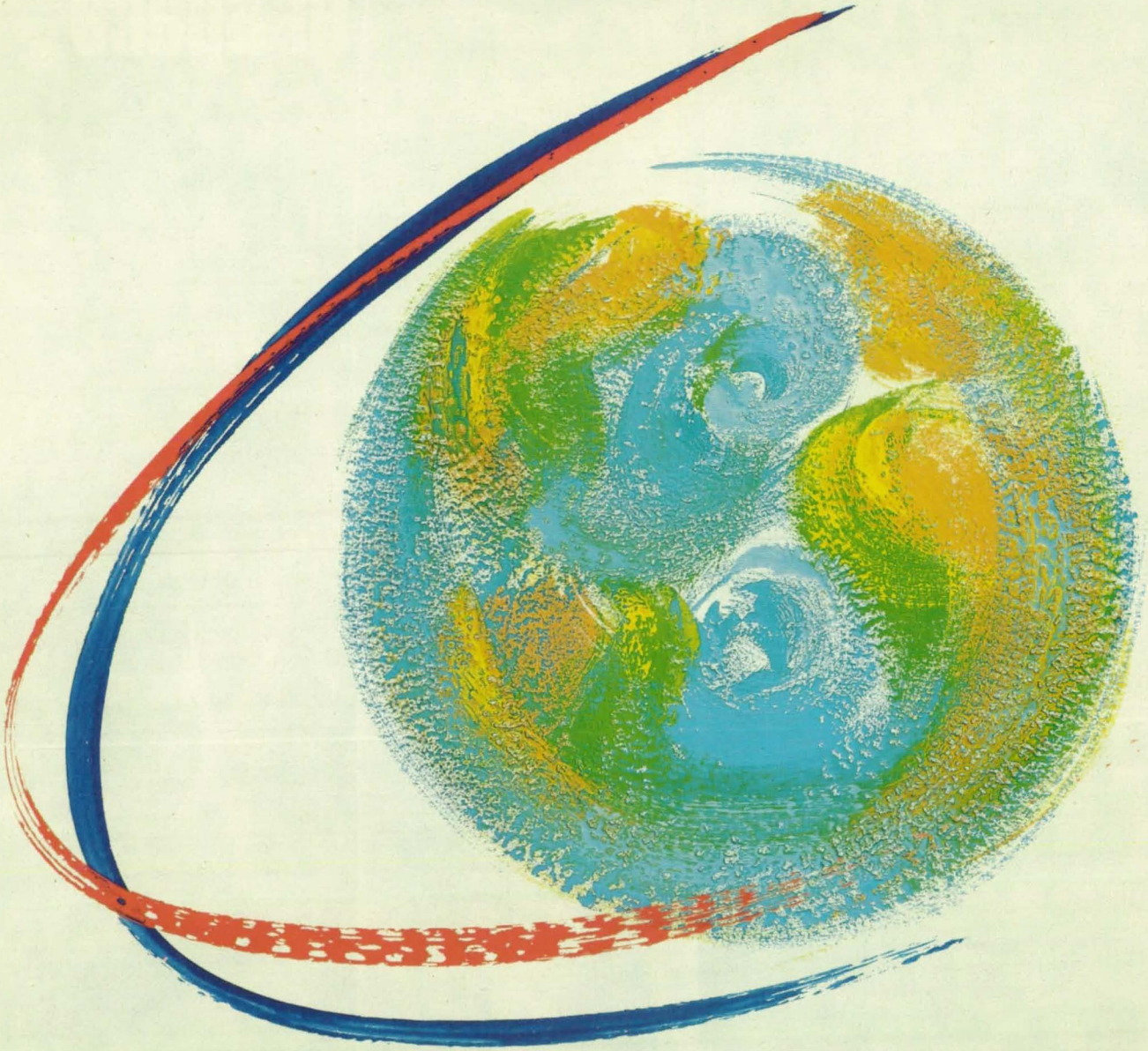
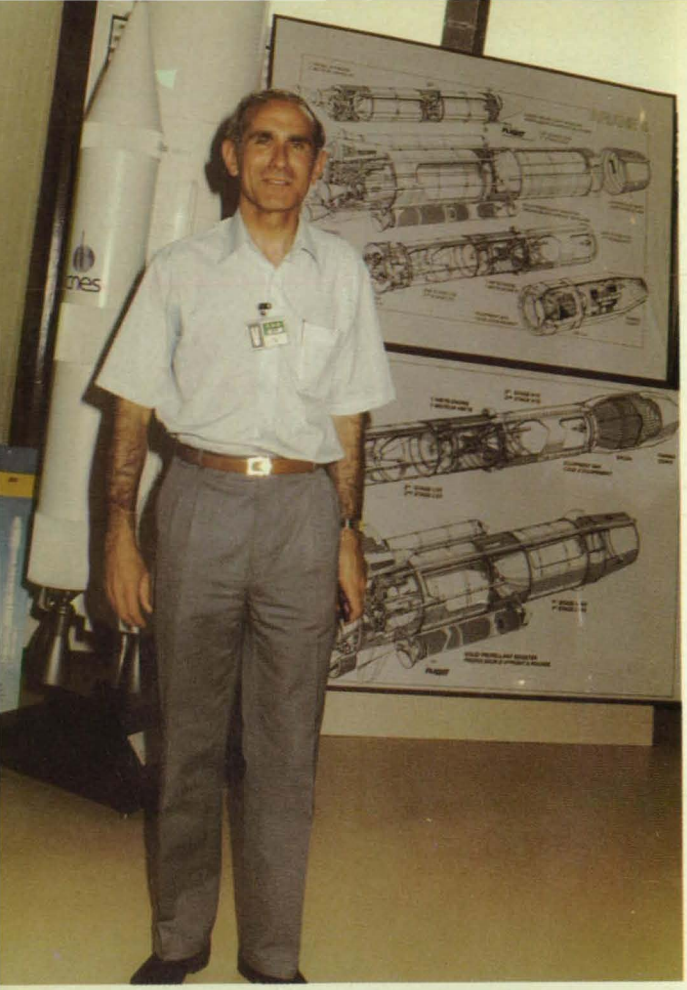




Paul Quiles, Minister for Posts, Telecommunications, and Space

France has been active in space R&D since the early 1960s. In 1965, France placed a satellite in orbit using its own resources. Today France is the number three spacefaring nation, after the United States and the Soviet Union. French efforts are balanced between a strong national program under the leadership of the Centre National d'Etudes Spatiales (French Space Agency) and a leading role in the projects of the European Space Agency.

A characteristic success of the national program is the series of SPOT remote sensing satellites: SPOT 1 has been in operation since 1986; SPOT 2 was placed in orbit early in 1990; SPOT 3 is under construction; and SPOT 4, decided upon in 1989, will ensure continuity of data until the end of the century. Pictures from SPOT, with 10-meter resolution, are marketed by the SPOT Image Company and its U.S. subsidiary, SICorp.

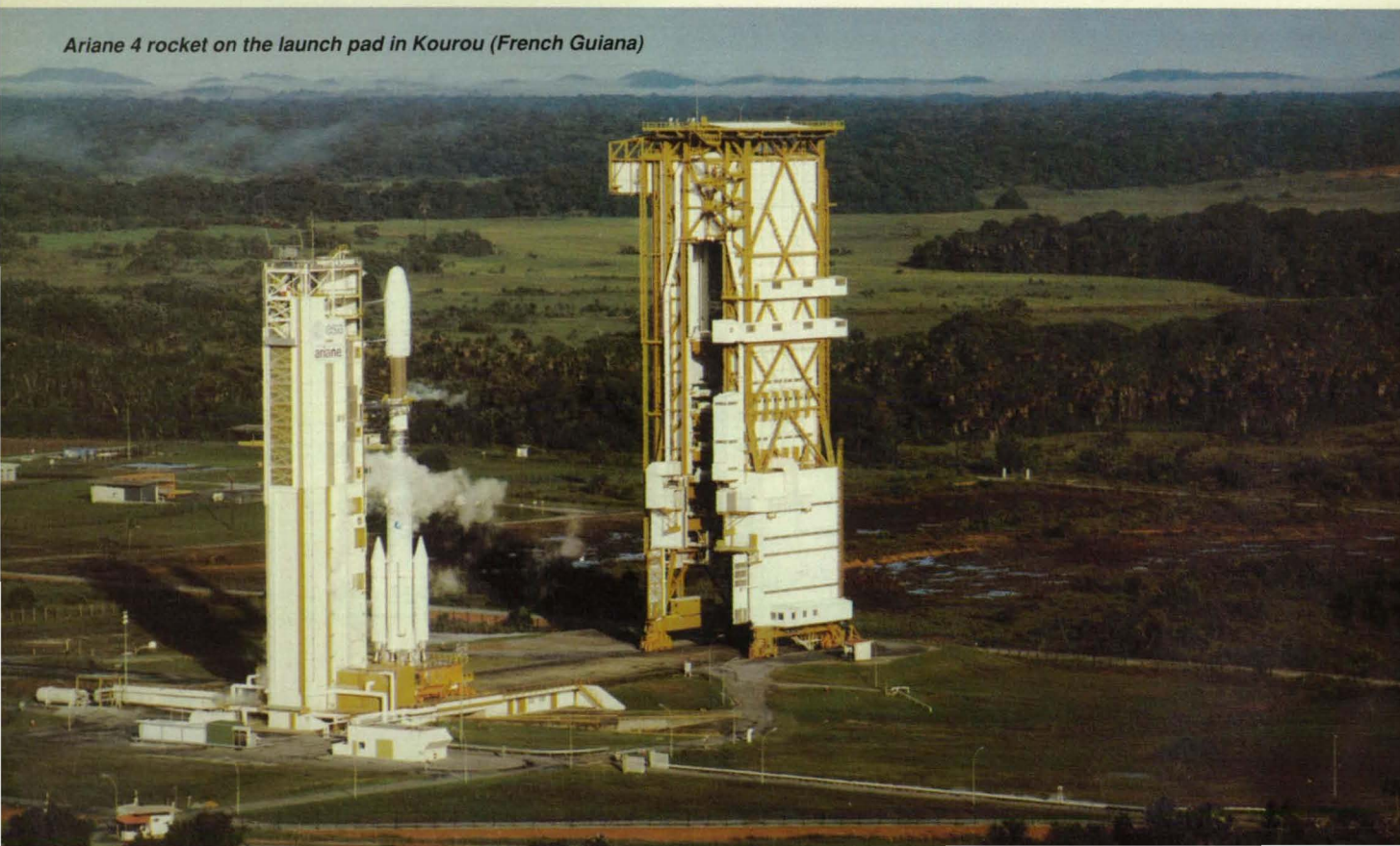
France promoted the European launch vehicle Ariane and made a major contribution to the funding of the European Space Agency program. Arianespace, the company set up to market the launcher, has gained more than half the world market open to commercial competition.

The French space industry is the European leader. Its capabilities and experience range from the production of sensors and complex systems to exercising full responsibility as main contractor for complete satellite and ground equipment systems.

I am sure that beyond current scientific collaboration, illustrated by the Topex-Poseidon project, the tradition of scientific and commercial cooperation between France and the United States will go from strength to strength.

Paul Quiles

Ariane 4 rocket on the launch pad in Kourou (French Guiana)



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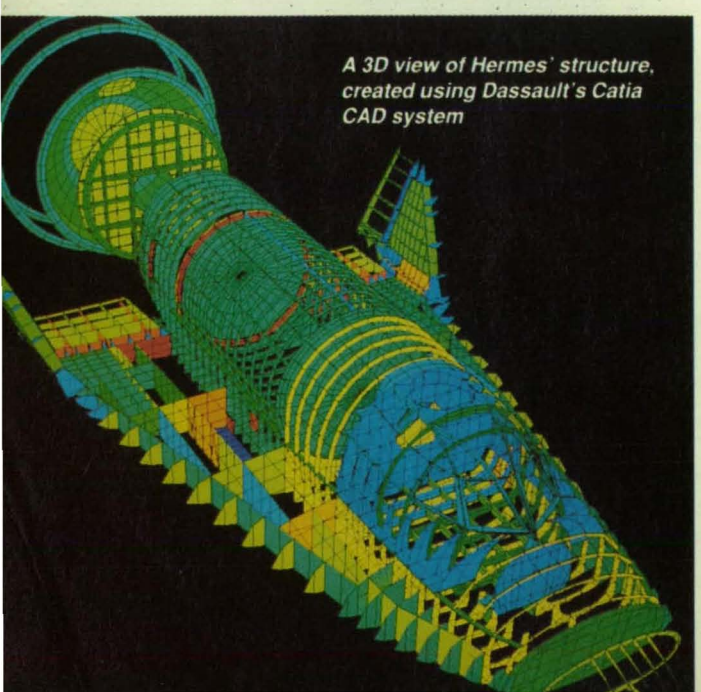
Magnetically-suspended reaction wheel developed by Aerospatiale to pilot the SPOT satellite

France's High Technology In Space

France is the leading space power in Europe. Its space effort began in March 1962 with the creation of a national space agency, the Centre National d'Etudes Spatiales (CNES). France was a founding member of European space organizations such as the ESRO and the ELDO, which were replaced in 1973 by a single cooperative body, the European Space Agency (ESA).

The French are politically, financially, and technically influential at ESA. In addition to being the largest contributor, providing more than a third of the ESA's funds, France has provided valuable proposals, including the ESA's first launch vehicle, Ariane, and now the Ariane 5 heavy-lift launcher and the Hermes manned spaceplane.



A 3D view of Hermes' structure, created using Dassault's Catia CAD system

Together with the Columbus space station initiated and principally sponsored by Germany and Italy, Hermes and Ariane 5 are the largest and most expensive programs under way in Europe. The development of this unprecedented space triad represents a $20 billion investment by the ESA's 13 member states.

Ariane 5 is to replace past Ariane rockets for commercial launches of geostationary and polar satellites. It is also designed to loft into low-Earth orbit the Hermes spaceplane, which will service the European orbital infrastructure, including Columbus. Hermes also will have the capability to visit foreign space stations, including the American Freedom station and the Soviet Mir facility. The hypersonic glider will carry three crew members and three tons of payload into space station orbits at approximately 450 km. Its initial autonomy of seven days could later be expanded to one month.

Hermes and Columbus, while appearing modest compared to U.S. and Soviet capabilities in similar domains, will be extremely important to Europe because they will give it autonomous access to manned space flights. This ambitious goal is within European capabilities, both technically and financially. European aerospace firms, especially those presented in this survey, have the high-tech capabilities needed to meet the challenges of manned space flight. ❑

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A mock-up of Hermes' cockpit. Matra is responsible for Hermes' electronic data management system.

From Satellites And Rockets To The Goa
An Overview Of French Industry's Ac

This year, France will celebrate the 25th anniversary of its first satellite launch. On November 26, 1965, the 41 kg Asterix satellite was launched from Hammaguir in the Sahara desert and put into orbit to test the performance of its pioneering rocket, Diamant.

Since then, France has continually increased its space effort. In 1990, CNES will spend nearly $2 billion for space activities, with the lion's share (40 percent) going to ESA. The French aerospace industry presently employs more than 10,000 people, mainly skilled engineers and technicians. Major French aerospace companies include: Aerospatiale, Matra, Alcatel, Dassault, SEP, SNPE, Arianespace, CLS Argos, SPOT Image, and Novespace. The latter four are among the 15 commercial subsidiaries CNES has founded over the last 20 years.

Reorganizing The Space Industry

Three leading French aerospace companies are prime contractors for satellite systems in the fields of communications, observation, and science. The government-owned Aerospatiale and the privately-led Matra are manufacturing scientific, communications, direct broadcasting, and remote sensing satellites as part of national and international programs. Both have expertise in developing subsystems such as structures, thermal and attitude controls, data processing equipment, on-board computers, and software. They also develop instruments and systems for biomedical and materials processing experiments in the microgravity environment of space.

Alcatel Espace, the only major French company fully dedicated to space activities, is a leading manufacturer of satellite payloads and space-borne equipment for communications and military surveillance systems. The French Ministry of Defense selected Alcatel as prime contractor for the Syracuse military communications satellite system. The contract for Syracuse 2 is worth $700 million.

Aerospatiale and Alcatel are working on an agreement to merge their respective satellite activities into a single unit. The joint venture should be established by the end of 1990. Matra Space recently teamed with Marconi Space Systems to create Matra Marconi Space (MMS). Matra is majority owner and will retain its previous deal with British Aerospace to

jointly develop Eurostar satellite platforms. In a similar arrangement, Aerospatiale is cooperating with MBB of Germany to build Spacebus platforms.

Matra has established alliances with several other European companies, including Crisa (Spain), Spacebel (Belgium), and Intecs (Italy). These joint ventures are part of an effort by aerospace companies to diversify and build market share in order to cope with the unified European market of 1993.

Matra Extends Its Base

Last year, Matra extended its strong European base by gaining control of Fairchild Industries in the United States. The French company bought three divisions of Fairchild—Space, Communication and Electronics, and Control Systems—with a combined staff of 2100 and total sales of $250 million in 1989. The new entity, named the Fairchild Space and Defense Corp. (FSDC), "will remain an autonomous American company," according to Claude Goumy, MMS chairman.

With its European subsidiaries and American acquisition, MMS now represents a space group with 4000 workers, sales approaching $830 million, and orders totalling approximately $1.5 billion. The unit's operating profit is between six and seven percent, according to Goumy. MMS is now ranked third among the world's satellite manufacturers, behind two American giants, Hughes Aircraft and GE Astro Space. Goumy expects MMS to grow 15 percent annually. "The group will employ 5000 workers and achieve $1 billion in sales by 1992," he predicted.

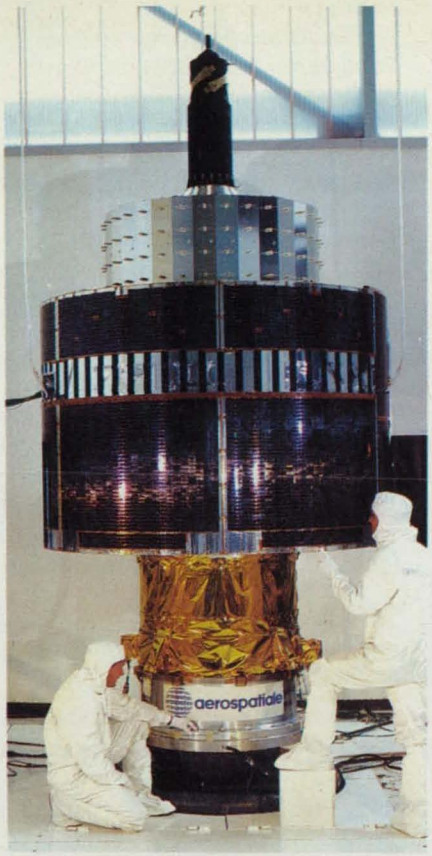
Matra is involved in five areas of space business: communications satellites, observation satellites, scientific satellites and instruments, space-borne avionics, and launcher equipment bays for Ariane. The company is prime contractor for numerous civil and military satellites, including Telecom 2, Hispasat, Locstar, SPOT, Helios, ERS, Hipparcos, and Soho. The Solar and Heliospheric Observatory (Soho), part of the International Solar-Terrestrial Physics Program, will be launched by an American rocket in 1995.

Matra has developed space-borne instruments for Earth observation satellites, including CCD cameras for SPOT and imaging radiometers and infrared sensors for Meteosat satellites. One Meteosat radiometer set a world record by sending more than 400,000 images during its seven-year lifetime.

VSATs (very-small-aperture terminals) also attracted Matra. Through Polycom, a cooperative venture with France Telecom, the company has sold more than 1000 VSATs in 70 countries. These one-way terminals are jointly developed by Matra, Fuba of Germany, and Harris Corp. of the U.S. Matra is now addressing the two-way VSAT market and also wants to enter the direct broadcasting business.

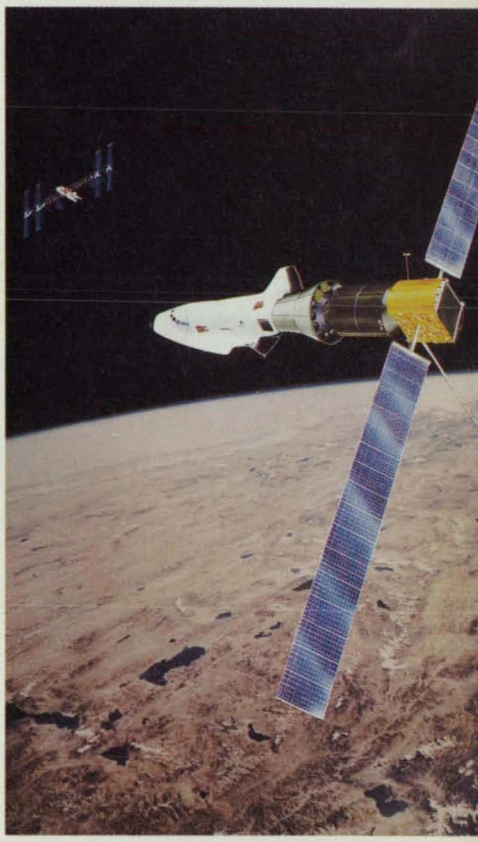
One way Matra hopes to increase its space business is by expanding into the area of satellite services. The French group is a shareholder in service companies such as Arianespace and SPOT Image, and intends to gain a foothold in the mobile communications business by participating in new ventures such as Locstar, the French radio-determination satellite system (RDSS) initiated by CNES.

Locstar will be developed and operated by the privately-owned company Locstar SA, another commercial subsidiary of CNES. The L-band RDSS will be a two-way system designed for mobile use on land, at sea, or in the air. It will use two MMS-built geostationary satellites scheduled for launch by Ariane in 1992. Locstar will compete with other RDSS systems sponsored by international organizations such as Eutelsat and Inmarsat. Eutelsat is presently promoting its Euteltracs system, a European version of the U.S. Omnitracs system. Alcatel Espace recently signed a contract with Qualcomm Inc. to promote and sell Euteltracs mobile receivers in Europe.

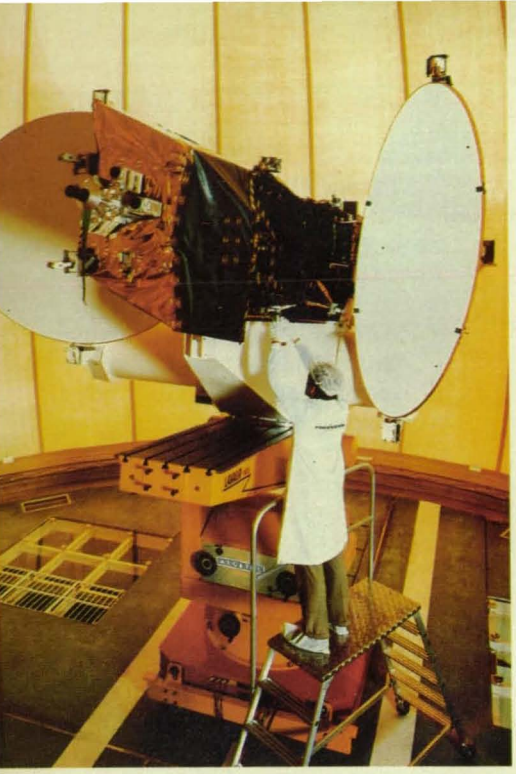


Aerospatiale and Matra built the highly successful series of Meteosat satellites for ESA.

Of Manned Space Flight: Achievements And Challenges



An artist's conception of the Hermes spacecraft docked with the Columbus space station



Alcatel Espace's Electronics In Space

The Alcatel group was restructured earlier this year and two new units were formed: a radio, defense, and space company chaired by Jacques Imbert, and a space division headed by Jean-Claude Husson, who also serves as president of Alcatel Espace.

The French firm is a leading producer of communications satellite payloads and space-borne electronic equipment, including power amplifiers, repeaters, receivers, transmitters, multiplexers, filters, and antennas. It develops satellite antennas for the 2 to 90 GHz range and also produces ground stations. Telspace, an Alcatel subsidiary, has sold more than 2000 Earth stations worldwide

TDF satellite antenna tower tested under radome at Alcatel Espace's Toulouse facility

and is now moving into the VSAT market.

Alcatel Espace has equipped more than 40 national and international satellites. The company developed payloads and equipment for several communications and direct broadcasting satellites, including TDF, TV-SAT, Tele-X, Telecom 2, and Eutelsat 2. It provided telemetry, command, and ranging equipment for scientific satellites such as Giotto and Ulysses, and produced much of the on-board electronics for SPOT, Helios, and other Earth observation satellites.

Alcatel is a member of the international team Ford Aerospace selected to build five new Intelsat 7 communications satellites. Moreover, it received a contract from GE Astro Space to build a transmitter-receiver for NASA's Mars Observer craft, scheduled for launch in 1992. The equipment will relay data collected on Mars' surface by French balloons deployed by the Soviet spacecraft Mars 94.

The first European experiment in inter-satellite link is being developed at Alcatel Espace under a CNES contract. The Ka-band orbital link will be tested between two European satellites: Olympus 1, already in geostationary orbit, and the retrievable carrier Eureca, planned for launch aboard the space shuttle in September 1991.

Under contract to ESA, Alcatel has participated in design studies of Data Relay Satellites slated for launch in 1996. The European DRS will transmit data in the Ka-band at 400 MBits/s.

In summary, Alcatel Espace's know-how covers the technologies of communications satellite systems from 400 MHz to 30 GHz. In cooperation with the Canadian companies Spar and Comdev, the French firm is working on military equipment using even higher frequencies—40-60 GHz (ELF).

Alcatel's expertise extends to microwave instruments and data processing techniques for space-borne synthetic aperture radars (SARs). The company is in charge of the radio frequency calibration subsystem for the Active Microwave Instrument of ERS-1, the first European radar satellite. The radar processing equipment employs surface acoustic wave devices and other innovative technologies

French Boost To Fairchild Space

Fairchild Space is the well-known manufacturer of Explorer satellites and multi-mission modular spacecraft for NASA. One of its top achievements is the Topex oceanography satellite, which will be the first NASA satellite launched by an Ariane rocket. Fairchild also develops deployable masts, louvers, and other electromechanical components for satellites.

The company is highly skilled in electronics. It has, for example, developed a solid-state mass memory called N-Chip which is based on three-dimensional VLSI. This "technological jewel" could replace magnetic tape recorders on satellites within two to three years, according to Mr. Goumy.

Fairchild recently was awarded two classified contracts from the Department of Defense and has been selected along with another American firm for definition studies of the new scientific satellite Gravity Probe B. Fairchild is also competing for the Orbital Solar Lab and looking for a role in the space station Freedom program.

The company is proud to have been chosen for the on-orbit servicing of the Hubble Space Telescope. Fairchild first demonstrated its capability for repair-in-space in 1984, when it provided the tools and techniques for repairing the Solar Max satellite. To maintain the Space Telescope over its 15-year lifetime, Fairchild has developed over 100 different tools and devices, including a battery-powered screw.

"Fairchild's new goals are to participate in the follow-on Landsat project and in the next generation of weather satellites, Tiros and DMSP, as well as the Mission To Planet Earth program," Goumy said. Matra's input will be crutial to Fairchild's participation in the Earth-survey program. The French company has extensive experience in developing platforms, sensors, and complete systems for Earth observation satellites. It is now constructing a large polar platform called SPOT Mk2 for ESA's Columbus program. Equivalent to the U.S. platform being developed for the EOS program, Matra's platform should be suited for Mission To Planet Earth applications.

"The production of small satellites for civil and military applications is another area where Fairchild could benefit from Matra's know-how," said Goumy. Such spacecraft, weighing only a few hundred kilograms, could be used for scientific experiments, environmental surveys, pollution monitoring, communications links, and a variety of other applications. MMS and Fairchild Space plan to submit a proposal for a worldwide mobile communications system based on a constellation of 24 small satellites in low-Earth orbit. The project will compete with similar ventures such as Orbcomm and Starnet. ❑

developed by AME Space, Alcatel's Norwegian affiliate.

Alcatel Espace is studying designs of C- and S-band imaging radars for future civilian satellites, including the European Polar Platform. CNES awarded Alcatel a contract to build a prototype SAR called Radar 2000 which will feature a resolution of 4 to 20 m with a field of view ranging from 20 to 40 km. The rapid-scanning, phased-array antenna will be fitted with several hundred transmitting-receiving modules using monolithic circuits. Alcatel researchers are also studying a high-resolution space-borne radar for military applications such as the detection of surface ships.

CNES awarded Alcatel Espace $20 million to develop the first French space-borne radar-altimeter, dubbed Poseidon, which will fly with an American SAR on the Topex oceanography satellite to be launched by Ariane in June 1992. From its orbit 1300 km above the Earth, Poseidon will measure ocean altitude with an accuracy of 3 to 4 cm. A prototype of Poseidon is now being tested at CNES. "Its performance seems at least as good as that of the American radar-altimeter," said Mr. Husson.

Matra and Alcatel are jointly developing the Telecom 2 satellite for French civil and military communications.

Aerospatiale: From The Force de Frapp To Satellites And Rockets

Aerospatiale–Strategic and Space Systems Division is tasked with developing satellites and rockets as well as ballistic missiles for the French "Force de Frappe." This year, for the first time, "space is exceeding military business," according to Michel Delaye, the new division head. It represents about 52 percent of the division's total turnover, estimated at $1.3 billion.

Over the past 25 years, Aerospatiale has contributed to the development of 60 satellites and today is prime contractor for approximately 40 percent of all civilian satellites developed in Europe. Its space group served as prime contractor for several recent communications and meteorological satellites, including Meteosat, Arabsat, TDF 1 and 2, Tele-X, and Eutelsat 2. On May 28, Aerospatiale delivered the Eutelsat 2/F1, the first of five new communications satellites ordered by Eutelsat. The satellite is planned for launch this year by Ariane, as are the MOP 2 and TDF 2. TDF 1 and 2 are France's first direct broadcasting satellites; they can relay up to five television programs through powerful beams over France and most of Europe.

Another recent achievement by Aerospatiale's space division is the Infrared Space Observatory (ISO), built for ESA. This sophisticated astronomy satellite is equipped with a 60-cm aperture telescope installed inside a large cryostat cooled by liquid helium. The 2.4-ton observatory is slated for launch by an Ariane 4 in 1993.

Aerospatiale is developing several

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AEROSPATIALE, the European leader of space transport system technology, is going forward once again, to 1995, 1998, 2015 and even beyond.

The Ariane 5 Space Transport System will be launched in 1995. For this new, more powerful rocket, AEROSPATIALE is systems integrator and stage contractor. Ariane 5 will carry satellites and even parts of future European space stations into orbit.

In 1998, Ariane 5 will lift off with Europe's Spaceplane, Hermes, built by an AEROSPATIALE-led team. Hermes is designed to taxi three astronauts and their material to and from space stations.

AEROSPATIALE space infrastructure expertise should keep Europe in the forefront in the year 2015. Designs for post Ariane 5 launchers, transfer and escape vehicles and an independent European station, are already in AEROSPATIALE's computers.

After Diamant and Ariane 1, 2, and 3, we're developing the Ariane 5 Space Transport System for the European Space Agency. We're used to making Europe's dreams come true.

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The Infrared Space Observatory is the largest and most sophisticated scientific satellite built by Aerospatiale.

other French and European satellites, including SPOT, Helios, and ERS-1. For the Helios military reconnaissance satellite, it is providing the structure, solar panels, and thermal control system, as well as the main instrument —an optoelectronic camera that will take high-resolution visible and infrared pictures. The first Helios satellite, weighing about 2 metric tons, is planned for launch into heliosynchronous orbit by Ariane in mid-1993.

Aerospatiale is the European leader in space transportation systems, including Ariane rockets and the Hermes spaceplane. It manufactures propellant tanks for the liquid-fueled Ariane rockets. The company integrates the first and third stages of the launchers at a facility in Les Mureaux, near Paris. New facilities were built to integrate the Ariane 5's cryogenic first stage, which is 5.4 m in diameter and 30 m tall. When fully assembled, it will be ferried by a barge to Le Havre, where it will be shipped to Kourou.

Aerospatiale's space and aircraft divisions are working in tandem to develop the Hermes spaceplane. "It's a challenging program that requires major breakthroughs in several advanced space technologies," said Delaye. "But it will pave the way for the development of piloted space systems and hypersonic reentry vehicles by European industry, who will then be better prepared to address the design of future shuttles."

The company is also studying servicing vehicles for the European in-orbit infrastructure. This includes a transfer orbital stage and a crew rescue capsule. Supported by its experience with ballistic reentry bodies and Hermes, Aerospatiale has signed an agreement to assist the Lockheed Missiles and Space Company in responding to NASA's request for the Assured Crew Return Vehicle (ACRV).

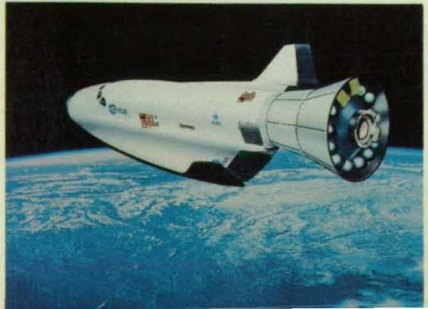
Delaye's team is conducting preliminary concept and design studies of a follow-on to Ariane 5. This is part of the company's internal work on future reusable space vehicles. According to Delaye, Aerospatiale favors a two-stage, rocket-type vehicle that would lift off vertically and land horizontally on a runway.

Aerospatiale's space, aircraft, and tactical divisions are participating in an assessment study of hypersonic vehicles sponsored by the French Ministry for Research and Technology.

Aerospatiale assembles the first and third stages of the Ariane 4 at its integration and testing facility in Les Mureaux, near Paris.

The aircraft division developed the Concorde and is now cooperating with British Aerospace on preliminary studies of a next-generation supersonic transport, while the tactical division developed the world's only operational ramjet missile: the ASMP medium-range nuclear missile.

Artist's concept of the Hermes spaceplane in orbit

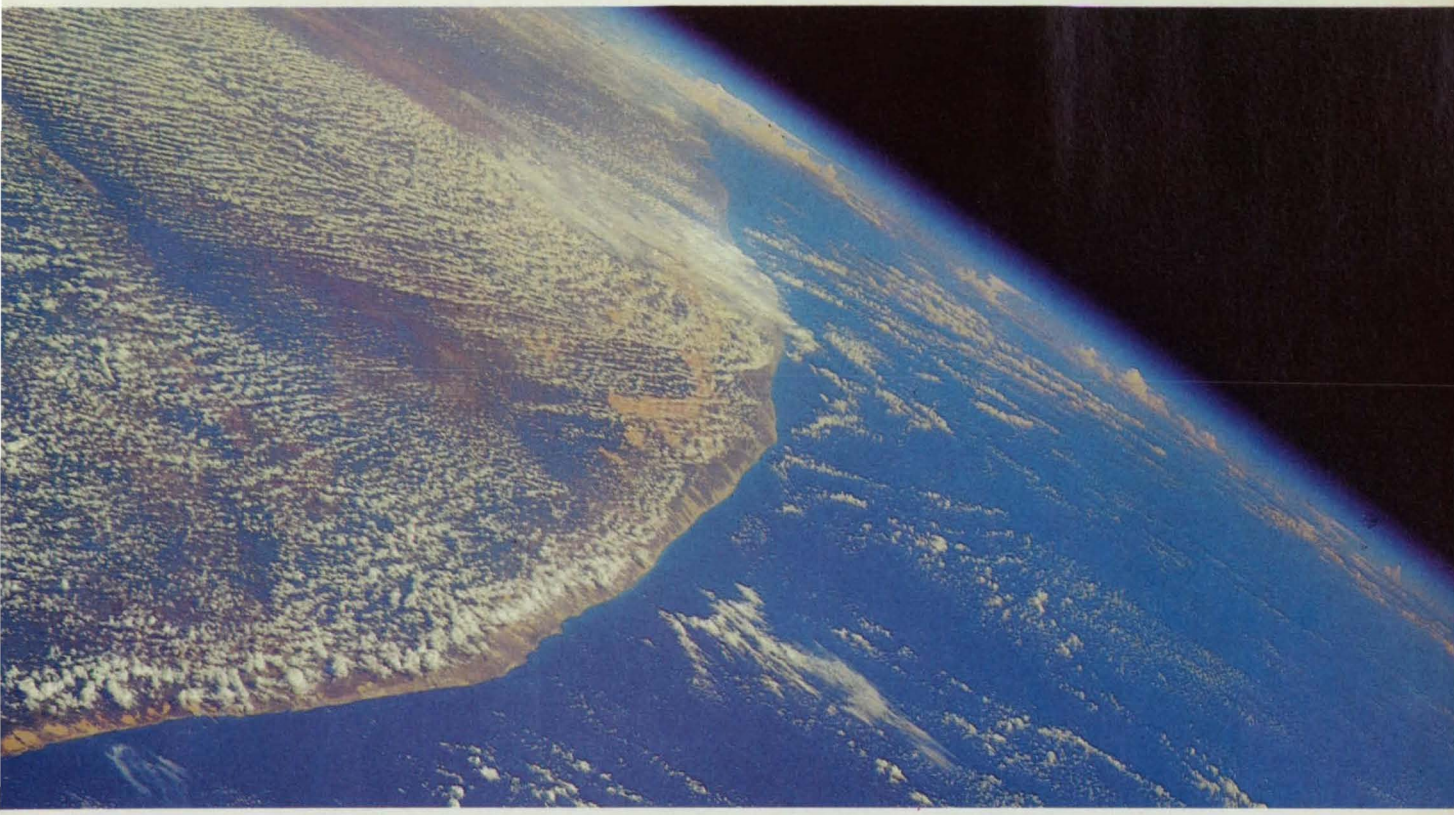


Dassault Goes To Space With Hermes

Dassault, the well-known combat aircraft manufacturer, became a major player in the space industry five years ago when it was named delegated prime contractor for the Hermes spaceplane. Dassault's space activities began in 1962 with the development of the MD 620 ballistic missile and concept studies of a hypersonic vehicle called TAS. In 1972, under contract to Boeing and Grumman, the company designed, developed, and tested a candidate thermal protection system for the space shuttle.

The Hermes project marks Dassault's reentry into the space business after more than a decade of absence. The company is responsible for Hermes' aerodynamic design, reentry trajectories and related systems, atmospheric flight control systems, and subsonic flight tests. These tasks are extremely challenging because of Hermes' small size and mass, explained Jean Roubertie, Dassault's director of space programs. The spaceplane will weigh between 21-23 metric tons and be designed for an extended flight envelope ranging from 160 to 16,000 knots and atmospheric reentry from Mach 29. External temperatures will vary from -101° to +1816°C.

Hermes' aluminum structure will require thermal protection systems that can support the effect of oxidation during 30 successive reentries. "Hot" fuselage parts such as the nose, winglets, leading edges, and control surfaces will be made of carbon and ceramic composite integral structures developed by Aerospatiale and SEP. "Cold" surfaces will be covered by



Settling in.

Traveling at 23,000 miles per hour, Europe's manned orbiter Hermes will quickly leave the coast of Somalia in its wake. And head into the sixteenth sunset of the day.

Just over the horizon, a rendezvous awaits. The Columbus Attached Module, an inhabited scientific platform moored to America's Space Station, prepares for a link-up. Hovering at a safe distance— Columbus Free Flyer, an automated plant for medical and crystal research. And tracking along a heliosynchronous orbit six degrees due west is the Columbus Polar Platform, a complex remote-sensing satellite dedicated to the study of our planet's ice-caps.

In less than a decade, Europe's ambitious agenda in space is scheduled to become a reality. Alcatel Espace looks forward to working with the European Space Agency, and partners like NASA and CNES, to make the process of settling in a little easier.

Our contribution? Earth-to-orbit transmission links. An orbital computer-driven video master station. Keyboard and display sets for the Columbus workstation. And the kind of innovative scientific and telecommunications payload packages for which Alcatel Espace has forged an international reputation over twenty-five years, and across more than fifty multi-venture spacecraft programs.

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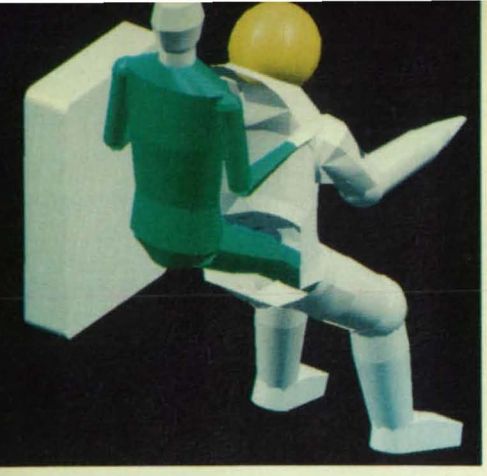


Dassault is developing EVA suits for future Hermes astronauts. This CAD simulation shows an astronaut climbing into an EVA suit after opening the backpack containing the life support system.

ceramic tiles or lightweight multilayered insulation comprised of glass or quartz fibers.

Flight control of the hypersonic glider will be achieved through configuration controlled vehicle (CCV) techniques developed for the Rafale. For atmospheric test flights at subsonic speeds, Hermes will be dropped from an aircraft carrier such as Airbus. Dassault has also proposed using a modified Falcon jet for testing and qualifying approach and landing procedures one year before the first orbital flight, now planned for 1998.

Dassault is also involved in technology development for astronaut extra- and intra-vehicular activity (EVA/IVA). More than 30 European firms are developing EVA/IVA suits and life support systems under contract to Dassault and Dornier of Germany. The IVA system includes ejection seats for Hermes' three crew members. Dassault is considering using ejector seats similar to those developed for the Soviet shuttle Buran. They would enable safe ejection at speeds up to Mach 3.

In addition to Hermes, Dassault is investigating reusable hypersonic space transportation systems as part of the Star-H study funded by CNES. Star-H is derived from Dassault's TAS research. The new design employs a large hypersonic plane to launch a small spaceplane propelled by a jettisonable booster. This element is the only nonrecoverable part of the 400-ton vehicle, scaled to carry a Hermes-type spaceplane in low-Earth orbit with a payload of approximately 3 tons. The Star-H program aims to build a realistic data base on aerothermodynamics, airframe-engine integration, stage separation, structures, and materials. Further, it looks to define aerodynamic codes, structural loads, and other parametric laws which could be used in designing manned hypersonic vehicles for space or transatmospheric missions.

Dassault is also conducting studies of planetary reentry systems in cooperation with Marconi of the United Kingdom, Dornier, and SEP. The studies involve various types of aeroshells designed to protect entry probes dropped on outer planets or bodies such as comets.

Now in the beginning stages, space activities will account for a modest three percent of Dassault's turnover in 1990. The company hopes to raise that figure to ten percent.

SEP, The Motor Specialist

SEP (Societe Europeenne de Propulsion) is the only company in Europe and one of the few in the world with the capability to produce both liquid and solid rocket engines of various sizes for civil and military applications. Its production ranges from small tactical missiles to large stages for ballistic missiles and space boosters, and includes conventional and cryogenic liquid engines for space vehicles. The company has 4000 workers and an annual turnover of approximately $800 million, according to SEP chairman Jean Sollier, who compares the firm's size to that of Thiokol in the U.S.

SEP's main business is liquid rocket engines for the Ariane family of launchers. The company will produce several hundred Viking and HM7 engines for Ariane 4 rockets. Each Ariane 4 uses nine Vikings on the first and second stages and one HM7 on the third stage. The Viking is a storable liquid propellant engine which delivers an average thrust exceeding 700 kN. The HM7 is the first operational cryogenic engine in Europe. The turbopump-fed engine burns a mixture of liquid oxygen and hydrogen with a rated thrust of more than 60 kN and a chamber pressure of 31-36 bars.

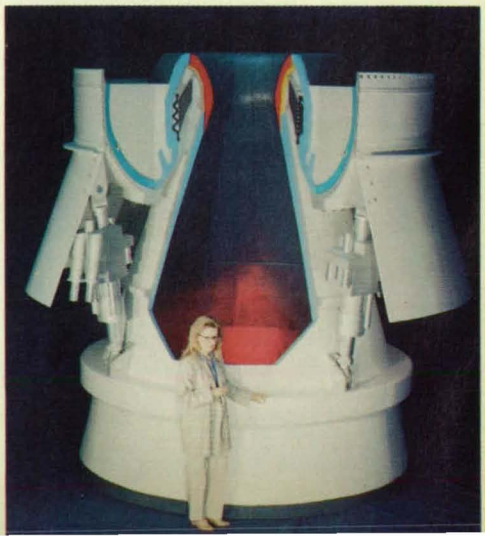
SEP is prime contractor for the Vulcain cryogenic engine that will propel the Ariane 5's first stage. An open-cycle turbopump engine, the Vulcain works under a chamber pressure of 100 bars to deliver approximately 110 tons of thrust. It burns about 24 tons of hydrogen and 128 tons of oxygen in 560 s with a specific impulse of 430 s. SEP received a contract worth more than $260 million to develop the Vulcain. The first engine, delivered in April, will be fired this summer at the SEP test bed in Vernon, near Paris.

SEP has teamed with the Italian firm BPD to develop and manufacture the Ariane 5's huge solid boosters. The joint venture, called Europropulsion, received a $670 million contract. Ariane 5 will use two solid boosters to lift the rocket during the first two minutes of flight. Each booster weighs about 260 tons, including 230 tons of composite propellant, and has a nominal thrust of 600 tons. The boosters are 26 m long, 3.1 m in diameter, and have three segments, including two weighing more than 100 tons. They are produced on the launch site in Guiana.

The French firm is now developing advanced rocket engines for future applications on launch vehicles. Last year, it successfully tested an HM7 cryogenic engine equipped with a ceramic nozzle made of a carbon-silicon carbide material called Sepcarbinox. The engine was test-fired for 750 s and 900 s and sustained operating temperatures up to 1800°C. The ceramic nozzle is 1 m in length and diameter and weighs only 25 kg. SEP research shows that a cryogenic engine fitted with this type of non-deployable nozzle can increase payload mass by 65 kg on Ariane 4 and 1650 kg on Ariane 5.

SEP is also conducting research on low-thrust liquid engines under contract to DGE. It has tested the major components of a 20 N engine designed for attitude control of satellites and the Hermes spacecraft. During preliminary ground tests, the injector and thrust chamber have been fired for one hour at 1600°C. Previously, the company developed MMH-N_2O_4 engines for attitude control of TDF and TV-SAT

Full-scale mock-up of the Ariane 5 booster (open view)



Ariane : a triumph of teamwork.

From Diamant to Ariane, 30 years of success.

Great successes are always group successes.
Ariane is a striking example of this.
Everybody involved in the Ariane programme can now rejoice in its success.
The SNPE team has played a role in space conquest ever since the first Diamant rockets were launched.

SNPE :

- produces in its Toulouse plant UDMH liquid fuel
- provides (through its subsidiary PYROMECA) various pyrotechnical devices, mainly flexible linear shaped charges and transfer lines
- develops in cooperation with BPD Difesa e Spazio solid propellant grains for ARIANE strap-on boosters

Through a common subsidiary REGULUS, SNPE and BPD will operate a dedicated solid propellant plant in Kourou, French Guiana, which is currently being built under the responsibility of SNPE INGENIERIE.

SNPE
DEFENSE ESPACE
mastering energy.

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direct broadcasting satellites. It also built the Mage Apogee boost motor for satellite transfer into geostationary orbit.

SEP has established technological and commercial links with some prominent U.S. aerospace firms. Five years ago it signed a long-term agreement with Rocketdyne to work on liquid propulsion concepts for future launchers. It has sold licenses for its advanced composite materials to three American companies: Corning Glass, for development of a carbon-carbon product for human prothesis; Dupont de Nemours, for a ceramic material used in a classified defense program; and B.F. Goodrich, for carbon-carbon disks applied to aircraft brakes.

Earlier this year, SEP was chosen to provide the composite rocket engine nozzle for the ERINT experimental missile developed by LTV. Flight tests will begin in 1991.

"The U.S. is a high-priority market for SEP," said Mr. Sollier, who hopes to participate in propulsion research for the National Aerospace Plane and other U.S. aerospace projects. SEP and Snecma recently set up a joint venture called Hyperspace to work on hypersonic propulsion for future atmospheric vehicles.

SNPE: Making Magic Powder For Rockets

SNPE (Societe Nationale des Poudres et Explosifs) is developing and producing solid propellants for civil and defense applications such as tactical and ballistic missiles and space rocket motors. Last year, the company established a defense and space division headed by Pierre Dumas. The division is responsible for half of SNPE's turnover, which amounted to $650 million in 1989. Five years ago, the group established a sales branch in the United States. SNPE Inc., located in New Jersey, is developing the company's full range of chemical products.

SNPE's main customer for space products is CNES. The company started with UDMH (unsymetrical dymethylhydrazine), which has been produced by its chemical division in Toulouse since 1983. Initially, the liquid propellant for Ariane rockets was purchased from China and the Soviet Union. Now, however, Ariane's liquid fuel is produced in France and is purer than the imported versions.

The company is working with BPD of Italy to produce solid propellant for Ariane 5 boosters. They are using Butalane, a composite propellant made of aluminum and ammonium perchlorate. It delivers a specific impulse of 244 s (French standard), which is similar to the performance of the space shuttle's boosters. SNPE recently expanded its ammonium perchlorate manufacturing facility in Toulouse to increase its annual production from 800 tons to 6000 tons, which is half the production capacity of existing U.S. facilities. The Toulouse plant will be activated in July, according to Claude Grosmaire, SNPE's director of space propulsion.

SNPE and BPD have formed a new company called Eupe'a (European Perchlorate Ammonium) to coproduce the chemical agent in Toulouse. The companies previously established a joint venture called Regulus to build and operate a manufacturing plant in Kourou for the two largest segments of the Ariane 5 boosters. The "Usine de Propergol de Guyane" (Guiana propellant plant) will be inaugurated later this year. The highly automated plant will have only 150 workers.

Based on a launch rate of eight rockets per year, production for Ariane 5 will amount to 3800 tons by 1998 and is expected to continue until the year 2015. According to Mr. Dumas, this represents an annual turnover of more than $60 million for Regulus.

SNPE is also investigating new chemical molecules for advanced propellants. One of the most promising is a polyazido-glycidyl known as PAG. An energetic binder is used instead of conventional polybutadiene to achieve better performance in terms of specific impulse. PAG will enable the development of nonpolluting propellants (without ammonium perchlorate) for booster applications.

Arianespace Markets Launchers Worldwide

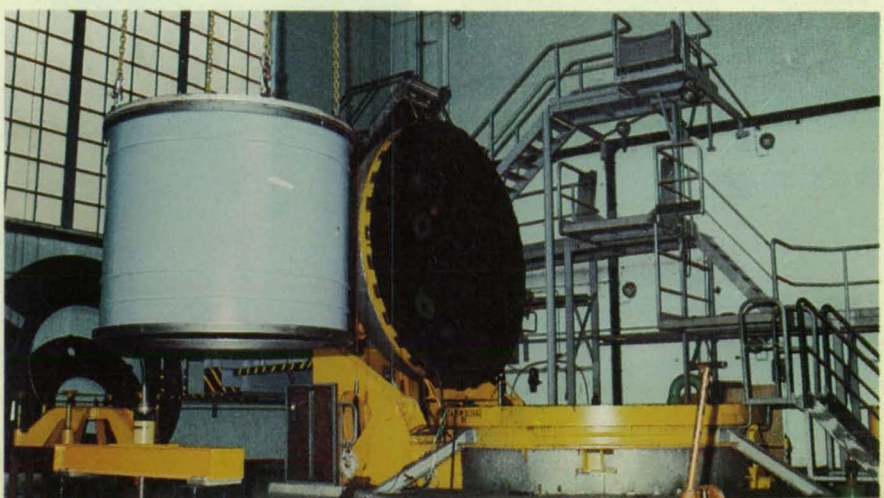
Arianespace is celebrating its tenth anniversary in 1990. The company was founded in March 1980 by 36 leading European manufacturers in the aerospace and electronics sectors together with 13 major European banks and CNES. It was the first private company set up to fund, manufacture, market, and launch large commercial rockets. In 1982, a fully-owned subsidiary, Arianespace Inc., was established in Washington, DC to deal with American customers.

Arianespace has captured more than half of the world market for commercial launches. In addition to nine initial contracts signed by ESA, Arianespace has logged 83 launch contracts with nearly 30 customers worldwide. Six American companies—GE, GTE Spacenet, Alpha-Lyracom, Hughes Communications, GE Astro Space Division, and the Satellite Transponder Leasing Company—as well as two international organizations—Intelsat and Inmarsat—have entrusted their precious communications satellites to the European rocket. Global sales over the past decade exceed $4.7 billion for the 83 satellites booked by Arianespace, of which 54 have been launched. With the signing of nine new contracts since the beginning of the year, the company now has orders for 38 satellite launches, representing $2.8 billion in sales. Last year, the company's total sales were $670 million.

This success is due in part to the pragmatic approach taken by Ariane's promoters, who decided in the early 1970s that the best rocket for commercial operations would be one of conventional design, optimized not to achieve the highest expected performance but rather the lowest possible cost.

The Ariane 1 made its maiden flight in 1979. Since then, Arianespace has successfully flown improved versions,

SNPE's manufacturing plant near Bordeaux prepares solid propellant for Ariane rockets and ballistic missiles.



They share a common language. They have a single culture – space. They belong to Matra Marconi Space, the first international space company. Across national boundaries. Without technological limits. Their goal: to bring higher technology nearer to users.

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including the new Ariane 4, which will be the company's workhorse for the remainder of the decade. The most powerful of the series, Ariane 4 enables single or dual launches of payloads totalling up to 4.4 tons in geostationary transfer orbit.

Among the 36 Ariane rockets flown during the past decade are eight Ariane 4s. The eighth one failed during the last Ariane launch in February (flight V36). Tighter quality controls have been introduced at industrial levels to prevent the reoccurance of such a problem. Launches will resume in late July or early August, according to Frederic d'Allest, Arianespace chairman. To make up for the lost time, nine flights instead of seven or eight are planned for coming years.

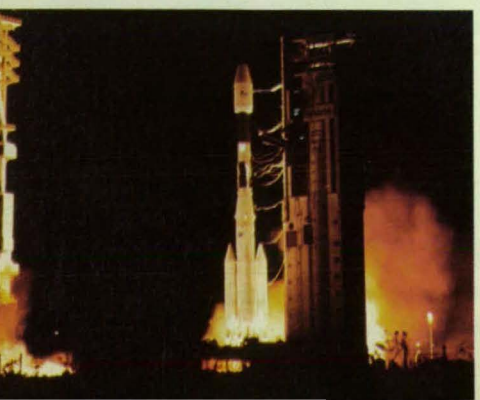
Last year, Arianespace awarded contracts to European industry to produce 50 Ariane 4s—the largest single order for commercial rockets ever issued. While fulfilling this order, the European space industy will also be preparing the follow-on rocket, Ariane 5. First flights of the more powerful rocket are planned for 1995 and it should be operational for commercial satellite launches the following year.

Weighing 740 tons at lift-off, Ariane 5 will have a payload-carrying capacity of 5.9 or 6.8 tons for dual or single launches in geostationary transfer orbit and a maximum of 23 tons in low-Earth orbit when launching the Hermes spaceplane. Arianespace will commercially operate Ariane 5 and is also a candidate to operate Hermes following its test flights in automatic and manned modes, scheduled for 1998-99.

CLS Argos Offers Low-Cost Data Collection System

CLS Argos markets a simple, low-cost data collection system consisting of specialized electronic packages developed by French industry which are installed on board NOAA weather satellites in polar orbit. The system can locate transmitting beacons on the ground or at sea with an accuracy of 300 m. Throughout its orbital track, the satellite automatically receives the platforms in its field of visibility, collects the data, and sends it back to a CLS data processing facility in Toulouse, Melbourne, or Washington, DC. A fourth processing center will soon be opened in Tokyo. CLS headquarters in Toulouse is linked by computer lines to the overseas centers and to its two subsidiaries in the United States: Service Argos Inc., which operates the system for North American users, and North American CLS, which develops value-added products to complement the service.

Night launch of an Ariane 4 rocket



More than 3000 Argos platforms are now in service worldwide. Initially, the system was dedicated to environmental survey applications, but has recently been extended to the field of environmental protection. As part of a U.S. initiative to control fishing campaigns in the Pacific, Argos has been selected to equip more than 700 fishing boats from Japan, Korea, and Taiwan. "The most important use of the Argos system is to protect ocean resources," said Michel Taillade, president of CLS Argos.

Earlier this year, CLS Argos signed an agreement with Eumetsat, the European weather satellite organization, to provide a data collection service on Meteosat spacecraft. This service, dedicated to environmental applications, will begin in October. Next year, CLS will provide the same service using the GOES series of geostationary weather satellites operated by NOAA.

CLS Argos also operates the control center receiving radar-altimetry data from Doris, the French orbitography satellite system, which was introduced on the SPOT 2 satellite launched earlier this year.

"We foresee continued growth in CLS activities for at least five more years," said Michel Cazenave, CLS Argos chairman. The company achieved a turnover of $10.5 million last year and is expected to reach $12 million in 1990. Areas of potential growth include oceanography, meteorology, hydrology, and wild animal tracking. Last year the system was used to track albatross. The birds were equipped with tiny transmitters and released. The satellite tracking revealed that albatross can fly for amazingly long stretches approaching 16,000 km.

An albatross is equipped with a beacon developed by CLS Argos. Satellite tracking has revealed that albatross can fly over 900 km per day.

SPOT Image: Commercializing Remote Sensing Data

SPOT Image sells remote sensing data collected by the SPOT family of observation satellites. Two SPOT satellites are now in orbit, working in parallel to obtain visible and near-infrared images of the Earth. Each spacecraft is equipped with two CCD cameras to capture multispectral and panchromatic pictures at resolutions of 20 and 10 meters. These high-resolution digital images are easily processed and enhanced.

The SPOT 1 satellite, launched in February 1986 with an expected three-year lifetime, has lasted over four years. This fall, it will be replaced by the SPOT 2 satellite launched by Ariane in January. The second craft is a carbon copy of the first, as is the next satellite, SPOT 3, which should be ready for launch by 1992. SPOT 4, an improved version with a four-year design life and an additional midinfrared band, is in the early stages of development. It will repace SPOT 3 when that satellite can no longer function. "We'll

From Rafale to Hermes

The most advanced technologies

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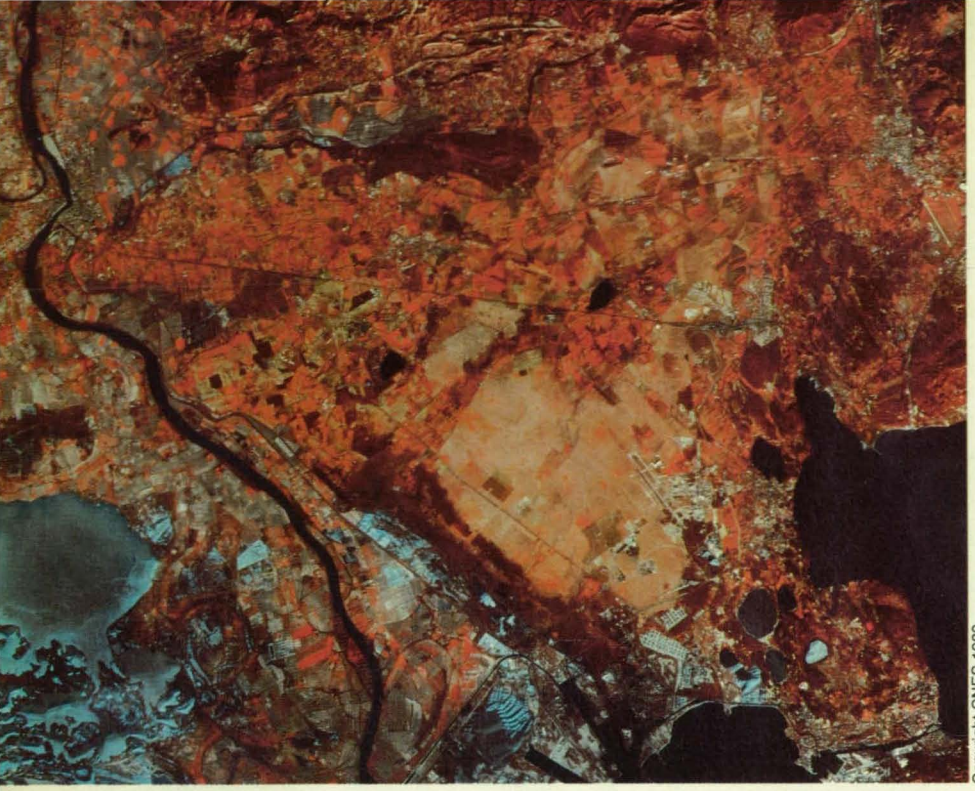


A high-resolution image of the La Crau region of France collected by SPOT from 800 km

be able to provide an uninterrupted flow of data into the next century," said Gerard Brachet, chairman of SPOT Image.

Last year, SPOT Image achieved sales of $23 million and should reach $26 million in 1990. Twenty percent of its market is in the United States, where it has established a fully-owned subsidiary called SICorp. According to Brachet, the company's U.S. sales are expected to increase by 25 percent in 1990. One reason is the $4.7 million contract the Department of Defense recently awarded to SICorp for the delivery of several thousand SPOT scenes, mostly 10 m raw data, by late 1991. The data will be processed by the Defense Mapping Agency and used in preparing the flight missions of USAF Tactical Air Command pilots.

Thirty percent of SICorp's customers are government agencies and the other 70 percent private users and state organizations such as the Florida Department of Planning and the Oregon Department of Water Resources. SPOT data is used in such diverse areas as mapping, petroleum and mineral exploration, crop analysis, hydrology, and hazardous waste monitoring.

SICorp recently introduced a product called Quadmap. It is a "spatiocarte," a map developed from satellite data at the scale of 1/24,000° which is compatible with maps provided by the USGS. SICorp has already received an order for several hundred Quadmaps from the U.S. National Forest Service.

The company's next product will be a "1AP" film for analog data processing machines used by photogrammetry services to exploit stereo images from SPOT. It also plans to introduce a set of spatiocartes at scales of 1/50,000°. With these enhanced products, SPOT Image hopes to lure customers from the aerial photography market. "Our major competitor is not Landsat but aerial photography," Brachet said.

Novespace, A Team Of Skilled Consultants

Novespace is the first private company created to put space technology to profitable use in other economic sectors, and to promote the use of space microgravity by industry. Established four years ago under the impetus of CNES and eight banks, Novespace is directed by Jean-Pierre Fouquet, who previously worked in this line with Aerospatiale, after spending time as scientific attache for space affairs at the French embassy in Washington, DC.

Novespace has assembled a team of highly-skilled consultants that can

Soterem: Pioneering The Microgravity Business

Soterem is a good example of a successful small enterprise in aerospace. The company was started 15 years ago with only ten people and $20,000 capital. Last year, it achieved sales of $6.5 million with a staff of 56.

The company serves as a design, engineering, and manufacturing subcontractor in the automotive, nuclear, and space industries. In addition to space kits, it has developed such innovative products as a programmable electronic gearbox used to synchronize electronic motors, a 2D-vision recognition system, and a water-jet cutting machine that works at high pressures to cut composite sheets for printed circuit boards.

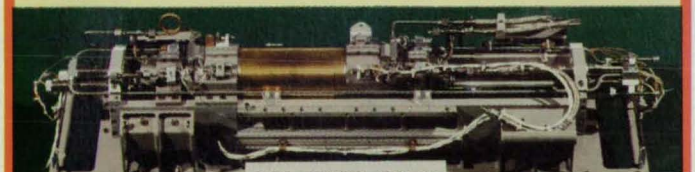
Space activities account for 40 percent of Soterem's business. The company produces satellite integration dollies, solar panel deployment mechanisms, specialized battery chargers, and ground support equipment for French satellites. It also manufactures pedestal structures and servo-positioning mechanisms for ground tracking antennas. Moreover, Soterem has extensive experience in developing sample cartridges and space furnaces for materials processing in zero gravity. Its major achievements in this area include:

- CPF (Crystal Pulling Furnace), a three-zone furnace designed to achieve pulling speeds of 10^{-4} to 10^{-3} cm/sec. up to 1200°C with a thermal gradient of 30°C/cm. CNES will use the furnace to investigate thermo-solutal convection under microgravity conditions.
- AGHF (Advanced Gradient Heating Facility), a Bridgman-type furnace for directional solidification of metals and semiconductors in weightlessness. The AGHF works at temperatures up to 1400°C with a thermal gradient of more than 140°C/cm.
- MZF (Multi-Zone Furnace), used for vapor-phase crystal growth experiments. The facility has three independent isothermal zones heated by sodium fluid circulating in pencil-like heat pipes. Four MZFs will be installed in the MFA (Multi-Furnace Assembly) of Eureca, the European Retrievable Carrier slated for launch aboard the space shuttle in 1991.
- Mephisto, a sophisticated facility for studying materials solidification in zero gravity. It can achieve high thermal gradient up to 500°C/cm and solidification rates from 5.10^{-2} to 5.10^{-5} cm/sec. Soterem built the mechanical and thermal elements of the furnace, designed by CNES and CEA (the French Atomic Energy Agency) as part of a cooperative program with NASA. Mephisto is planned for six flights on the space shuttle with the IML 2.

In 1988, Soterem was selected to develop the Large Primate Facility designed to accommodate two Rhesus monkeys for up to 18 days in space. The facility is to be delivered within two years to fly on the shuttle as part of a CNES-NASA cooperative venture.

The contracts for the primate facility and Mephisto are the largest Soterem has received to date. Each is worth more than $1.7 million. "We now expect to address larger contracts and find other customers abroad," said John Williams, Soterem's project manager for space activities. Target areas include Asia, the Soviet Union, and the United States. ❑

Mephisto is a sophisticated furnace used to study basic solidification processes in materials under microgravity conditions.



solve problems as diverse as finding French partners for interested foreign firms (and vice versa), conducting feasibility or market studies in high-tech fields, or performing product opportunity analyses for microgravity research. This multifaceted approach has proven highly attractive to clients in Europe and Japan.

The company publishes a magazine called *Mutations* that presents innovative technologies available for transfer. It is distributed free of charge to 20,000 readers, including 15,000 in France and 5000 in the rest of Europe, the United States, and Japan. Novespace acts as an intermediary, bringing together technology developers and potential users and following through on the transfers as they evolve toward their final legal, financial, and technical status.

In the microgravity arena, Novespace is again taking a multifaceted approach, ranging from promotion and consulting to actual system operation. To make non-aerospace companies aware of the benefits of experiments conducted in weightlessness, Novespace publishes a bimonthly newsletter in French, *Mutations Microgravite,* which reports on worldwide activities in this field.

Since raising awareness is only the first step, Novespace also proposes case studies and various experimental opportunities, encompassing drop towers, experiments on board the space shuttle and Mir space station, and parabolic flights.

Novespace was named exclusive commercial operator for parabolic flights on a Caravelle aircraft converted by CNES for low-G experimentation. This facility has been used by French, German, and Japanese clients for more than a year. ❐

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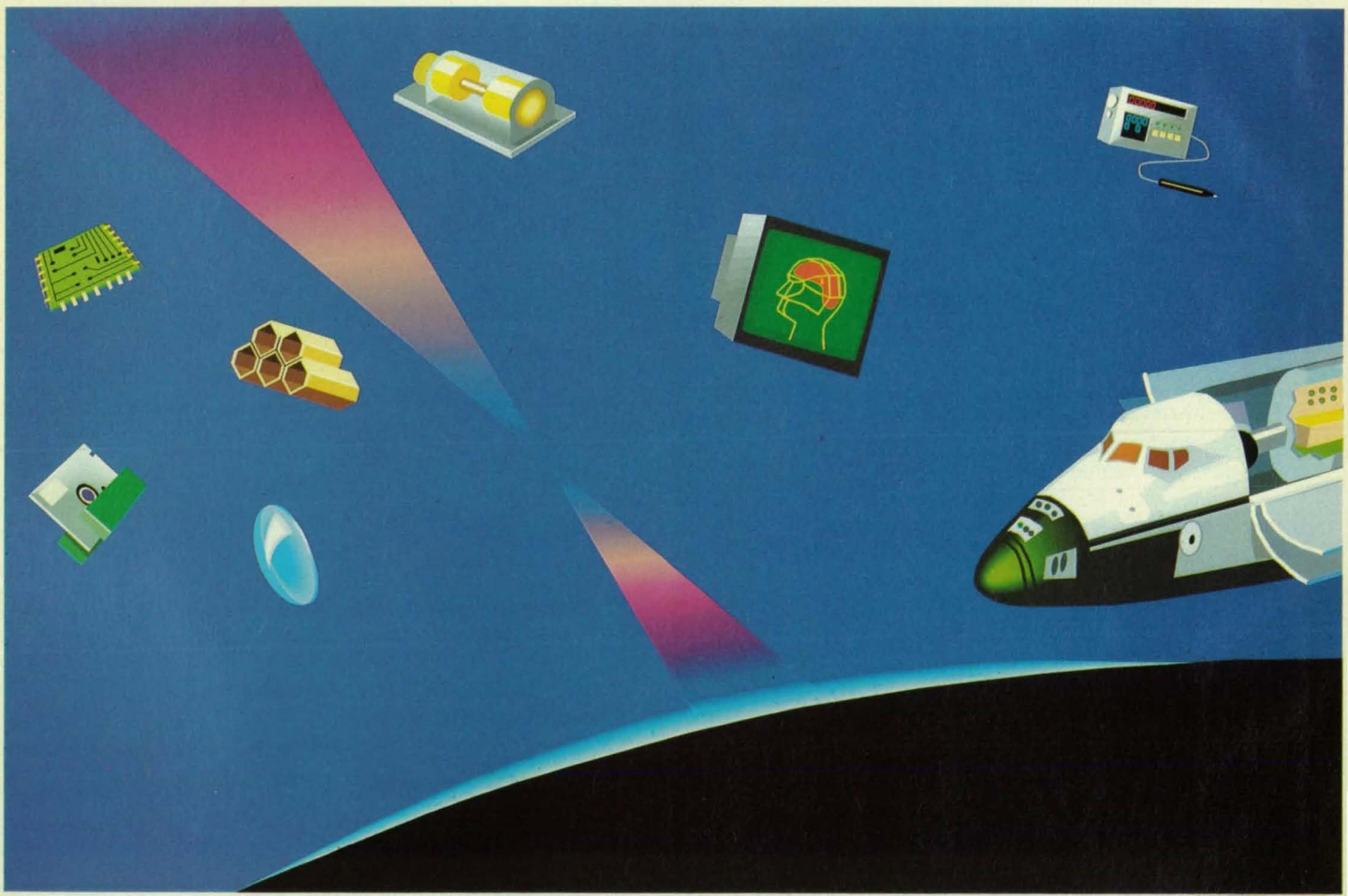

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TECHNICAL CONSULTANT : Novespace - tél. : 011-33-1-42334141 contact : Jean-Pierre FOUQUET

Circle Reader Action No. 351

Mathematics and Information Sciences

Pivotal-Function Assessment of Reliability of Software

Improved estimates of reliability with statistical confidence are obtained when relatively few testing data are available.

Langley Research Center, Hampton, Virginia

At any stage of the software-testing process, it may be desirable to assess the current reliability of the software or predict its future behavior. The usual application of asymptotic results is inadequate for computing these limits, especially when only a small number of bugs (design flaws and coding errors) have been found during the testing process. Consequently, an approach has been developed to establish the utility of pivotal functions for estimation and prediction of the reliability of the software.

With a geometric rate model as a basis, pivotal functions are derived for generating confidence limits for reliability at a specified mission time and for generating prediction limits for the time to the next failure. These confidence and prediction limits provide a means of assessing the quality of a piece of software in ways that account for the number of bugs found and the effects of sampling variation associated with the random order of discovery of bugs.

The process of testing and development consists of inserting a series of randomly selected test cases into the software and correcting bugs as they occur. Interest is focused on the intervals of time between detections of bugs. In general, as more bugs are removed, the interfailure times are expected to increase. Hence, the reliability of the software is expected to increase as the process continues.

Confidence limits for reliability and prediction limits for the time to next failure are derived on the basis of Moranda's geometric deutrophication model. Previous work in this area has emphasized estimation of the parameters of the model by least-squares approximation or maximum-likelihood techniques as employed by Moranda. However, the emphasis here is on the generation of confidence and prediction limits for reliability.

To generate these limits, pivotal functions are constructed, and the percentage points of the distributions of the pivotals are produced by Monte Carlo simulation. Theoretically, asymptotic normality of the estimators could be used to construct asymptotically-distribution-free confidence limits for reliability. However, because of the inadequacy of the asymptotic approximations for small numbers of bugs, confidence and prediction limits based on the limiting distributions would be poor approximations to the true limits. Many of the existing software-testing data consist of relatively small numbers of bugs detected, with more than 50 bugs detected being uncommon. Unless other approaches, such as estimating the percentage points of the pivotal distributions by higher-order approximations of their moments are considered, the use of the simulated pivotal distributions provides the better way of computing the confidence and prediction limits, especially for real data, where the number of bugs discovered is small.

Pivotal functions are effective tools for the determination of confidence limits for the reliability of software and prediction limits for the time to next failure. The method of pivotal functions provides exact confidence and prediction limits regardless of how many bugs have been found in the software. Furthermore, the distributional form of the interfailure times does influence the confidence level of the prediction limits, but the method of pivotal functions appears robust for a special case of Pareto-distributed interfailure times. Because of the sensitivity of the model to the distribution of interfailure times, the use of the Moranda model should be restricted to cases in which interfailure times are exponentially distributed.

This work was done by Kelly J. Hayhurst of **Langley Research Center**. *For further information, Circle 50 on the TSP Request Card.*

LAR-13842

Procedure for Labeling Linear Finite-State Codes

The procedure simplifies the structures of encoders.

NASA's Jet Propulsion Laboratory, Pasadena, California

A method for labeling the state diagrams of linear finite-state codes has been developed. It simplifies the implementation of the encoder hardware. The method can also be used to label a state diagram that is not completely connected to obtain a linear finite-state code that has a larger free distance.

An (n, k, m) finite-state code on a c-connected state diagram is defined as a code that has the following properties:

1. The code has rate k/n.
2. Its operation can be represented by a state diagram with 2^m states.
3. There are $2^q (c \leq m)$ branches going into each state and 2^c branches going out of each state.
4. Each branch of the state diagram is associated with a code (code word length = n and code size = 2^{k-q}), and any two different codes associated with different branches are disjoint.

The problem of finite-state codes is related to the problem of convolutional codes. A typical encoder of an (n_1, c, m) convolutional code consists of a linear sequential circuit (with c shift registers) that accepts c input bits and puts out n_1 bits. The operation of such an encoder can be represented by (1) a state diagram with 2^m states, 2^c branches going into each state, and 2^c branches going out of each state; or (2) a $c \times n_1$ transfer-function matrix $G[D]$, the entries of which are polynomials in D, representing the generator sequences of the code.

To guarantee a noncatastrophic finite-state code with good distance properties, the labeling of the branches of the state diagram must satisfy the following conditions: (1) different labels out of each state; (2) different lables into each state; and (3)

no disjoint paths with identical labels that remain unmerged indefinitely.

The labels of the state diagram of a finite-state code can be assigned by using the linear sequential circuit (with shift registers) of a noncatastropic (n_1, c, m) convolutional code. Let the c shift registers have lengths $l_1, l_2, \ldots l_c$, where $l_1 + l_2, \ldots l_c = m$. The pth row of the corresponding $c \times n_1$ transfer-function matrix thus consists of polynomials in D of degree no greater than l_p for $1 \leqslant p \leqslant c$.

Each branch in the state diagram is assigned the n_1-output-bit sequence $b_0, b_1, \ldots, b_{n_1-1}$ of the shift register. There is assigned, to the branches of the state diagram that are associated with the n_1-bit sequence $b_0, b_1, \ldots, b_{n_1-1}$, the label $i = b_0 + 2b_1 + \ldots + 2^{n-1} b_{n_1-1}$. Each of such labels represents one of the disjoint codes. There are 2^{n_1} of them. This modified state diagram of the convolutional code is used as the state diagram of an (n, k, m) finite-state code on a c-connected state diagram.

A shift-register circuit can be constructed to generate the state diagram of a finite-state code that satisfies conditions 1, 2, and 3. Condition 1 is satisfied if, for a fixed shift-register content, different inputs to the shift registers produce different outputs. This can be achieved if there exists at least one $c \times c$ submatrix $\Omega_j(D)$ of the transfer-function matrix $G(D)$, $i = 1, 2, \ldots, \binom{n_1}{c}$, such that the term "1" appears exactly once in each row and in each column of $\Omega_j(D)$. Similarly, condition 2 is satisfied if, for a fixed input, different shift-register contents produce different outputs. This can be achieved if there exists at least one $c \times c$ submatrix $\Omega_j(D)$ $j = 1, 2, \ldots, \binom{n_1}{c}$ such that the term D^{l_p} representing the last shift-register stage of the pth shift register appears exactly once in row p for $1 \leqslant p \leqslant c$, and each of these $D^{l_1}, D^{l_2}, \ldots, D^{l_c}$ terms appears in different columns of $\Omega_j(D)$. As long as the (n_1, c, m) convolutional code that generates the state diagram of the finite-state code is noncatastrophic, then the labeling also satisfies condition 3.

Even though a finite-state code has a linear convolutional structure, the overall code may not be linear if the cosets are not properly assigned to the outputs of shift registers. To perform a proper assignment, one proceeds as follows:

Let C be the parent (n, k) code. Let S be an (n, k_1) subcode of C. By virtue of a theorem from linear algebra, there exists a subcode W of C (W is an $[n, k - k_1]$ code) such that

$$S + W = C$$
$$S \cap W = \{0\}$$
$$\dim S + \dim W = \dim C$$

The 2^{k-k_1} cosets are constructed by adding each word in W to S. That is,

$$\mathbf{w} + S \quad \forall \quad \mathbf{w} \in W.$$

The set of all binary $k - k_1$-tuples is isomorphic to W. Let $\{\mathbf{w}_0, \mathbf{w}_1, \ldots, \mathbf{w}_{k-k_1-1}\}$ be a basis of W. Let $b_0, b_1, \ldots, b_{k-k_1-1}$ be the $k - k_1$ output bits of the convolutional encoder. Let the coset assigned to the branches labeled by the binary $(k - k_1)$-tuples $b_0, b_1, \ldots, b_{k-k_1-1}$ be denoted by $L(b_0, b_1, \ldots, b_{k-k_1-1})$. Then the assignment

$$L(b_0, b_1, \ldots, b_{k-k_1-1}) = S + \{b_0\mathbf{w}_0 + b_1\mathbf{w}_1 + \ldots + b_{k-k_1-1}\mathbf{w}_{k-k_1-1}\}$$

of cosets to the branches in the state diagram guarantees the linearity of the code.

This work was done by Kar-Ming Cheung of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 79 on the TSP Request Card.*
NPO-17774

Space Information for Educators

Anyone with a personal computer, modem, and telephone line can obtain educational materials from NASA.

Marshall Space Flight Center, Alabama

Access to a collection of NASA information, stored in a computer in Huntsville, Alabama, can be obtained over telephone lines from computers in classrooms and homes. The information is available free of charge. (However, users must pay their own telephone charges.)

The data base offers information on the following topics:

- NASA news — NASA workshops for teachers, news releases, Space Shuttle status reports, recent speeches by NASA managers, television schedules, Space Shuttle manifests, and current Space Shuttle flight activities.
- Research in aeronautics — documents

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*Note: XMODEM is a public-domain file-transfer protocol.

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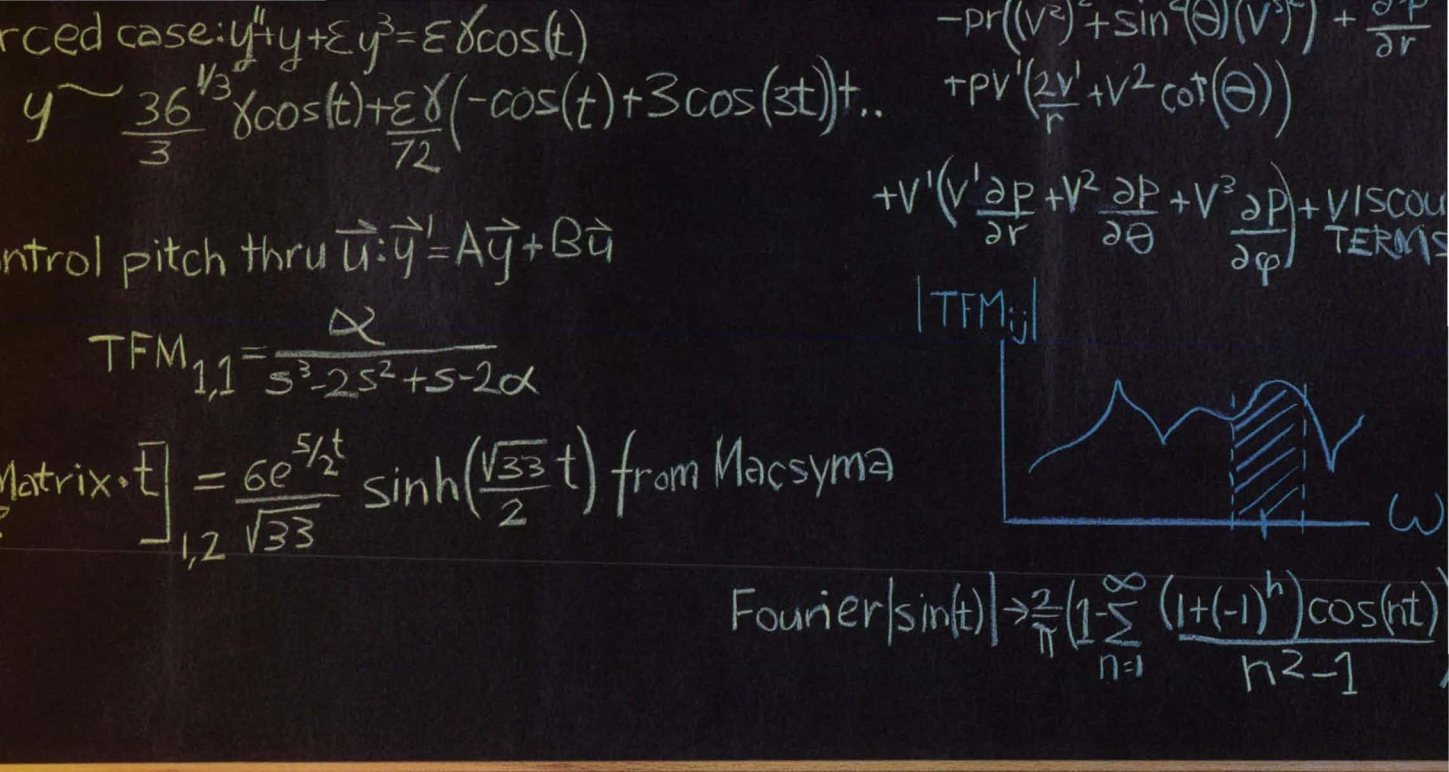

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Circle Reader Action No. 524

on the National Aerospace Plane, aircraft propulsion, wind tunnels, and aircraft design.

- Space exploration before the Space Shuttle — Mercury, Gemini, Apollo, and Skylab programs; planetary probes; and satellites of the 1950's, 1960's, and 1970's.
- Exploration with the Space Shuttle and beyond — spacecraft, payloads, astronauts, planetary probes, space observatories, and satellites.
- NASA and its centers — the responsibilities and resources of research centers.
- NASA educational services — Aerospace Education Services Project, Urban Community Enrichment Program, Summer High School Apprenticeship Research Program, Space Science Student Involvement Project, teacher workshops, educators mailing list, telelectures, teacher resource centers, and science fair support.
- Classroom materials — space science lesson plans and activities, astronomy information, film and video lists, computer programs, career information, computer graphics, and a source list for pictures and posters.
- Space program spinoffs — reports on the ways in which space research benefits industry and the public.

NASA Spacelink has a main memory of 14 megabytes and disk storage space for 708 megabytes. It can communicate with eight callers simultaneously at bit rates of 300, 1,200, or 2,400 baud.

The system is designed to communicate with a variety of computers and modems (see table). Callers can reach it by dialing 205-895-0028. First-time callers will be greeted by an introduction to NASA Spacelink and will be asked for background information so that NASA can mail them information as necessary. They will acquire personal user names and passwords so that they can gain access to the system quickly on future calls.

Easy-to-use menus are presented to callers. For example, a teacher planning a lesson for sixth graders about food for astronauts would choose item 9 on the main menu, Materials for Classroom Use. From subsequent menus, the teacher would select item 2, Living in Space Activities, Grades 1-6, then item 2, Food Lesson Plans, then item 6, Grades 4-6. The last selection would call up a document containing suggested activities for sixth-grade students.

This work was done by Bill Anderson and Dean Martin of **Marshall Space Flight Center** *and Alan Cunningham of Data General Corp. For further information, Circle 75 on the TSP Request Card. MFS-27221*

Probabilistic Determination of Motions of Robots

A heuristic-path-planner method has potential to reduce computing time.

NASA's Jet Propulsion Laboratory, Pasadena, California

A heuristic path-planning algorithm is a subject of continuing research on probabilistic methods for guiding the motions of robots. The probabilistic approach is motivated by the need to reduce the computational burden imposed by the exact approach, in which motion is typically determined by searching a graph of a deterministic representation of free configuration space available to a robot. The exact approach is practical only if the environment is static, if there are few degrees of freedom, if long motion-planning times are acceptable, and if fast computing resources are available.

In the heuristic path-planning algorithm, the probability of successful motion of a robot through a region of space is obtained from a geometric model and captures the effects of objects in the region and the kinematics of the robot arm. This information is used to guide an on-line search and results, in most cases, in the successful determination of a path within a reasonably short time.

The method embodied in the algorithm can be regarded as a search method in which each robot link tries to move along multiple paths in the attempt to move the whole robot arm toward the goal. In a process reminiscent of diffusion, the motion of each link is influenced by a gradient term that attracts the arm to the goal and repels it from the vicinity of any given object (the presence of which could be detected by sensors). The gradient term is associated with a distribution of motion-transition probabilities, which are conditional probabilities determined by obstacles and by the kinematics of the robot arm. Thus, the algorithm can also be regarded as a Monte Carlo approach to the solution of an equation for diffusion.

This work was done by J. Balaram of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 128 on the TSP Request Card.*

NPO-17738

Minimal-Inversion Feedforward-and-Feedback Control System

Three control subsystems can be designed independently of each other.

NASA's Jet Propulsion Laboratory, Pasadena, California

Recent developments in the theory of control systems support the concept of a minimal-inversion feedforward-and-feedback control system consisting of three independently designable control subsystems. The concept is applicable to the control of a linear, time-invariant plant described by the following equations of state:

$$\dot{\mathbf{x}}(t) = A\mathbf{x}(t) + B\mathbf{u}(t);\ \mathbf{x}(0) = 0$$

$$\mathbf{y}(t) = C\mathbf{x}(t) + D\mathbf{u}(t)$$

where $\mathbf{x}$ is the $n \times 1$ state vector, $\mathbf{u}$ is the $m \times 1$ input vector, $\mathbf{y}$ is the $m \times 1$ output vector, and A, B, C, and D are constant matrices of appropriate dimensions. The plant is assumed to be controllable, observable, and cyclic, so that its transfer-function matrix has no pole•zero cancellations.

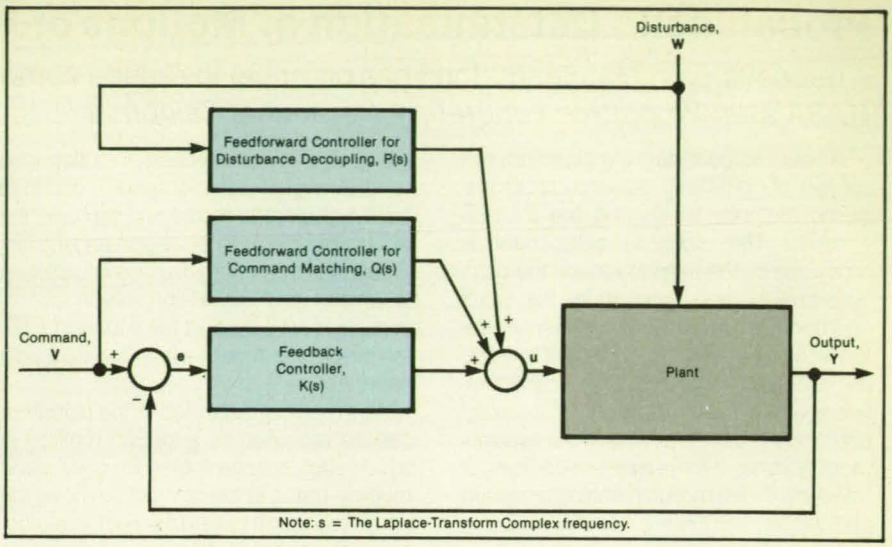
The developments begin with the simplification of the inverse-transfer-function

matrix, followed by construction of a minimal-order-state-space realization of the simplified matrix. The poles of the minimal-order inverse have been shown to be the transmission zeros of the system. As a result, necessary and sufficient conditions for existence and stability of the inverse system can be stated simply in terms of the zero polynomial of the original system.

The related problem of perfect control of the output variables; namely, matching of commands and decoupling of disturbances by means of feedforward controllers, has also been formulated and solved in a transfer-function setting. It has been shown that a necessary and sufficient condition for existence of the required controllers is that the zero polynomial of the transfer function of the plant not be identical to zero or unstable. The required controllers are realized by a parallel combination of a proportional-multiple-derivative term and a dynamic term, where the order of the dynamic term is equal to the number of transmission zeros in the transfer function of the plant.

The resulting conceptual system includes a feedback controller to enhance the stability and robustness of the system, a feedforward controller to ensure matching of commands, and another feedforward controller to decouple disturbances (see figure). This proposed combination of feedback and feedforward controllers has the full advantages of both types of controllers. In other words, the stability and robustness offered by the feedback controller is combined with the output-control capabilities of the feedforward controllers in a single control scheme. An important feature of this control scheme is that each controller performs only its own specific task and has no effect on the features obtained by the other controllers. These separated and yet coordinated controllers can be designed independently based on the open-loop plant and then integrated in the overall control scheme.

One interesting feature of the proposed system is that the feedback controller $K(s)$ is placed entirely in the forward path and acts only on the tracking error **e**. This is different from the classical servomechanism configuration in which the feedback controller is partly in the forward path acting on the position error and partly in the feedback path providing velocity damping. The proposed configuration in which the feedback controller $K(s)$ is collocated has the main advantage that the design of $K(s)$ can be carried out based on the open-loop plant and independently of the feedforward controllers $P(s)$ and $Q(s)$.



The **Proposed Control System** would include three controllers, each of which could be designed independently of the others.

This work was done by Homayoun Seraji of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 1 on the TSP Request Card.*
NPO-17701

Algorithm for "Bang-Bang" Control Laws

Switching times are updated to minimize errors in final positions.

NASA's Jet Propulsion Laboratory, Pasadena, California

An algorithm computes "bang-bang" control laws for single- or multiple-input systems, both those describable by linear dynamical equations and those describable by nonlinear dynamical equations that are linear in the control vectors. The algorithm is needed because analytical solutions of "bang-bang" control problems are intractable for all but the simplest systems.

In "bang-bang" control, the trajectory of a robotic manipulator or other system consists of segments, along each of which the system is accelerated and decelerated with maximal control effort. The problem is to find the switching times t_i ($i = 1$ to N), which are the times when any one element of the control vector $\mathbf{u}(t)$ changes sign.

The algorithm is based on the assumption that an optimal solution exists and that the optimum control law has the "bang-bang" form $|u_i(t)| = M_i$ for all $t \geq 0$, where u_i is the ith component of **u** and M_i is a positive constant. The algorithm finds the solution iteratively, taking the following general approach:

1. Guess the switching times $(t_1, t_2, \ldots, t_N)$.
2. Guess which element in $\mathbf{u}(t)$ switches at each of the $(t_1, t_2, \ldots, t_N)$.
3. Guess the initial control vector, $\mathbf{u}(0)$.
4. Guess the final time, t_{N+1}, which will eventually become t_f^*.
5. Compute

$$\frac{\partial \mathbf{x}(t_f)}{\partial t_i}$$

(where **x** is the state or position vector) to find the change in the final state $\mathbf{x}(t_f)$ due to a change in each of the earlier switching times t_i.

The map from each switching time to the final state is continuous. This enables an update of the switching times based on the gradient of the miss distance (the distance between the actual and desired final states) with respect to the switching times. The idea is to refine the switching times in each iteration to drive the system closer to the desired final state.

If the assumed number of switching times is greater than the optimum, some of the t_i computed by the algorithm may approach each other, thus reducing the effective number of switching times. When the initial guess, $\mathbf{u}(0)$, of the control vector is erroneous, some of the t_i may become negative, thus changing the effective $\mathbf{u}(0)$. These self-correcting features were not anticipated theoretically.

Under some conditions, the solution produced by the algorithm is optimal with respect to time. When the optimal control law is not "bang-bang," the algorithm provides a suboptimal "bang-bang" strategy.

This work was done by John Ting-Yung Wen of Caltech and Alan Desrochers of Rensselaer Polytechnic Institute for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 78 on the TSP Request Card.*
NPO-17603

Perfusion Bioreactor Module

Cell cultures can be grown or maintained under controlled conditions.

Lyndon B. Johnson Space Center, Houston, Texas

The perfusion bioreactor module is a self-contained, closed-loop cell-culture system that can operate in microgravity or on Earth. This equipment can support the growth or long-term maintenance of cultures of human or other fragile cells for experiments in basic cell biology or process technology. The system is designed to support the proliferation (initially at exponential rates of growth) of cells in a complex growth medium and to maintain confluent cells in a defined medium under conditions optimized to permit or encourage selected functions of cells, including the secretion of products of cells into the medium.

The system (see figure) provides continuous measurement and control of the environment of the cells. It continually supplies oxygen and critical nutrients and removes toxic metabolic wastes. The bioreactor is controlled by a dedicated microprocessor-based controller, which is connected to sensors, transducers, relays, and control circuits. The system measures the mass-transport efficiencies and rates of transfer of gases. It can control the mechanical stress imposed by mixing and by devices (e.g., filters) that separate the cells from the medium. It can remove and concentrate samples of the cell-free culture medium for external analysis. It can also be connected to downstream bioseparation modules that can separate protein products directly from the effluent streams of the concentrated culture medium.

The system consists of five subsystems. One is the reaction vessel, which is equipped with a coaxial spin filter and independently-rotated, hydrodynamically contoured, flexible stirring vanes. This stirring-and-filtration subsystem is designed to operate within an optimum range of rotational speeds for uniform mixing, suspension of the cells or particles carrying cells, and minimal shear or collision trauma to the cells. The vanes are rotated slowly for mixing. The filter can be spun slowly to enhance control of the shear to which the cells are exposed or rapidly enough for withdrawal of the medium at a rate of 80 to 100 mL/min.

The medium-circulation loop connects the other subsystems. It includes two blocks of sensors that measure the pH, pCO_2, pO_2, and oxidation/reduction potentials. From the differences between the pO_2 and pCO_2 in the inflow and outflow streams, the microprocessor can calculate the metabolic rates of the cells. Valves add concentrated culture medium or acid or base for control of pH, as needed. The hollow-fiber dialysis subsystem is controlled independently and has its own pump. The bubble trap (mainly for use in microgravity) removes bubbles formed by the dissolution of gas or by inadvertent injection of gas through a leak in the oxygenator.

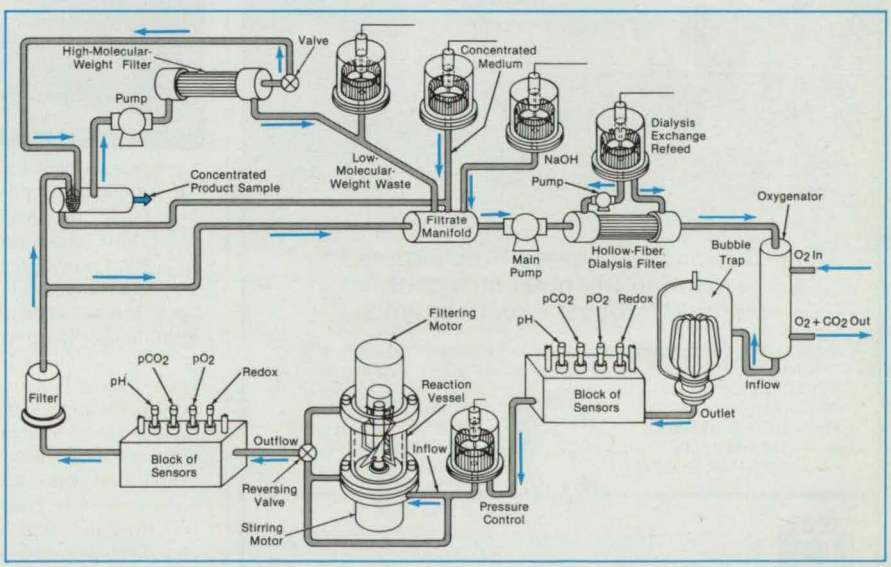
The product-concentration side loop includes a high-molecular-weight filter that removes serum proteins from the growth medium and concentrates samples of the circulating medium for analysis. Connections are provided to send the low-molecular-weight filtrate to a waste reservoir or to return it to the main circulation loop.

The gas-exchange subsystem consists mainly of the oxygenator, which contains a semipermeable membrane or hollow-fiber gas-exchange module. Oxygen is transported through the membrane or fiber to saturate the depleted medium, and carbon dioxide is transported out of the medium. This subsystem operates similarly to a conventional blood oxygenator.

The microprocessor-control subsystem automatically maintains the operation of the bioreactor at the prescribed schedule of operating parameters, records data from the sensors, displays the status of the system, and alerts the technician to conditions that require intervention. This subsystem can be connected with any of a variety of personal computers, which can operate independently to analyze data statistically and to predict adverse trends in operating parameters.

This work was done by Dennis R. Morrison of **Johnson Space Center**. *For further information, Circle 33 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center [see page 16]. Refer to MSC-21361

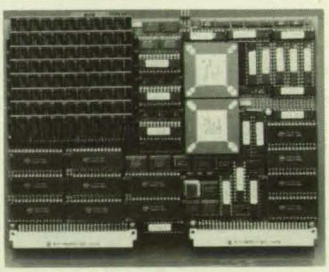


The **Perfusion Bioreactor Module** monitors and maintains a cell culture in a growth or maintenance medium under controlled conditions.

New on the Market

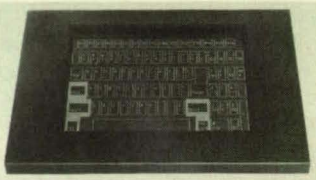
The MicroView **Scanning Tunneling Microscope** from EG&G Princeton Applied Research Corp., Princeton, NJ, can resolve atomic level images as an electrochemical reaction occurs. Using the quantum-mechanical phenomenon of "tunneling," in which electrons appear to bore through barriers such as air or a vacuum, the MicroView electrochemically stimulates a sample in-situ and measures the resulting reaction while a real-time graphic image of the reaction site is displayed on a video monitor.
Circle Reader Action Number 790.

Using liquid crystal lenses and a unique infrared technique, the CrystalEyes™ stereo **3D computer graphics peripheral** from StereoGraphics Corp., San Rafael, CA, emulates human vision to produce a vivid, flicker-free 3D depth effect. The field-sequential, electro-stereoscopic system consists of eyewear and an infrared emitter, for use with a stereoscopic monitor and 60/120 Hz workstation.
Circle Reader Action Number 798.



Designed for digital signal processing and imaging applications, the MSP-6C30 high-speed, floating-point **VME array processor** from Analogic Corp.'s Computer Design and Applications (CDA) Div., Peabody, MA, uses single or dual Texas Instruments TMS320C30 processors in an architecture that provides up to 66 MFLOPS of processing power. The processors can operate separately or in combination on computationally-intensive tasks. When used with CDA's SMB-6E screen memory board, the MSP-6C30 functions as a combined array and pixel processor that supports high-speed cines and zoom operations for dynamic imaging applications.
Circle Reader Action Number 794.

Controlyne's TIGERTEC PDTK/1, a flat-panel, **plasma-lit AT keyboard** for data entry, replaces standard keyboards in low visibility light or darkness. The neon-orange-colored keyboard responds to touch via an infrared beam which scans the surface and converts the touched key to physical coordinates. The coordinates are transferred to the computer in ASCII form through the serial port.
Circle Reader Action Number 800.



A portable **fiber optic microscope** from Photovolt, Indianapolis, IN, provides wide-range magnification for aircraft maintenance, automotive, biotechnology, plant maintenance, semiconductor, and other applications. Dubbed the Microwatcher VS-20s, the microscope features CRT monitor, videotape recorder, and video printer interfacing capabilities. An optional carrier can simplify on-site inspections while recording the inspection for later review.
Circle Reader Action Number 792.

Designed for small potting applications, the Epoxer **dispenser** from Chem-Mixx Technology, Medford, MA, provides convenient handling of one-component epoxy adhesives, potting compounds, and other catalyzed long-pot-life materials. The portable device features a reusable cartridge, control tube, and dispense tip and is available with cartridge capacities of 20 or 200 cc.
Circle Reader Action Number 796.

New on the Market

Ideal for applications where heat or fire is a concern, AZ-Fire Flex **noise absorption panels** from Azonic Inc., Burnsville, MN, offer a flame-spread rating of 4.66, a smoke density rating of 24.66, and are available in a variety of thicknesses. Azonic products fabricated with the new AZ-Fire Flex material include ceiling tiles and hanging baffles.
Circle Reader Action Number 782.

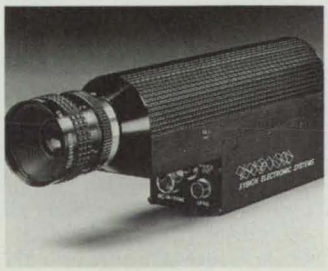
The SuperView **"direct" projector** developed by the Plus Corp. of America, Allendale, NJ, projects three-dimensional objects, transparencies, and reflective art onto any screen surface, eliminating the need to switch back and forth between overhead and opaque projectors. Projections are in full color and with complete detail of depth, shade, and scale. The portable projector features a power zoom lens for on-screen magnification of small materials or objects.
Circle Reader Action Number 788.

Only 0.12 mm thick, Sanyo Electric's new Amorton™ **solar cell film** can be shaped to conform to three-dimensional surfaces that normally would not accommodate single or polycrystal cells, or glass/stainless steel substrate flat-panel cells. The film's light weight yields a power-to-weight ratio of 200 milliwatts per gram, ten times that of conventional glass cells. The Amorton film will be demonstrated in early July, when it will be used to power the experimental Sunseeker aircraft during its flight across the U.S.
Circle Reader Action Number 786.

The LEEPvideo System I **artificial reality/telepresence system** uses two synchronized, image-compressed RS-170 signals to provide aural and visual presence with the widest field of view available in a head-mounted display, according to the manufacturer, Pop-Optix Labs, Waltham, MA. The monochromatic, LCD-based system comes with an instrumented puppet head that can be handheld or mounted on servo-driven platforms, remote vehicles, or robots. Its "eyes" have a field of view similar to that of human eyes and its "ears" provide true binaural spatial sound.
Circle Reader Action Number 778.

With a footprint of less than 3.2 square inches, Interpoint's new subminiature HR300, 30-watt **DC-DC converter** uses less than 1/3 the board area of standard commercial converters. Its power density rating is 20 watts per cubic inch. Each HR300 part is hermetically sealed in metal for EMI/RFI shielding and maximum resistance to moisture and corrosion.
Circle Reader Action Number 784.

A compact, low-profile **CCD camera** for microscopy, radiology, nondestructive testing, surveillance, and other low-light-level TV applications has been introduced by Xybion Electronic Systems, San Diego, CA. The ISS-255 camera produces images in RS170 format compatible with standard VHS recorders and monitors, and is equipped with an 18 mm GEN-II micro channel plate intensifier that provides 30 line pairs/mm resolution and a minimum intensifier gain of 18,000. The camera offers a sensitivity of 10^{-6} foot-candles and 400 TV lines of resolution.
Circle Reader Action Number 780.



New on the Market

Citranox **acid detergent** from Alconox Inc., New York City, is scientifically formulated with sequestrants to remove milkstone, scale, metal oxides, trace metals, calcium deposits, and carbonates, while its powerful emulsifiers clean off fats, oils, grease, and solvents. The aqueous, phosphate-free detergent cleans metal, plastic, glass, rubber, and ceramics in hard or soft water. It is recommended for manual, flow-through, and ultrasonic cleaning methods.

Circle Reader Action Number 774.

The SC\FOX™ BOX **stand-alone computer** from Silicon Composers, Palo Alto, CA, uses the Harris RTX 2000™ real-time microprocessor to achieve 18 MIPS performance for applications such as real-time control, data acquisition, image and signal processing, factory automation, and process control. All non-memory instructions execute in one clock cycle, while memory access instructions take two cycles. The chip has a parallel multiplier that performs a 16-bit by 16-bit multiply with a 32-bit result in one cycle.

Circle Reader Action Number 766.

Panasonic Communications and Systems Co., Secaucus, NJ, has introduced the Data Partner JT-785, an MS-DOS handheld **data collection computer** featuring a backlit touch-panel screen. The lightweight unit uses a 16-bit 80C88-equivalent microprocessor to process data at 4.9 MHz and offers up to 768K RAM. It displays text and graphics at a resolution of 160 x 200 dpi and has a 21-key keypad.

Circle Reader Action Number 772.

A 37-pin high-density **connector** from Ceramaseal, New Lebanon, NY, provides state-of-the-art probing, monitoring, and operating of low- and high-vacuum chambers and systems. The moisture- and corrosion-resistant connector operates on 600 volts DC power, and is bakeable to 200°C. Its rugged construction enables its use up to 1000 psi.

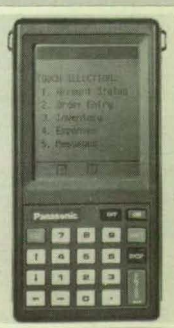
Circle Reader Action Number 776.

A new high-speed **IEEE 488 bus extender** from IOtech Inc., Cleveland, OH, communicates at rates as high as 800 Kbytes/sec and connects devices up to 1,000 meters away without speed degradation. The Extender488/HS also expands the bus by allowing up to 27 devices to be connected to one controller—13 more than the IEEE bus normally allows. Both bus extension and expansion are performed transparently.

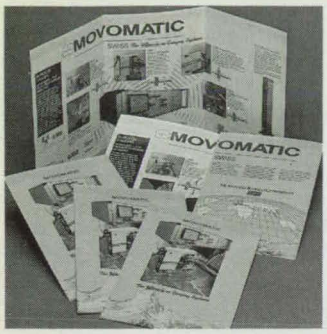
Circle Reader Action Number 768.

An innovative **sensor technology** developed by GTE Laboratories, Waltham, MA, can detect any gas that contains or reacts with oxygen, including nitrous oxide, hydrogen, methane, and ethane. The proprietary technology employs an electrochemical pumping principle to create a flow of ionized oxygen through a stabilized zirconia ceramic body. This yields an electrical ouput directly proportional to the concentration of gas being sensed. Because the electrical output is a linear function of the gas concentration, the technology achieves greater accuracy than the more commonly used logarithmic approach.

Circle Reader Action Number 770.



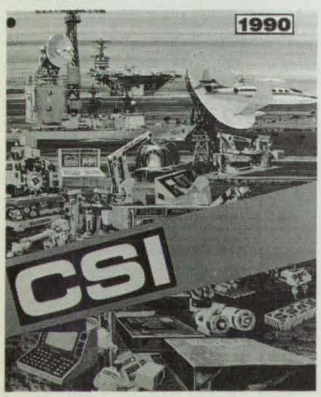
New Literature



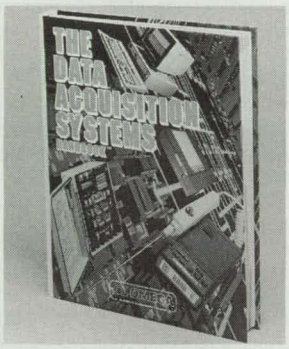
A full-color brochure from Movomatic USA, Greenville, RI, features the company's in-process and post-process **gaging systems**, including the CR Series diameter gaging systems, designed for in-process grinding applications, and the TMP 81 lateral positioning gage for active or passive part positioning. Metrology equipment, stepper motor controls, and honing and grinding machine controller systems are also described.
Circle Reader Action Number 708.

A new brochure from Du Pont Electronics, Wilmington, DE, discusses **ceramic technology capabilities** in high-end multilayer applications for the military. The brochure provides an overview of performance, design, and manufacturing advantages of ceramic thick-film and Green Tape ™ materials and technologies in multilayer substrates.
Circle Reader Action Number 710.

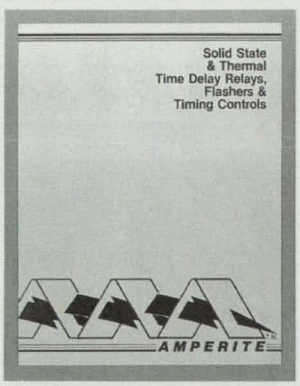
More than 60 families of **synchro, resolver, LVDT, RVDT, and Inductosyn™ converters** are described in a new short-form catalog from Control Sciences Inc. (CSI), Chatsworth, CA. The publication features CSI's card-mounted assemblies, modular families, instruments, rack-mounted systems, and airborne military systems. New products include a differential control transmitter, programmable binary-to-BCD converter, low-profile two-speed converter, and a synchro amplifier.
Circle Reader Action Number 712.



Concord Electronics Corp. of New York City is offering a free 180-page **electronic hardware and test accessories catalog** featuring lithium battery holders, transistor sockets, insulated terminals, multimeter and miniature test lead kits, patch cords, and jumpers. Other product highlights include an extensive line of RF connectors, slide-on and interseries adaptors, teflon terminals, plugs, jacks, and dual test adaptors.
Circle Reader Action Number 706.

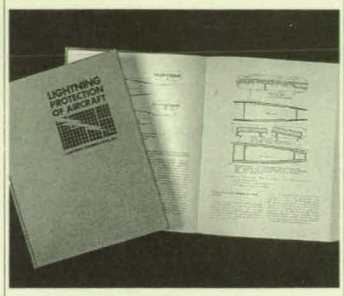


A 600-page **data acquisition and computer interface handbook** is available free of charge from Omega Engineering Inc., Stamford, CT. The handbook features data acquisition and engineering software, communications-based acquisition systems, plug-in cards, data logging systems, recorders, printers, plotters, industrial process controls, signal conditioners, and technical books.
Circle Reader Action Number 702.



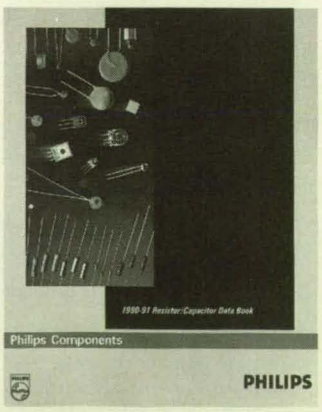
A free brochure from Amperite Co., Inc., Union City, NJ, describes the company's line of **thermal and solid-state timing controls.** Spotlighted are Amperite's B Series thermal time delay relays; C Series solid-state time delay relays; D Series solid-state flashers; and Glass Tube line of hermetically-sealed time delay relays and flashers. The products are available in various timing ranges, input voltages, contact functions, mountings, and sizes.
Circle Reader Action Number 704.

New Literature



A 500-page engineering handbook covers **lightning protection** of aircraft and other aerospace vehicles, systems, and components. Available from Lightning Technologies Inc., Pittsfield, MA, the handbook addresses the basics of natural lightning and the physical concepts and technologies of high-voltage phenomena that determine the effects of lightning on air vehicles. It includes the backgrounds and interpretations of civil and military airworthiness certification regulations and test standards, as well as results of recent flight research programs.
Circle Reader Action Number 720.

An innovative **insulation process** for motor parts, including armatures, rotors, and stators, is described in an eight-page brochure from Electrostatic Technology Inc., Branford, CT. Polymers in powder form are electrostatically charged; when a grounded motor part is passed through a coater, it is thoroughly and uniformly covered by the polymer. The part is then heated to flow and cure the polymer. The process does not require masking as there is no preheating of the part .
Circle Reader Action Number 724.



Philips Components' 700-page **resistor/capacitor data book** features aluminum electrolytic, ceramic, tantalum, film, and variable capacitors; fixed resistors; trimmers; and non-linear resistors. It includes an index and a competitor cross-reference section.
Circle Reader Action Number 718.

Semicoa Semiconductors, Costa Mesa, CA, is offering a free catalog detailing its high-reliability **transistors** for the industrial, military, medical, and aerospace markets. The catalog provides specifications for Semicoa's MIL-S-19500 transistors; NPN and PNP silicon power transistors; UHF, low-level, and high-frequency amplifiers; NPN, PNP, and high-current medium-speed amplifiers; and differential and dual amplifiers.
Circle Reader Action Number 714.

A 16-page catalog from Anorad Corp., Hauppauge, NY, provides detailed technical data, mounting dimensions, application notes, and selection assistance for Anorad's high-speed, brush-type and brushless linear **DC servo motors.** Products range from miniature brushless versions rated for 4.5 pounds continuously to industrial-grade models rated at 2000 pounds peak.
Circle Reader Action Number 716.

Diamonite Products' 50th anniversary brochure examines the past, present, and future of **technical ceramics,** tracing their evolution from spark plug insulators for World War II fighters to reaction-processed composite materials. The brochure provides an overview of ceramic design and manufacturing steps, including mixing/blending, drying, pressing, kiln firing, and finishing. It also discusses various manufacturing options and their impact on the finished part.
Circle Reader Action Number 726.

A new catalog from Signal Processing Technologies Inc., Colorado Springs, CO, includes block diagrams, features, and characteristics of the company's **data conversion and digital signal processing (DSP) integrated circuits,** including analog-to-digital converters, digital-to-analog converters, comparators, filters, and DSP products. The publication features a product selection guide.
Circle Reader Action Number 722.

Subject Index

MARKETPLACE

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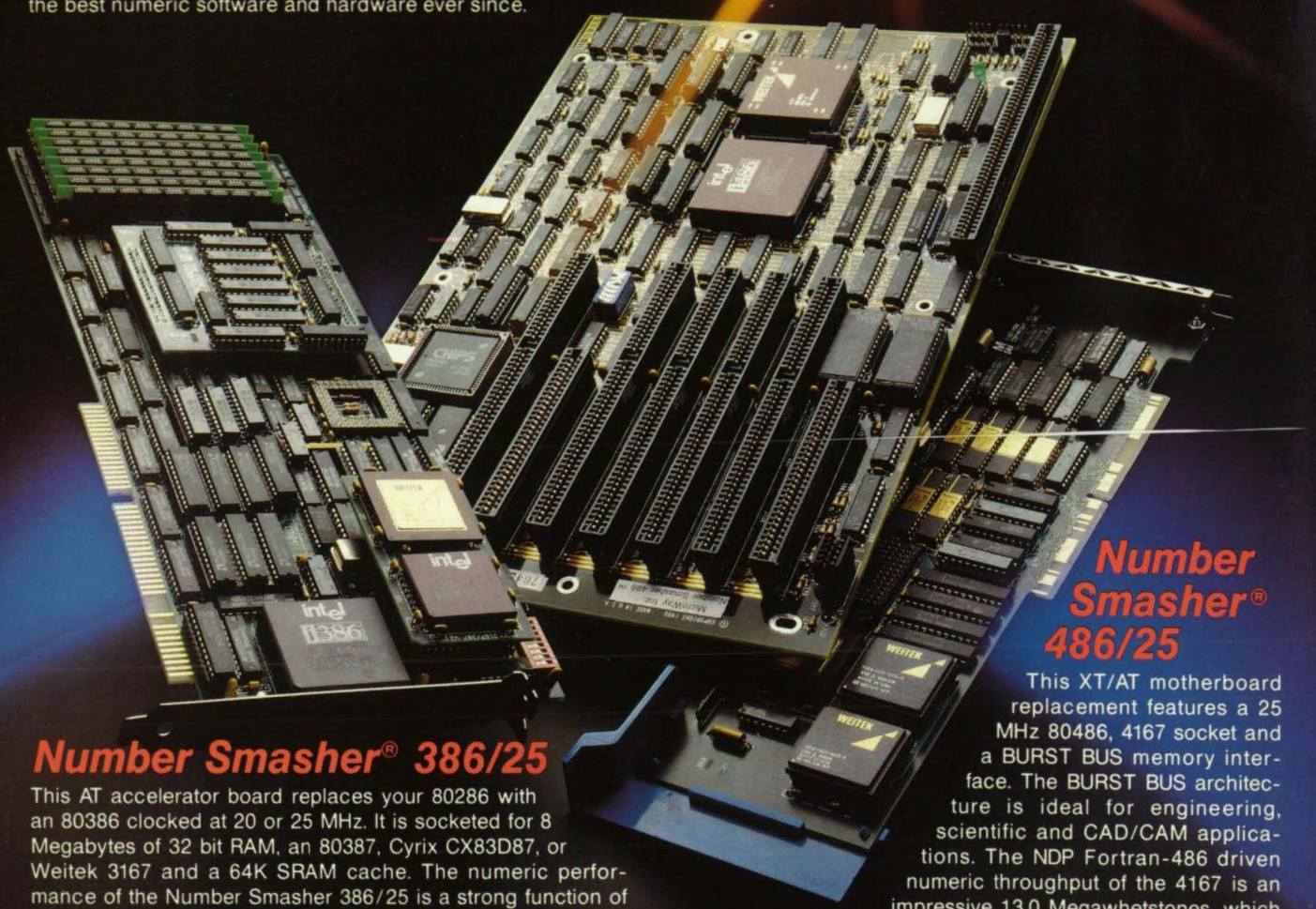

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Number Smasher 486/25 Numeric Performance

	486	4167
Megawhetstones	5.9	13.0
Megawhetscales	4.1	9.9

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