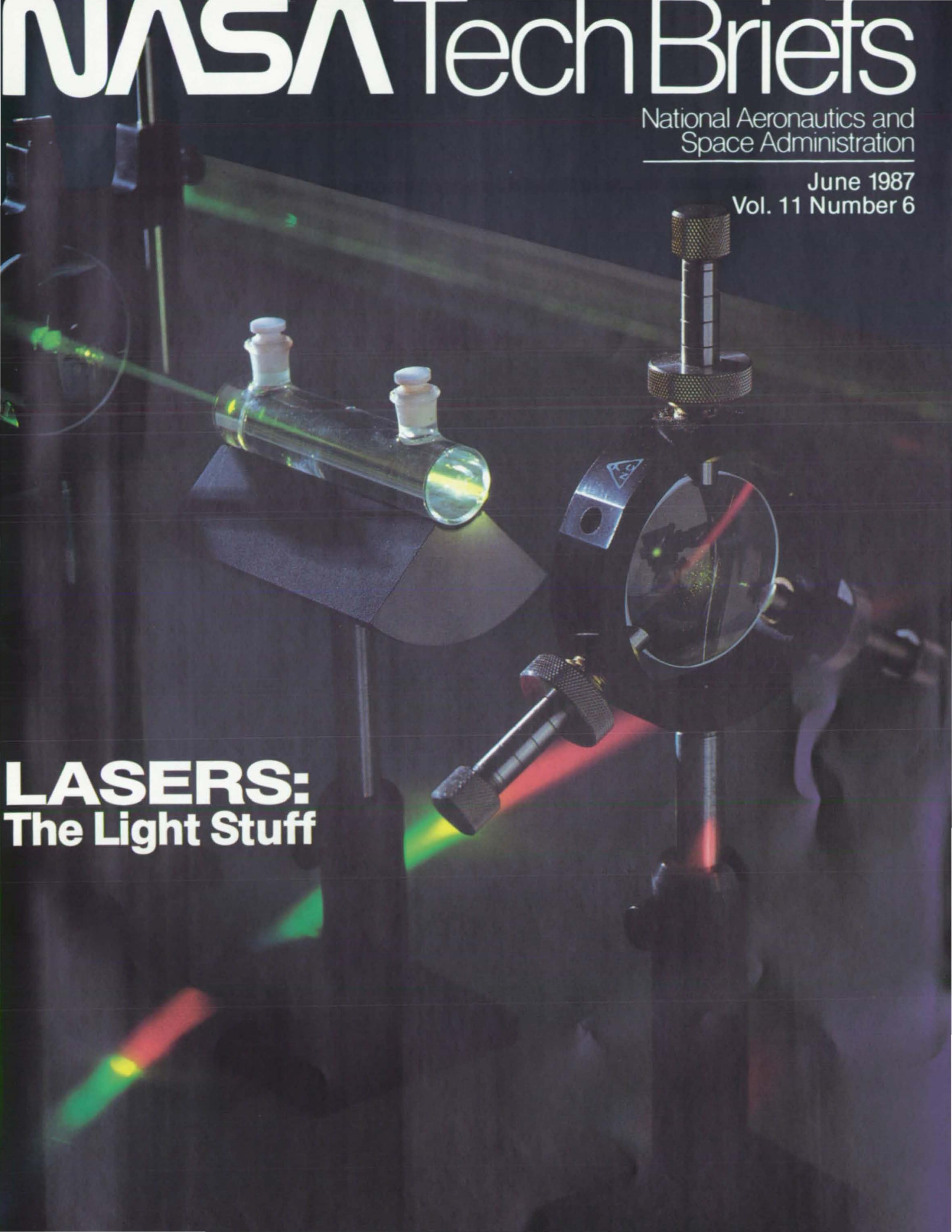
NASA Tech Briefs
National Aeronautics and Space Administration
June 1987
Vol. 11 Number 6



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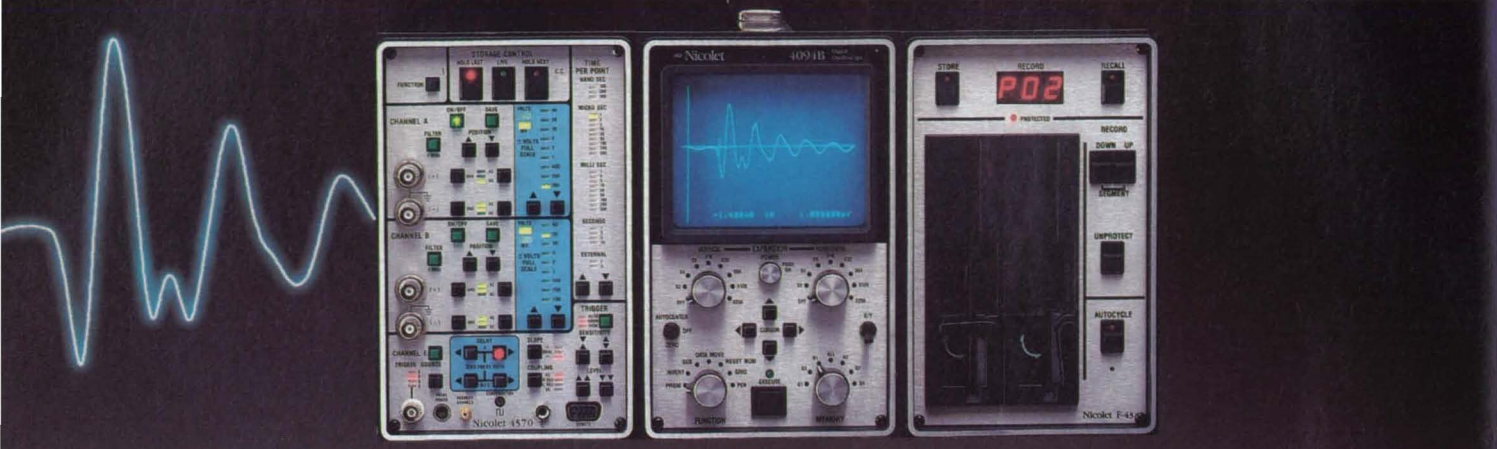

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Connected via the GPIB interface, the Nicolet Model 4094 digital oscilloscope teamed up with the Nicolet Model 42 arbitrary function generator provides instantaneous waveform storage and generation.

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Nicolet Digital Oscilloscopes

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"Instruments of Discovery"

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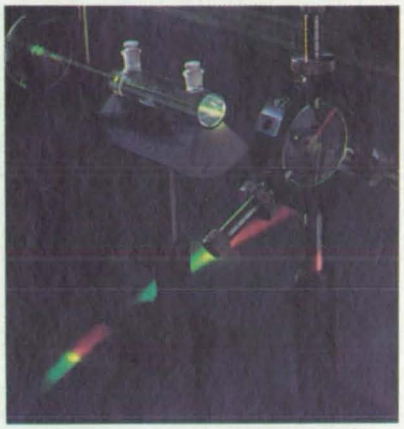
NASA Tech Briefs
National Aeronautics and Space Administration

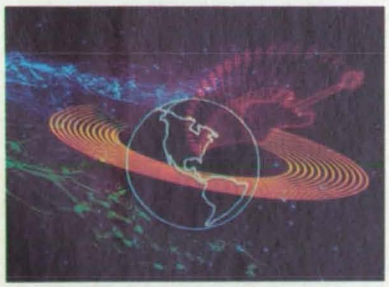
JUNE 1987
Volume 11 Number 6

ABP BPA

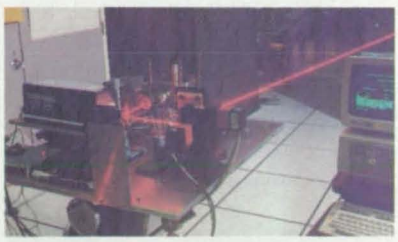
Special Features and Departments



On the Cover:
With extremely short pulses and a broad wavelength spectra, this laser system can show the energy distribution in molecules. More information on lasers can be found starting on page 10. Photo courtesy Spectra-Physics.



With a little innovation, Audio Visual Imagineering, Inc. is able to manipulate ordinary laser light into this work of art. NASA also has some inventive uses for lasers, as described in our cover story.



Currently under evaluation at NASA's Johnson Space Flight Center, this laser-based tracking system may help dock spacecraft with the Space Station a few years from now. Note the three mirrors on the target to the right. The tracking system is described on page 12.

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Technical Section Thumb Index

Thumb Index Technical Section

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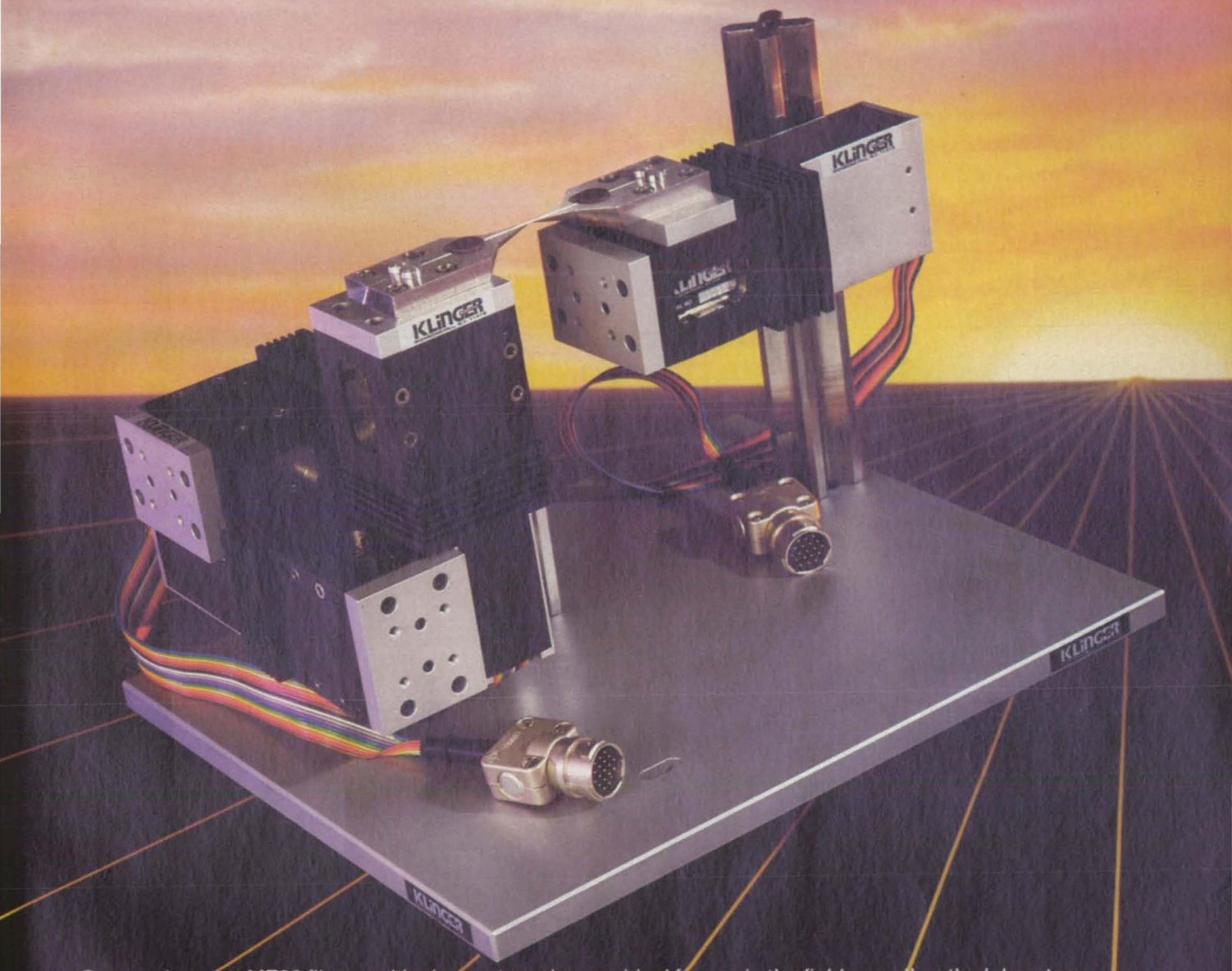
OUR FIBER POSITIONING SYSTEMS DELIVER 0.1 MICRON RESOLUTION...REPEATEDLY.



Our new low cost MF08 fiber positioning system simplifies the most difficult fiber test and alignment tasks.

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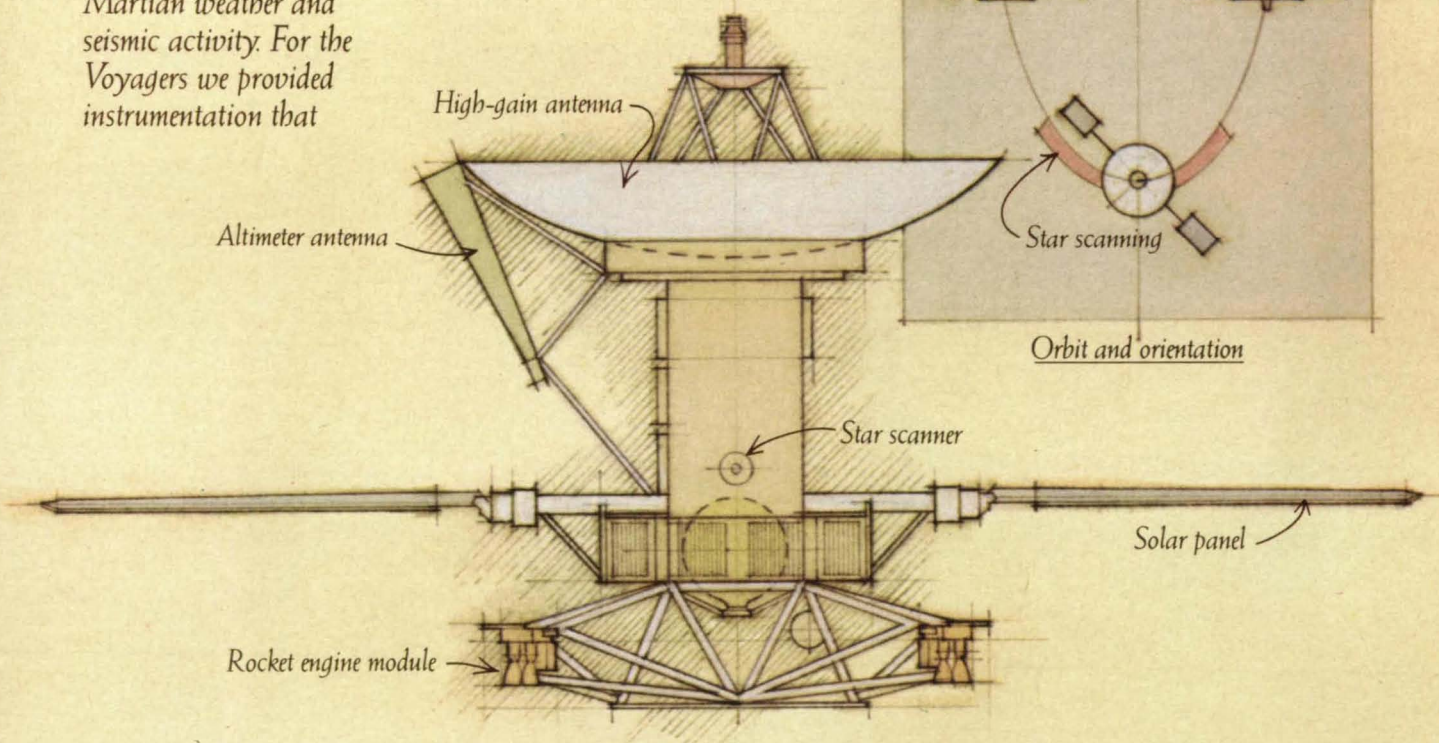
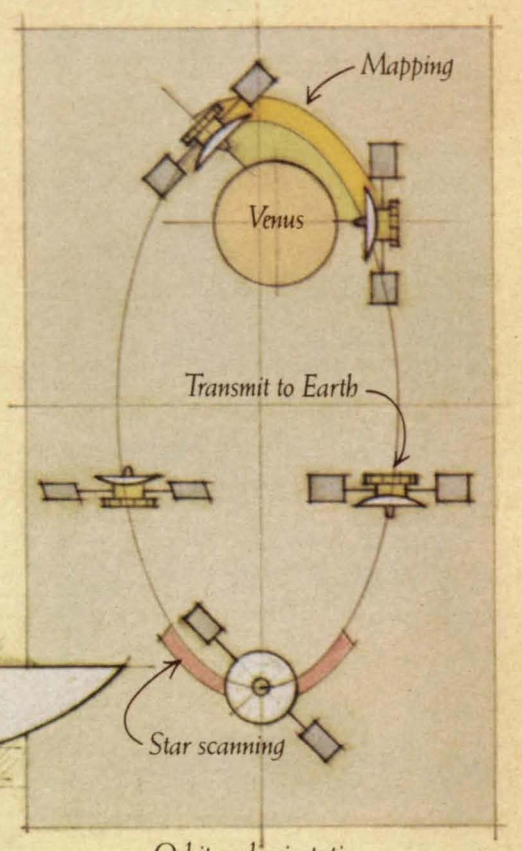
Circle Reader Action No. 368

In space: looking back to look forward.

What can the nature and origin of the universe tell us about the future of Earth? To help answer that question, we make craft and instruments for traveling billions of miles in space and seeing as far as 15 billion years back in time. Martin Marietta was the integrator and builder of two Viking landers, which sent back remarkable photos of the surface of Mars, examined soil samples, and studied Martian weather and seismic activity. For the Voyagers we provided instrumentation that reported on electromagnetic activity near Jupiter and Saturn–Voyager 2 went on to Uranus, some 2 billion miles from Earth. That was nine years after launch; next destination, Neptune, in 1989. These are but a few results of Martin Marietta's ability to create survivable, mystery-solving craft and their instruments–from concept through mission completion.



Magellan Spacecraft



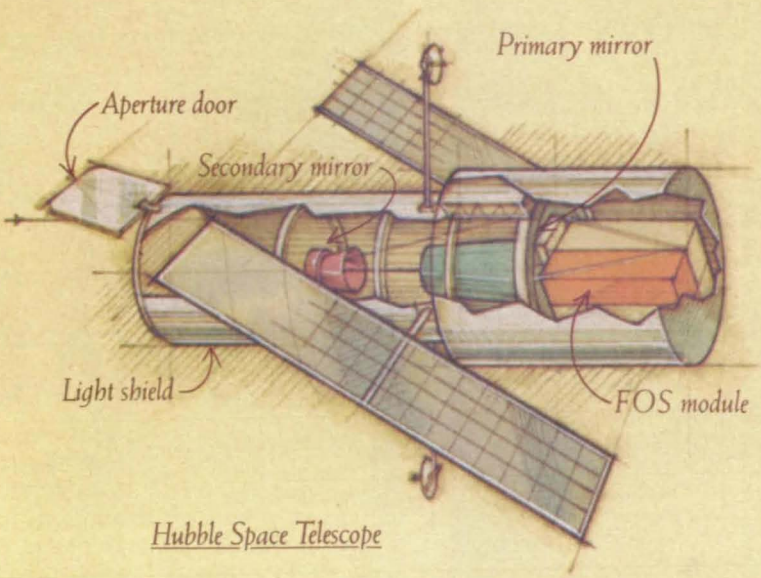
Orbit and orientation

Mission: map Venus.

From orbit, Magellan's radar will penetrate the planet's thick, gaseous cloud cover and send back photo-like images of nearly 90% of its surface. Our role: design, integrate, build and test the craft.

Viewing the infant universe.

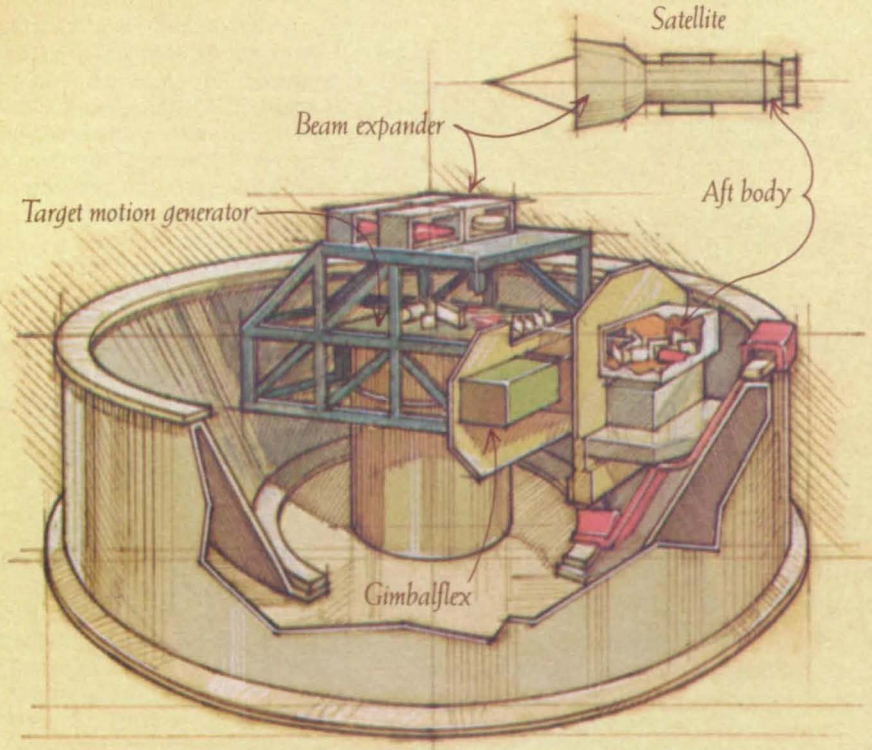
For the Hubble Space Telescope we are providing the Faint Object Spectrograph (FOS), which will see objects up to 15 billion light-years away. Since the universe is estimated to be 18-20 billion years old, astronomers will witness events close to its birth.



Hubble Space Telescope

The fine points of fine pointing.

Precisely controlled, space-spanning energy delivery and collection systems create difficult pointing and retargeting challenges, which we can now simulate. This new lab is working toward the precision to zero in on a football-size object 3,000 miles away, in support of the Strategic Defense Initiative research program.



Fine Pointing Simulator

Masterminding tomorrow's technologies

MARTIN MARIETTA

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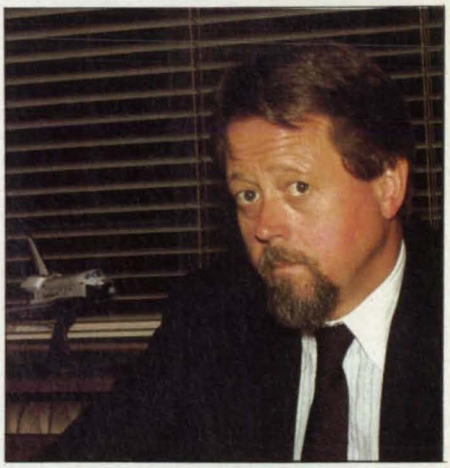
Editorial Notebook



In case you haven't noticed it, we've made some strides towards making your subscription to NASA Tech Briefs an easier process. Many readers have written to ask if there were some way they could see at a glance if they'd renewed their qualification within the past year.

Our Circulation Director, Anita Weissman, took those pleas to heart and went to the post office. The results are evident. You need only look above your name on the label on the front cover of the magazine to determine when your subscription to NTB will expire.

When you fill in your TSP requests or advertising inquiries, you need only to circle what you want. You do not have to requalify every time you make a request for further information. However, I suggest that you requalify 90 days before the date listed on your mailing label so that you will not miss an issue. If, for example, your label says EXP DATE AUG 87, requalify now. That will leave ample time for the post office to deliver the mail and for our circulation department to process the requalification. In fact, changes usually take place more quickly than that, but we suggest building in a margin for error so that you will be sure not to miss an issue.

Now that we've solved the expiration date problem, we're turning our attention to the superglue problem. We plan on providing you with peel-off labels in the near future. In fact, we've been planning on it for some time, as many of our readers are well aware. Just as I have waited to announce the new label configuration until after it has been in place, we will be certain that the equipment is able to perform the peel-off label task before we announce it as fact. □

Brie Schmerling

Plan To Attend

SPACE

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COMMERCE &
COMMUNICATIONS

November 17-20, 1987

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Houston, Texas USA

The Event

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- ELV Industry
- Heavy Lift Vehicles
- Space Stations & Industrial Platforms
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- Satellite Communications Technologies
- Satellite Communications Applications
- Robotics
- Information Systems
- Modeling & Simulation
- Artificial Intelligence
- Materials Processing
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- Commercial Space Roundtable
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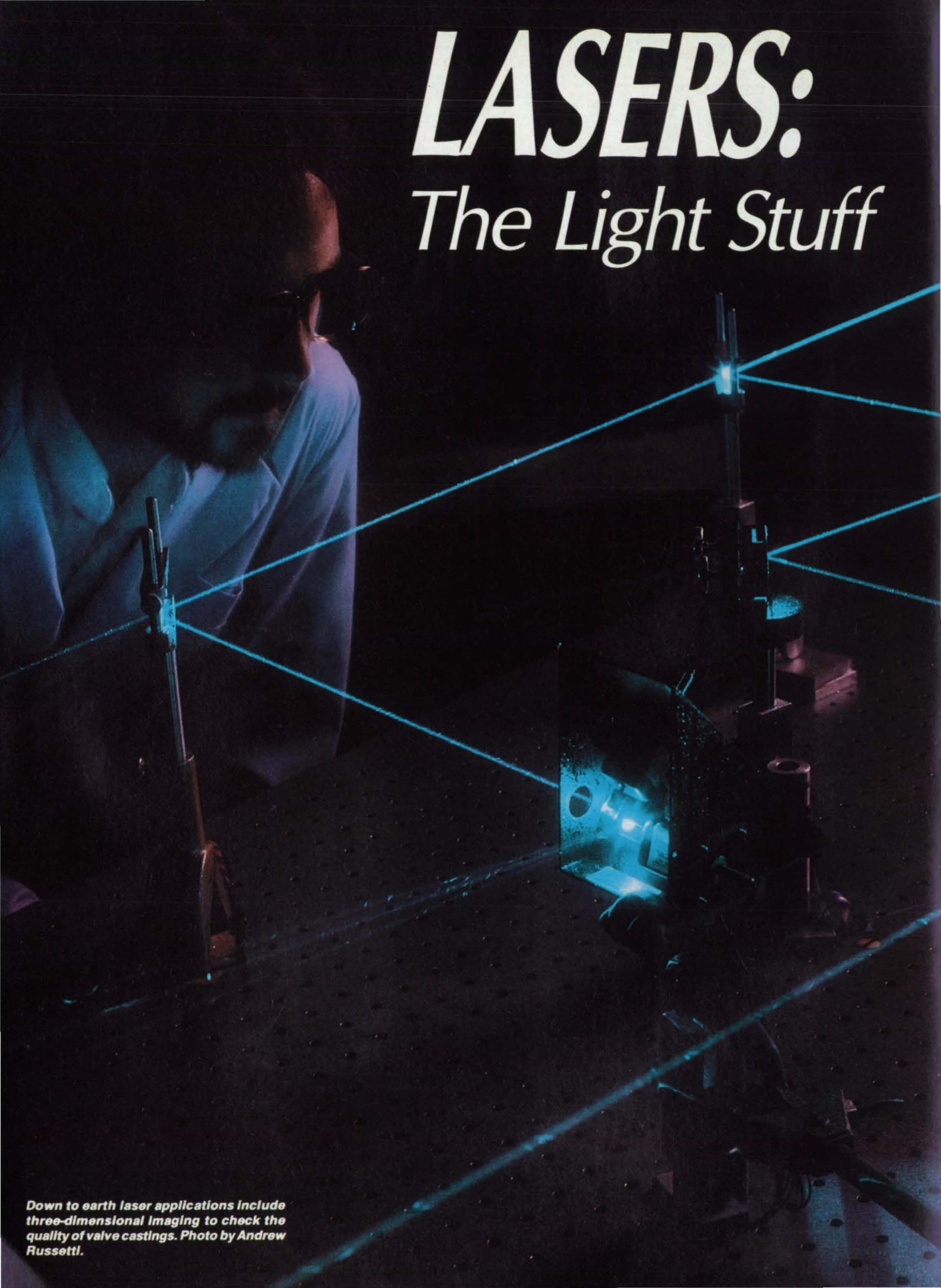
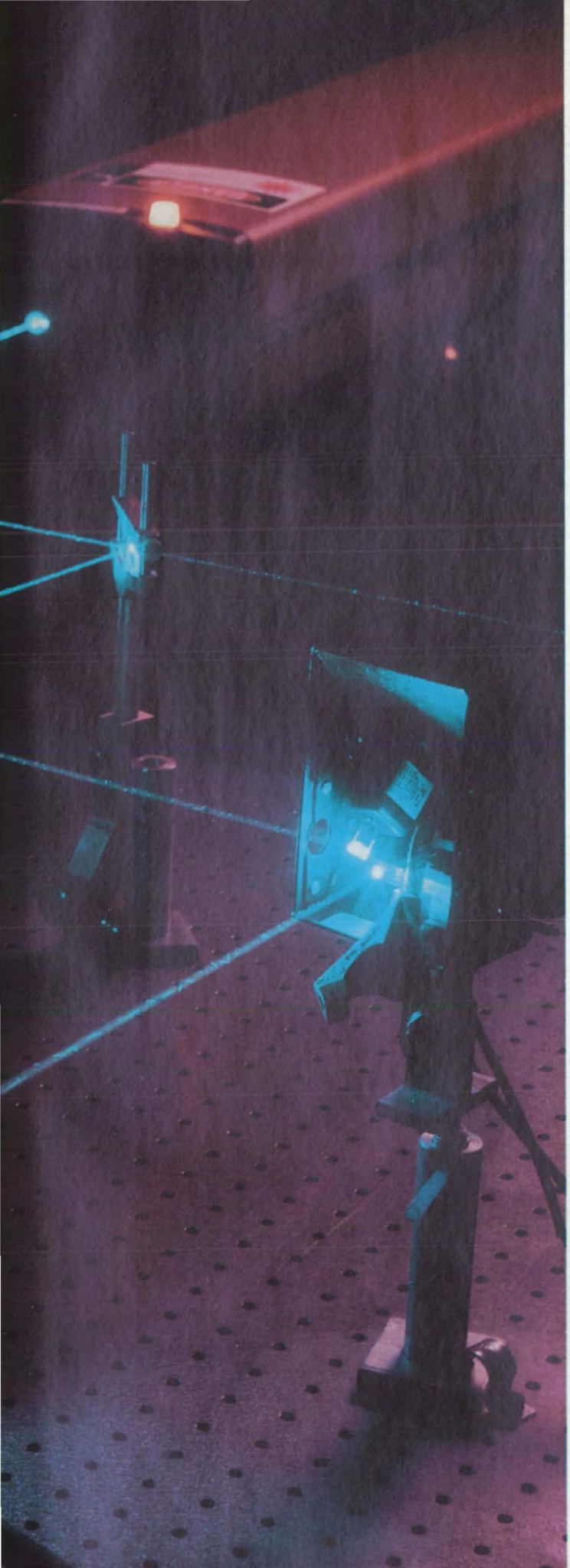
Circle Reader Action No. 409

LASERS:
The Light Stuff



Down to earth laser applications include three-dimensional imaging to check the quality of valve castings. Photo by Andrew Russettl.



In space, no one can hear you scream. No one can hear you talk, either. That will cause problems as astronauts get down to work up in the space station; they'll be unable to converse as they foray off to repair satellites. High on NASA's list of solutions is laser light, which can carry information across line-of-sight paths. Lasers will also be used as radar systems, enabling spacecraft to gently dock with the space station and each other.

Several factors make lasers a good choice for communicating in space. Laser "comm" systems are interference and multipath free. Because they emit little stray electromagnetic radiation, they provide a secure link. Best of all, they'll be able to reliably transfer data at high rates over long distances.

Blowing in the Cosmic Wind

Lasers aren't yet the answer to all space communication needs, however. Half of every communications system is the receiver, which detects and interprets the transmitted signals. In a laser-based system, the unattenuated sunlight in space can compete for the receiver's attention, significantly increasing the error rate.

Like the top of the Sears tower, the space station will flex and sway. Such movement could interrupt the tight link between the transmitter and receiver. Orbital anomalies and doppler shift will also have to be dealt with.

Researchers at NASA's Johnson Space Center (JSC) plan to use the Advanced Communications Technology Satellite (ACTS) to avoid or eliminate these obstacles. Configured to simulate the conditions on the space station, the experiment will include a full duplex laser communication link between the ACTS and either a free-flying or shuttle-attached platform. Also underway is a ground-based laser communications test system.

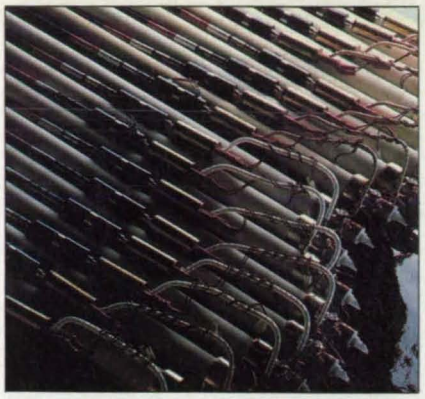
High Data Rates

Lasers will also be used inside the Space Shuttle. As communication requirements between the crew cabin and the payload bay increase, special accomodations must be made to transfer the needed data. While drilling a new hole on earth for supplementary cables is simple, it's not so easy in the Orbiter. Dozens of factors must be accounted for, as a pressurized thermal bulkhead will be penetrated. Modulated laser light, on the other hand, can effectively bridge the gap by beaming through windows.

Called Optical Communications Through Shuttle Window (OCTW), the system consists of a fiber optic link from the payload bay to one side of the aft shuttle window. On the other side of the window, inside the crew cabin, another light cable would connect to the portable computer or recorder. The optical transceivers would use laser diodes operating at 1300 nm. Why a laser? According to Jane L. Grady, a Project Engineer in the Microwave and Laser Section at JSC, "You can get more power out of a laser diode, and with the loss due to the gap at the window and the connections in the payload bay, we require a pretty luxurious power budget. We require enough power that the signal can be detected without error."

The optical link will enhance the communication capabilities within the orbiter. Says Grady: "The currently available bandwidth between cabin and bay is 50 Mbits/second. OCTW will eventually handle 200 Mbits/second. The system will provide an easy way to supplement the existing lines between the payload bay and the crew cabin."

Satellite repair will be a routine part of any manned presence in space. To reach those satellites, astronauts will use a JSC-developed handheld laser radar unit that, like a ►



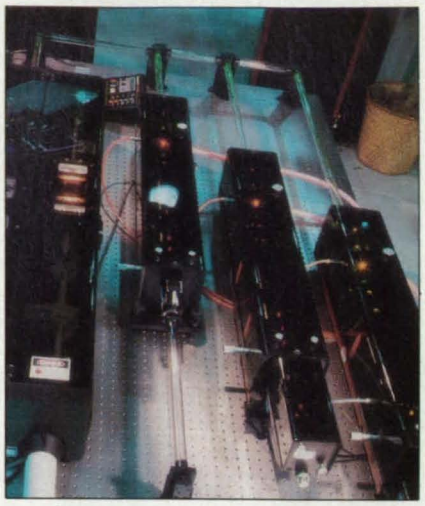
police speed radar, can track the range and speed of an object. The navigational aid will have a useful operating range of from zero to 3000 feet with a resolution of 0.1 foot. Using a 50 milliwatt semiconductor laser, the device will be able to track objects traveling between 0.1 to 30 feet per second. Unlike the police radar, the astronauts can vary the beamwidth, choosing the right beam for the right job. Distant targets call for precise, pencil-thin beams to maximize power on the target, while nearby targets often require wider beamwidths to spatially average error-inducing surface variations.

Other laser trackers will help dock Orbital Maneuvering Vehicles with the space station. Not only must three dimensions be accounted for, but precision will be necessary. The docking craft must match the space station's orbit, or the contact will jolt the station. Maybe not by much, but the perturbations can disturb sensitive equipment and experiments. Fuel-expensive orbital corrections will reduce those shocks, but they bring their own problems: Every time a control thruster fires, it leaves particles behind that can obscure optical surfaces.

A laser-based system will eliminate most of these difficulties. According to James C. Lamoreux, head of the Microwave and Laser Section of the Tracking Techniques Branch, "An accurate docking sensor lets you set up the velocity vector so that you won't have to do any further thrusting, or at least minimize it, as you get in close to the docking port."

Several laser docking sensor techniques are currently under development at Johnson Space Center. The most promising so far use solid state lasers to measure position, velocity and attitude for a large variety of vehicles and payloads. At a distance of about 22,000 feet, laser diodes on one of the vehicles will transmit light at the approaching vehicle. Corner cube mirrors will reflect the laser beams back to a sensor mounted near the transmitter. Through multiple switching and scanning techniques, the direction, distance and speed of approach will be calculated, and the information fed to

Though NASA will probably use diodes to generate laser light for their communication needs, other means are available for research applications. Coherent, Inc. manufactures laser models and subsystems, including plasma tubes, shown at left, and an ultrafast CW Nd:YAG laser, below.



the vehicles control thrusters. As the spacecraft near each other, more accurate detection techniques will enable a soft and precise docking.

Making Light Work

Because this system is designed for close tolerances, the technology may well be transferred to factory robotic assembly on earth. Says Charles Joslin, editor of *Advanced Manufacturing Technology*, a newsletter devoted to identifying emerging technologies, "Accurate sensing and positioning are drawing a great deal of interest. Current robotic positioning methods use feedback from jaw-mounted sensors, which leads to inaccuracies if the machinery is a little bit off." Applying the optical tracking technology to robotic assembly would give more realistic and precise control, he adds.

Though the environments are dissimilar, light can solve problems on earth as neatly as in space. Able to transfer large volumes of data over simultaneous channels, optical technology can be utilized wherever physical connections are difficult to maintain or impractical. In an automated warehouse, with robots communicating with computers, optical links could transfer commands presently transmitted over hardwire connections. In addition, eliminating the need for a fixed network of cables increases manufacturing flexibility.

The Future is Now

Now that NASA is able to bring reality to what was once science fiction, we see much more benign applications. Those lights flashing between spacecraft will carry information, or they'll be the guides that bring astronauts back to their home in space. □

NON-DESTRUCTIVE TESTING: NOBODY ELSE OFFERS SO MANY WAYS TO LISTEN.

The extensive use of composite parts in the aerospace industry has created a need for fast, reliable, cost-efficient methods of testing.

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***AUSS-IV** The industry standard.*

***AUSS-V** Adds new dimensions to ultrasonic testing.*

***ADIS** Updates existing inspection units.*

***MAUS** Provides fast, in-place inspection of composite parts.*

MCDONNELL DOUGLAS

NASA News Briefs

Dr. Sally Ride, the first American woman in space, will leave NASA this fall to assume a Science Fellow position at the Stanford University Center for International Security and Arms Control, Palo Alto, California. Ride first joined NASA in 1978 as an astronaut candidate. She served as capcom (capsule communicator) in Mission Control for four space shuttle flights, and participated in two flights- STS-7, launched in June 1983, and STS-41G, launched in October 1984.

June 1988 is the new target date for the next space shuttle launch. This delay reflects the decision, announced in April, to perform two major tests on the liquid-fuel main engines, and to obtain new tooling to improve the insulation seals for the solid-fuel booster rockets. Current plans are for two additional shuttle flights in 1988, followed by seven in 1989.

Two NASA contractors, International Business Machines (IBM), Federal Systems Division, Houston, and Martin Marietta Michoud Aerospace, New Orleans, are the first winners of the NASA Excellence Award for Quality and Productivity. The award, administered by NASA in conjunction with the American Society for Quality Control, is aimed at stimulating public awareness of quality and productivity to NASA and the United States in international economic competition.

Newly discovered evidence indicates that a significant methane atmosphere surrounds the planet Pluto, according to scientists at NASA's Jet Propulsion Laboratory. The findings bolster the stature of Pluto, which some astronomers have described as an asteroid masquerading as a planet due to its small size and odd orbit.

In an effort to lessen its dependence on the space shuttle, NASA has announced plans to acquire throwaway rockets for the launching of satellites. Expendable launch services will be procured from private companies after a transitional phase covering launches through 1991. This first phase will be without competitive bidding to insure the best match between commercial expendable rockets and the already designed payloads. Some launch services may also be acquired through the Defense Department.

The Air Force, in conjunction with NASA and the Department of Defense's Strategic Defense Initiative Organization (SDIO), is seeking design study proposals for an Advanced Launch Systems (ALS) that will provide low cost, reliable, and operationally flexible access to space. The design study is Phase 1 of an effort to lower the cost of space operations. The ultimate goal is to reduce the cost per pound to low earth orbit by a factor of ten compared to current space boosters.

A space data and information sciences research facility will be established at NASA's Goddard Space Flight Center, beginning October one. The facility will serve as a nerve center for a nationwide network of industry and university computer science researchers, who will be able to work on projects at their home institutions and share their findings via communications network meetings.

NASA's Deep Space Network (DSN) in Tidbinbilla, Australia, connected by microwave to Australia's CSIRO Parkes Radio Telescope, is being used to observe the newly discovered supernova SN 1987A. About 163,000 light years from earth, the supernova is the first detectable star explosion near the Milky Way since 1604.

The Tidbinbilla-Parkes microwave link was established for the 1986 Voyager 2 Uranus encounter. Similar antenna arraying will be utilized for the Voyager Neptune encounter in August, 1989.

28 organizations have submitted proposals in response to NASA's third announcement of opportunity to establish commercial space centers. The objective of the centers is to stimulate research in space which could lead to the development of commercially viable products on earth. NASA will fund up to six of the proposals, at one million per year each, for up to five years. Funding is anticipated by September.

A new study commissioned by NASA's Marshall Space Flight Center will assess the feasibility of liquid rocket boosters as replacements for space shuttle solid rocket boosters. The nine month study will focus on both pressure-fed and pump-fed liquid-fueled boosters.

An electrical transient caused by a lightning flash was the most probable cause of the Atlas/Centaur-67 accident on March 26, according to an investigation board's report. The board stated that launching the vehicle into atmospheric conditions conducive to triggered lightning was "in violation of the established criteria used to avoid potential electrical hazards."

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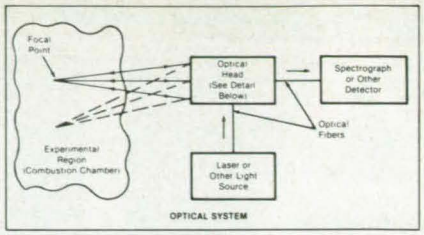
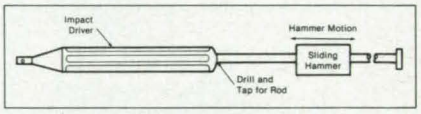
New Product Ideas

New Product Ideas are just a few of the many innovations described in this issue of *NASA Tech Briefs* and having promising commercial applications. Each is discussed further on the referenced page in the appropriate section in this issue. If you are interested in developing a product from these or other NASA innovations, you can receive further technical information by requesting the TSP referenced at the end of the full-length article or by writing the Technology Utilization Office of the sponsoring NASA center (see page 19). NASA's patent-licensing program to encourage commercial development is described on page 19.



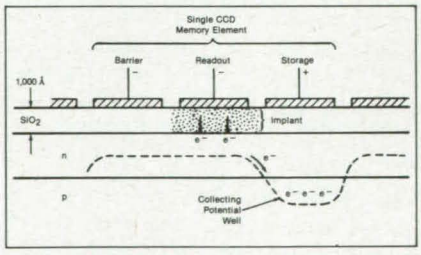
Remote Optical Combustion Analyzer

A rugged optical head enables remote, nonintrusive measurements of temperatures and chemical compositions in hostile environments — in combustion chambers, for example. The optical head beams light from a laser source to a test chamber, then collects the backscattered light from the chamber and sends it to the spectrographic equipment. The light delivered to the spectrographic equipment is analyzed to determine its spectral distribution or intensity. From these data, the temperature and chemical composition of the material in the measurement volume can be determined. (See page 32).



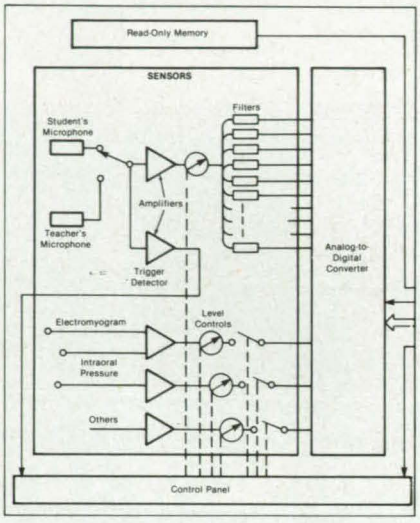
Impact Driver With Integral Sliding Hammer

A tool combines an impact driver with a sliding dead-blow hammer. It can be used for tightening fasteners or driving starter holes for a drill, for example. At the same time, the tool protects the user from accidental injury. The tool is an off-the-shelf impact driver that has been modified by the addition of a rod and sliding hammer. (See page 48).



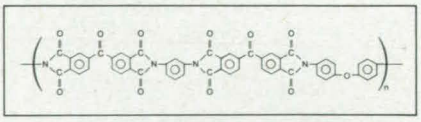
CCD Memory

A charge-coupled device (CCD) has been demonstrated to operate as either a ready-only memory (ROM) or a photon-programmable memory with a capacity of 640,000 bits, with each bit capable of being weighted to more than 1,000 discrete analog levels. The memory cell (1 out of 640,000) shown in the ROM mode is programmed by ion implantation within the SiO_2 layer beneath a readout gate. The signal charge is collected beneath a storage gate and later clocked and transferred in a normal CCD fashion to an output amplifier. The CCD memory can also be programmed by exposing each memory cell to an intense light pattern. The programmed information can be read out several times before the memory requires refreshing. (See page 24).



Visual Speech-Training Aid for the Deaf

A proposed system enables a deaf student to compare his/her sound with the "correct" sound. In this speech-training-system, microphone output is separated by filters into narrow frequency bands, changed into digital signals, formatted by a computer, and displayed on a television screen. Varied and interesting visual displays would be provided to encourage vocalization by a deaf infant. Schematic or pictorial diagrams of the vocal system may be provided to show sound-producing mechanisms (i.e., tongue positions) for each phoneme. Animation may be provided to demonstrate phoneme transitions or the formation of such transitory sounds as plosives. (See page 30).



High-Temperature Copolyimide Adhesive

Thermoplastic polyimides show potential for use as matrix resins and adhesives for aircraft applications. A system that shows the most promise to date is a random copolyimide with the structure shown in the figure. The copolyimide, designated STPI/LARC, is prepared from relatively inexpensive, commercially available chemicals. Lap shear tests at 204 °C after the exposure to boiling water show that the STPI/LARC retains 68 percent of its original strength. (See page 41).

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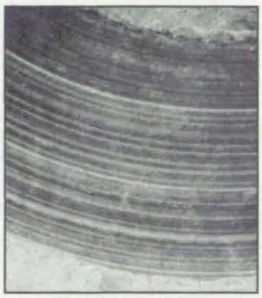
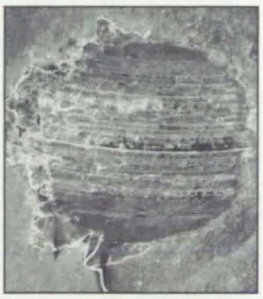
TUFOIL LIGHTNING GREASE (a jelled version of TUFOIL) works where all others fail. Field tests show that the life of crucial machine parts is greatly extended.

SCANNING ELECTRON MICROSCOPE PHOTOS 50X MAGNIFICATION

HEATS FAST
Molybdenum Disulfide Grease
(Test "C" below)

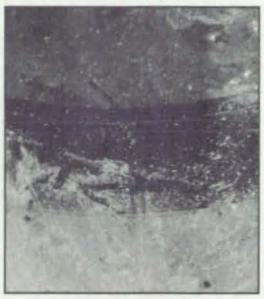


ROTOR BALL



STATOR BALL

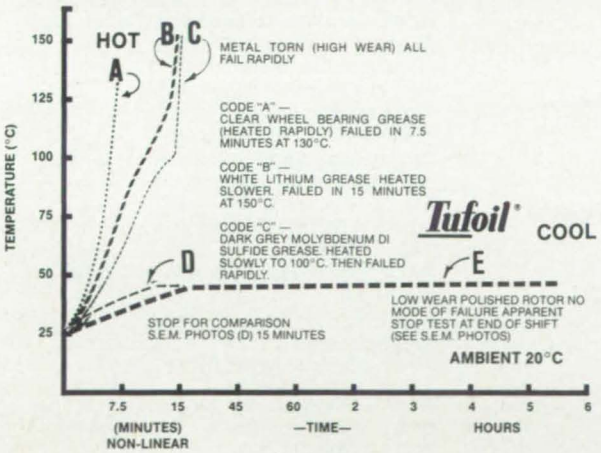
STAYS COOL
Tufoil Lightning Grease
(Test "D" & "E" below)



ROTOR BALL

STATOR BALL

4 BALL TEST OF GREASES
80 KG LOAD — 1700 RPM — .375 DIA. STEEL BALLS



The Tufoil lubricants have been under development for 15 years. They all contain Teflon™ or Fluon™
Teflon is Reg. TM of DuPont. Fluon is Reg. TM of ICI Americas, Inc. TUFOIL is Reg. TM of Fluoramics, Inc., U.S. Patents No. 3,933,565, 4,127,491 and 4,224,173. Other U.S. and International Patents issued and pending.

OEMs all over the world are using TUFOIL products to make machines run better, smoother and last longer.

Ground support vehicles start easier on cold mornings . . . turn table spindles have less rumble . . . automatic inserting machines run smoother . . . servos and steppers are more accurate . . . computer print heads are more accurate.

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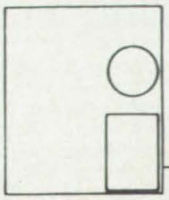
TUFOIL LIGHTNING GREASE STAYS COOL AND SHOWS LESS WEAR

Scanning electron microscope photos of the rotor and stator ball scars from "C" (moly disulfide grease) show a great deal of wear and metal distress. "A" and "B" were similar.

The newly developed TUFOIL LIGHTNING GREASE was tested for 15 minutes. The test was stopped at "D" so that S.E.M. photos of the balls could be made for comparison purposes. Both the rotor and stator marks appear polished and smooth. A great deal of super fine PTFE debris (teflon or fluon) can be seen at the bottom of the rotor photos. It is loosely bonded to the metal surface. Solvent rinsing will not easily remove it.

The wear areas on the stator were calculated, showing the spot on the control was 7.7 times larger than for TUFOIL grease (7.7 times the wear). Another test was set up with fresh balls ("E") and run for a full shift of 6 hours. The temperature stabilized at 50°C. The test was terminated with no mode of failure apparent. S.E.M. photos show highly polished surfaces with scar marks only slightly larger than those for "D" (the 15 minute sample).

We then life tested for 7 days (7 hours per day) . . . no failure and less wear than the moly disulfide produced in 15 minutes.



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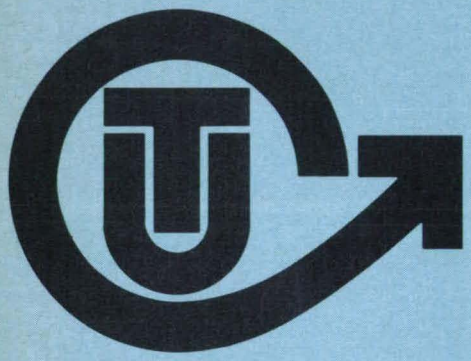

If you're a regular reader of TECH BRIEFS, then you're already making use of one of the low- and no-cost services provided by NASA's Technology Utilization (TU) Network. But a TECH BRIEFS subscription represents only a fraction of the technical information and applications/engineering services offered by the TU Network as a whole. In fact, when all of the components of NASA's Technology Utilization Network are considered, TECH BRIEFS represents the proverbial tip of the iceberg.

On the following pages, we've outlined NASA's TU Network—named the participants, described their services, and listed the individuals you can contact for more information relating to your specific needs. We encourage you to make use of the information, access, and applications services offered by NASA's Technology Utilization Network. You can save time and money by doing so.

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Daniel U. Wilde, President
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North Carolina Science and Technology Research Center (NC/STRC)
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J. Graves Vann, Jr., Director
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Technology Application Center (TAC)
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Stanley A. Morain, Director
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3716 South Hope Street, Room 200
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If you represent a public sector organization with a particular need, you can contact NASA's Application Team for technology matching and problem solving assistance. Staffed by professional engineers from a variety of disciplines, the Application Team works with public sector organizations to identify and solve critical problems with existing NASA technology.

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If you want additional information about the patent status of a particular technology or are interested in licensing a NASA invention, contact the Patent Counsel at the NASA Field Center that sponsored the research. Be sure to refer to the NASA reference number at the end of the tech brief.

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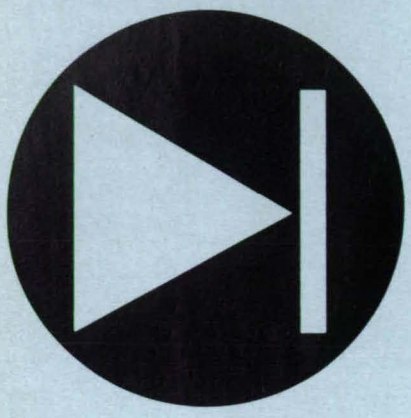
Electronic Components & Circuits



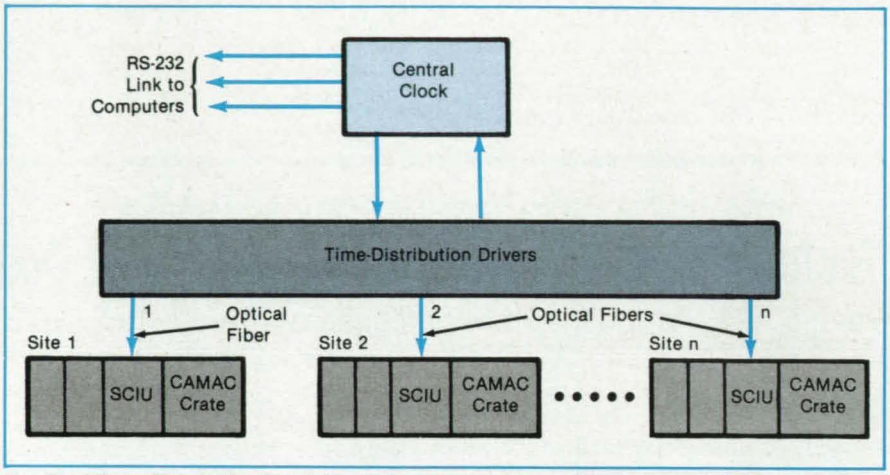
Hardware, Techniques, and Processes

Books and Reports

Real-Time Simulation Clock

A fiber-optic network delivers time signals to widely separated simulator sites.

Langley Research Center, Hampton, Virginia



The **Real-Time Simulation Clock** features independent multiple-job capability.

Real-time digital flight simulation at Langley Research Center is used to support a variety of research programs. The majority of this research involves man-in-the-loop simulation requiring the interconnection of digital computers, simulation cockpits, control consoles, graphics subsystems, and related equipment. The real-time simulation subsystem consists of several CYBER® computers and over 20 simulation sites. The system allows for several simultaneous simulation jobs on one CYBER® as well as any combination of sites in each integrated simulation job.

Of a number of alternatives studied for system upgrading, only a network and input/output system conforming to the International Computer Automated Measurement and Control (CAMAC) standards met the requirement for the replacement subsystem. A combination of off-the-shelf and newly designed CAMAC hardware is currently being installed. A CAMAC serial highway provides a distributed input/output system with extremely high data throughput and a direct interface.

In this system, the real-time simulation (RTS) clock provides the timing information for the synchronization of events throughout the RTS system and between the CYBER's®. The centrally located RTS clock generates the timing information and transmits it to the site-clock interface units (SCIU) located at the simulation sites (see figure). The network connecting the central clock to the SCIU's is a fiber-optic system that radiates from the central clock area to the remote sites. It consists of the time-distribution drivers and the fiber-optic cables routed to the sites. The central clock is connected to the simulation computers via RS-232 links.

The central clock consists of a MULTIBUS® -based system including an iSBC® 80/24 processor, an iSBC® 534 communication board, a 5-MHz oscillator board, and a time-interval-generating board. The processor initializes the central clock and responds to status requests from the CYBER's®. The communication board provides the RS-232 linkage to the CYBER's®. The oscillator board contains an oven-controlled 5-MHz crystal oscillator on which all timing information is based. The time-interval generator is a circuit card designed and built in-house to generate all timing information to be distributed to the sites.

The time-distribution drivers consist of CAMAC cards containing fiber-optic transmitters that receive the encoded timing information from the central clock and transmit it to the sites. The SCIU is a single-width CAMAC module that receives and decodes the timing information. It uses this information to generate frame timing for equipment at the site, to synchronize events with other sites, and to send timing information back to the CYBER's® via the CAMAC serial highway.

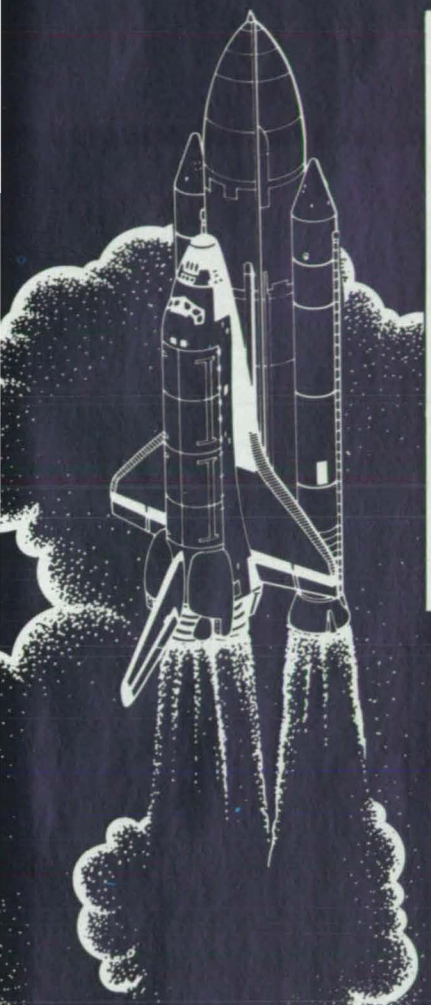
® MULTIBUS and iSBC are registered trademarks of INTEL.

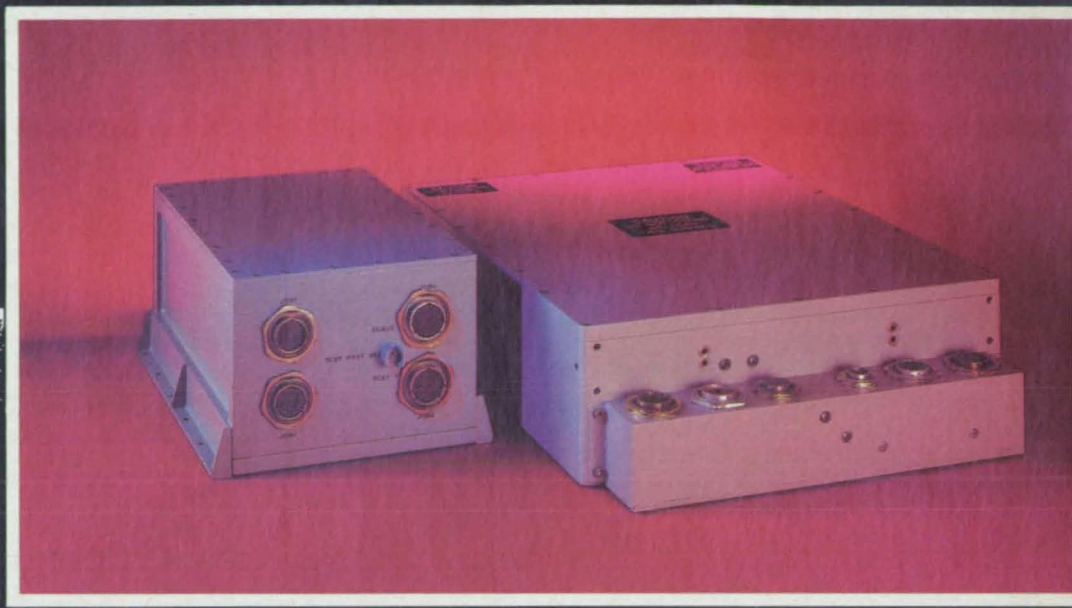
® CYBER is a registered trademark of CDC.

This work was done by Donald R. Bennington of **Langley Research Center**. *For further information, Circle 11 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Langley Research Center [see page 19]. Refer to LAR-13615.

MARS 1400/ADEU-910
Airborne High Density Digital Recording System





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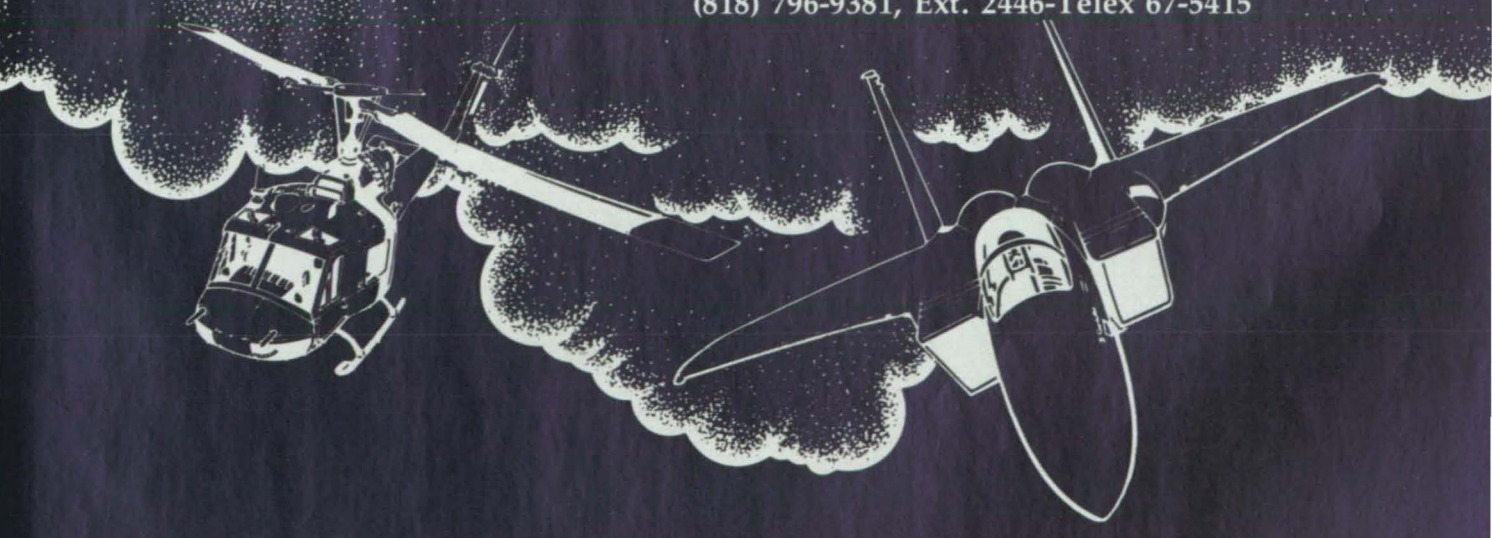

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Radial/Axial Microwave Power Divider/Combiner

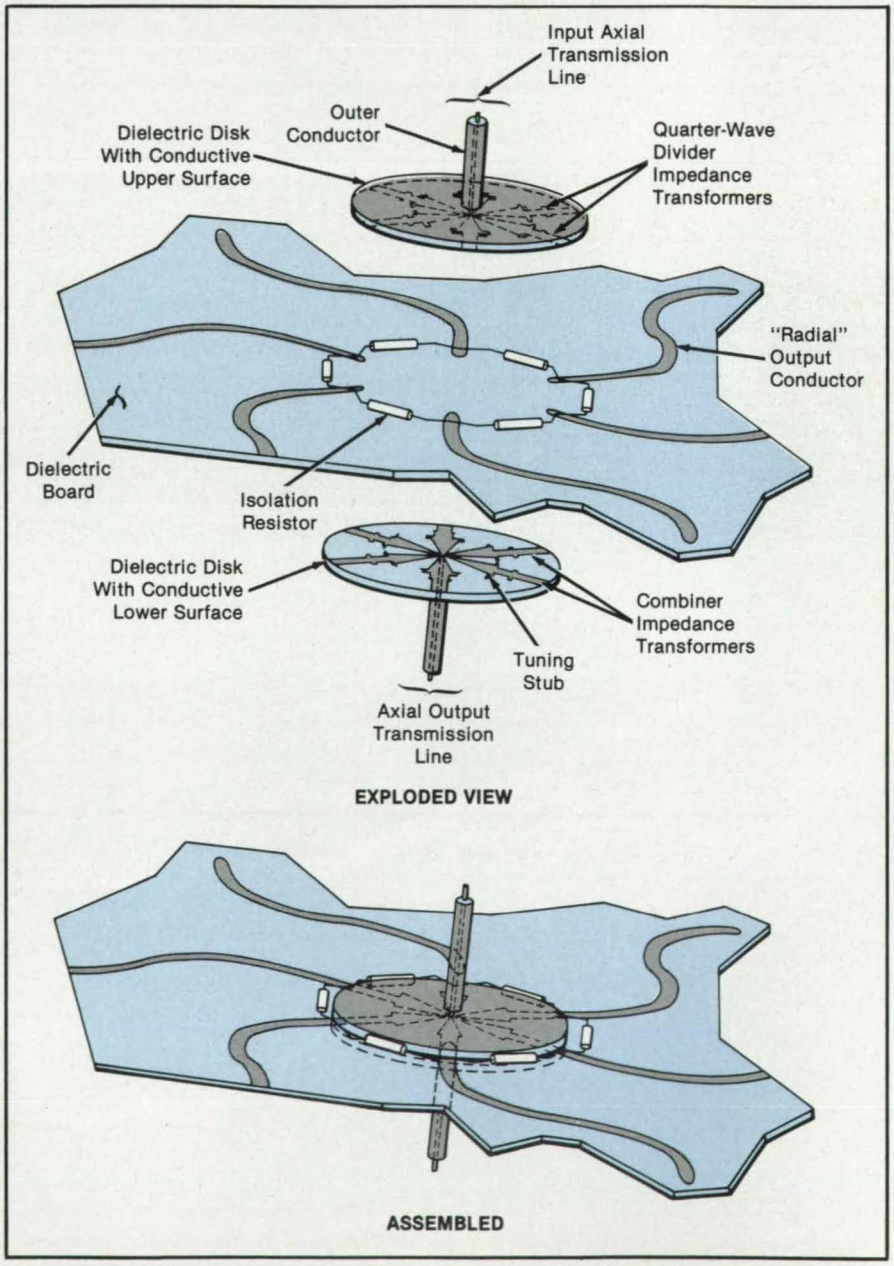
Parts are made on printed-circuit boards.

NASA's Jet Propulsion Laboratory, Pasadena, California

A variable coupling device divides or combines microwave power along an axial transmission line and/or a number of radial transmission lines. The device is made partly of electrically insulating boards coated on both sides with conductive copper foil in which circuit patterns are formed by standard printed-circuit techniques.

The device (see figure) includes a dividing-disk structure, a combining-disk structure, and an intermediate dielectric board that holds the generally radially oriented output conductors. The outer conductive surfaces of the dividing and combining disks are connected to the outer conductors of the input and output coaxial transmission lines, respectively. The conductive inner surface of the dividing disk is partly etched away, leaving a set of quarter-wave, power-dividing impedance transformers — one for each radial output conductor — to match the impedances of the output conductors to that of the input transmission line. A similar set of power-combining impedance transformers is etched onto the inner surface of the combining disk, except that the match in this case is to the output axial transmission line.

The radial output conductors are formed on the side of the dielectric board facing the dividing disk. The outer ends of the divider impedance transformers make electrical contact with stubs at the inner ends of the radial output conductors. Isolation resistors are connected between adjacent stubs to tie together the phases at all the radial outputs. In a typical system with 50-Ω input and output coaxial lines, these resistors would be 100 to 150 Ω each. The equal division of power and the equality of phase at equal radial distance along each radial output line are highly desirable in such applications as feeding multiple antenna elements.



Impedance-Matching and Power-Dividing transmission-line strips are formed on insulating disks and on a board by printed-circuit techniques. Power from the input transmission line is sent equally through the radial output conductors to radial output transmission lines and/or is coupled in varying degrees to an axial output transmission line.

Conductive patches are placed on the other side of the board (hidden in the figure), directly opposite the inner ends of the output radial conductors. The patches are thus capacitively coupled to the outer ends of the power-dividing impedance transformers, electrically in parallel with the output radial conductors. Phase-equalizing isolation resistors are also connected between these patches. The outer ends of the impedance transformers on the combining disk are connected to the patches.

The amount of axial coupling between the input and output axial transmission lines is determined chiefly by the thickness of the dielectric board. For maximum coupling, the combining and dividing disks are both aligned with each other and with the conductive pattern on the board. Provided that the necessary electrical contacts are maintained, the dividing and combining disks can be rotated slightly out of alignment to detune the device away from maximum coupling. The divider can also be operated as a combiner by reversing the flow of current.

This work was done by Yerriah P. Vaddiparty of Ford Aerospace and Communications Corp. for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 29 on the TSP Request Card.*
NPO-16966

Breakdown-Resistant RF Connectors for Vacuum

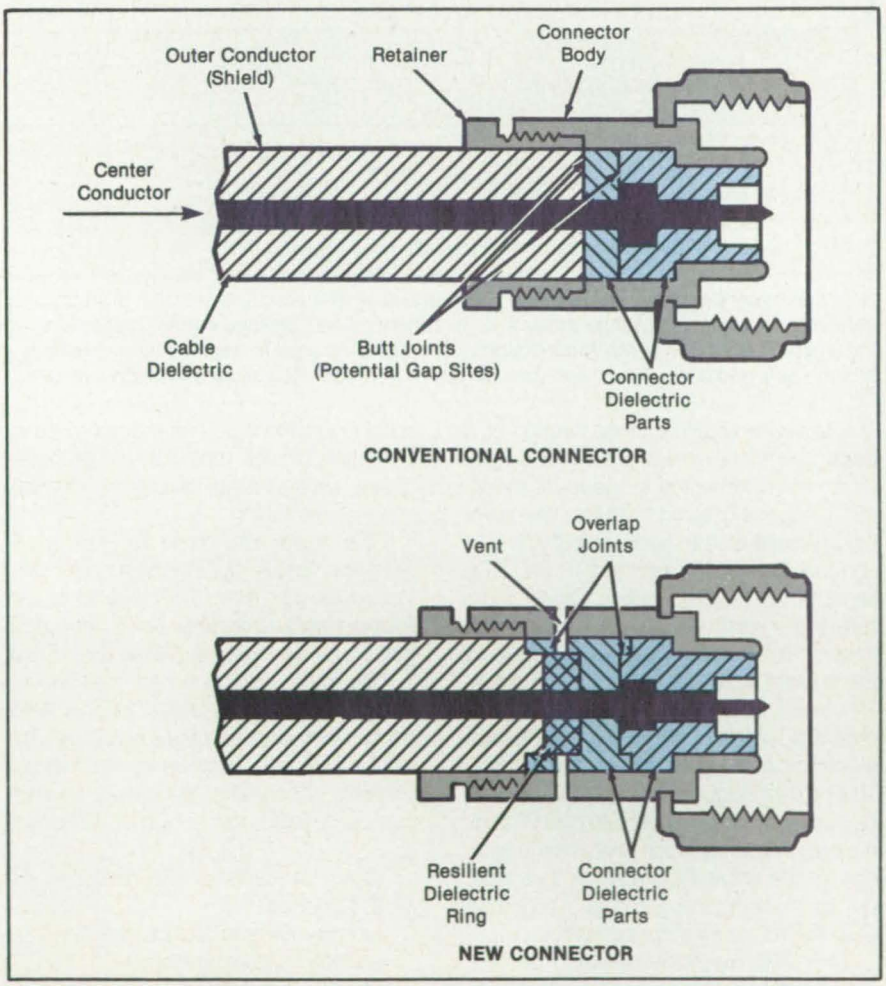
Resilient inserts compensate for insulation shrinkage.

NASA's Jet Propulsion Laboratory, Pasadena, California

A coaxial-cable connector for radio-frequency (RF) energy resists electrical breakdown in a vacuum. The connector can be used on RF equipment in vacuum chambers as well as in spaceborne radar and communication gear.

RF cables and connectors are especially prone to breakdown in a vacuum at power levels of 10 watts or more. This is because coaxial connectors tend to develop gaps between dielectric elements because of thermal expansion and contraction, aging, or manufacturing inaccuracies. RF breakdown can occur wherever a gap develops.

If the pressure in the void is between 0.01 and 0.1 torr (~1 to ~10 N/m^2), RF energy can ionize the rarefied gas, and the ionization can form carbon tracks that lead to electrical failure. If the pressure in the gap is about 0.001 torr (~0.1 N/m^2) or less, multipactor breakdown can occur. This breakdown is a secondary-electron-resonance phenomenon that happens only with RF energy in a vacuum. It rapidly develops into ionization and electrical failure.



Old and New Coaxial Connectors are compared in cross section. The resilient dielectric ring fills the gap created by the lengthwise shrinkage of the cable dielectric. The overlap joints eliminate straight paths between the center conductor and outer conductor. The vent allows trapped air to escape.

In the new connector, a resilient dielectric ring is placed between the solid dielectric pads on the connector and the insulation in the cable (see figure). The ring is slightly compressed (by about 50 percent of its thickness) in the assembled connection. Thereafter, shrinkage of the cable dielectric is taken up by expansion of the resilient ring so that a gap is not allowed to develop in the connector. Two types of silicone rubber dielectric compounds, RTV 3110 and 566, were tested for this application with excellent results.

As a further precaution, the butt joint between the solid dielectric parts in the connector is replaced by an overlap joint. This type of joint eliminates a straight-line path between the center conductor and outer conductor of the connector assembly to inhibit multipactor breakdown.

This work was done by Edward R. Caro and Walter J. Bonazza of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 63 on the TSP Request Card.*

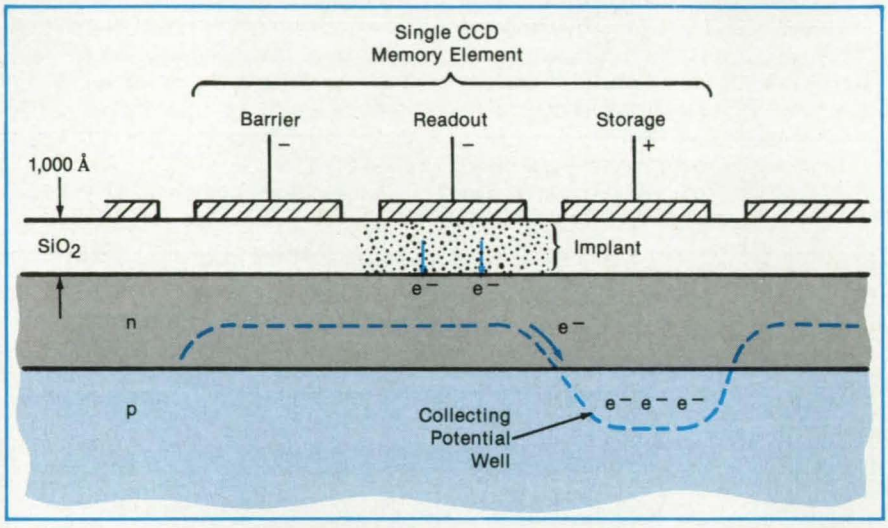
Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 19]. Refer to NPO-16764.

CCD Memory

A CCD memory device yields over 6.4×10^8 levels of information on a single chip.

NASA's Jet Propulsion Laboratory, Pasadena, California

A charge-coupled device (CCD) has been demonstrated to operate as either a read-only memory (ROM) or a photon-programmable memory with a capacity of 640,000 bits, with each bit capable of being weighted to more than 1,000 discrete analog levels. Larger memory capacities are now possible using the proposed approach in conjunction with CCD's now being fabricated, which could yield over 4×10^9 discrete levels of information on a single chip.



A CCD Memory Cell (1 out of 640,000) is programmed by ion implantation within the SiO_2 layer beneath a readout gate. When the gate is negatively pulsed, leakage current proportional to the implant dose flows into the n-channel. The signal charge is then collected beneath a storage gate and later clocked and transferred in a normal CCD fashion to an output amplifier.

The figure shows a cross section of a single memory element (1 out of 640,000), which is implemented in the ROM mode. Information is programmed into the memory cell beneath the readout electrode by a shallow implant formed within the SiO_2 layer. When the electrode is biased negatively (beyond where the n-channel inverts), a leakage current proportional to the implant dose flows through the oxide. The signal charge is then collected into a potential well located beneath a storage electrode and confined by a barrier gate. This process requires about 100 μs and occurs simultaneously in all 640,000 CCD elements. The information contained in each cell for the entire CCD array is then read out by clocking the gates in the normal CCD fashion to an output amplifier.

The CCD memory can also be programmed by exposing each memory cell to an intense light pattern, which also causes the conductivity to change within the SiO_2 layer proportionally to the incoming photon flux. The programmed information can be read out, as described above, several times before the memory requires refreshing.

This work was done by James R. Janesick, Tom Elliot, Dave Norris, and Fred Vescelus of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 72 on the TSP Request Card.*

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

California Institute of Technology
E. O. Ansell,
Director Patents and Licensing
307 Keith Spalding Bldg.
Pasadena, CA 91125

Refer to NPO-16150, volume and number of this NASA Tech Briefs issue, and the page number.

Controller for a High-Power, Brushless dc Motor

Driving and braking torques are controllable.

Marshall Space Flight Center, Alabama

A control circuit operates a 7-kW, 45-lb-ft (61-N-m), three-phase, brushless dc motor in both the motor and generator modes. In the motor mode, energy from a power source is pulse-width modulated to the motor through a modified "H-bridge" circuit. In the generator mode, the energy from the motor is pulse-width modulated into a bank of load resistors to provide variable braking torques. The circuit provides high-resolution torque control in both directions over a wide range of speeds and torques and has been tested successfully at bus voltages up to 200 Vdc and currents up to 45 A.

The control circuit includes control logic, a motor-driving amplifier, rotor-position feedback, and motor-current feedback (see figure). The control logic accepts pulse-width modulation data from an outside source (typically a computer) and commands the motor-control amplifier to apply to the motor a voltage proportional to the commanded pulse width. Hall-effect sensors on the motor provide rotor-position data, and the control logic selects the appropriate amplifier leg. Hall-effect current sensors provide the current feedback necessary to limit the motor current to prevent overstress of the bridge amplifier circuit and excessive torques on devices driven by the motor. Signals from the current sensors are conditioned and fed back to the control logic.

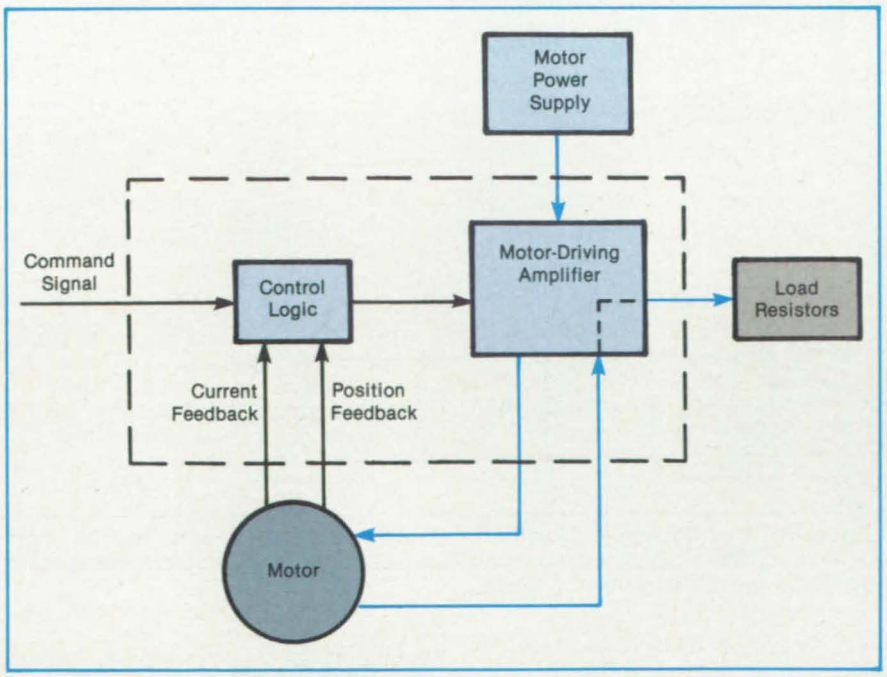
The control logic consists of command-decoding logic, pulse-width-modulation-generating logic, and motor-commutating logic. The control logic accepts parallel command data from the computer and commands the selected legs of the bridge to turn on. It also controls the routing of power to or from the motor through large power relays.

The motor-driving amplifier is a modified "H-bridge" with 10 power metal-oxide/semiconductor field-effect transistor (MOSFET) devices in parallel in each leg. Driving each group of 10 power MOSFET's is an optically isolated, high-current (3-A peak) predriver.

In the motor mode, the bridge circuit pulse-width modulates the bus voltage to the motor until the current reaches a steady-state or current-limit value. If the current reaches the current-limit value, the limit circuit turns off the upper bridge leg until the current decays below this value. The upper leg is then allowed to turn on again. This on/off cycle continues and maintains the current at the limit value.

In the generator mode, the motor current is pulse-width modulated through one or more of three external resistors selected in parallel. The alternate, high-current path is a short across the motor, provided by the bridge circuit. The alternation between the short and resistive paths provides for the control of the braking torque via the control of the pulse width. The use of several external load resistors is necessary to achieve proper torques without overstressing the bridge electronics.

This work was done by David J. Fleming and Terence A. Makdad of Martin Marietta Corp. for **Marshall Space Flight Center**. *For further information, Circle 94 on the TSP Request Card.*
MFS-28168



The **Control Circuit** channels the flow of electrical energy among the power supply, motor, and load resistors in a way that enables high-resolution torque control in both directions over a wide range of speeds and torques.

Oscillator or Amplifier With Wide Frequency Range

Inductive and capacitive effects are synthesized with feedback circuits.

Goddard Space Flight Center, Greenbelt, Maryland

An oscillator/amplifier is resistively tunable over a wide frequency range. Feedback circuits containing operational amplifiers, resistors, and capacitors synthesize the electrical effects of an inductance and capacitance in parallel between the input terminals. The synthetic inductance and capacitance, and, therefore, the resonant frequency of the input admittance, are adjusted by changing a potentiometer setting.

The oscillator/amplifier circuit is shown in Figure 1. The input signal is introduced in parallel to the noninverting input terminals of operational amplifiers A_1 and A_2 and to the potentionmeter cursor. The voltages produced by the feedback circuits in response to input voltage V_i are indicated at the various circuit nodes.

Extracting only those nodal voltages that affect the input current, the equivalent circuits of Figure 2 are constructed. The current in the upper branch of the potentiometer is given by $I_2 = V_i/[j\omega C_1 R_1 (R_m + R_3)]$, which is equivalent to the current that would flow in an inductance $L_{eq} = C_1 R_1 (R_m + R_3)$ connected between the input terminals. The current in the lower branch of the potentiometer is given by $I_3 = V_i j\omega C_2 R_2 \times (R_m + R_p - R_3)$, which is equivalent to the current that would flow in a capacitance $C_{eq} = C_2 R_2/(R_m + R_p - R_3)$ connected between the input terminals.

The synthetic parallel combination of inductance and capacitance has a resonant frequency

$$f = \omega/2\pi = (1/2\pi\sqrt{R_1 C_1 R_2 C_2}) \times [(R_p + R_m - R_3)/(R_m + R_3)]^{1/2}$$

Since the extreme potentiometer settings are $R_3 = 0$ and $R_3 = R_p$, the ratio of maximum to minimum resonant frequency is $(R_p + R_m)/R_m$. Thus, the circuit can be tuned over a wide frequency range by adjusting the potentiometer. For example, using the practical values $R_p = 1\ M\Omega$ and $R_m = 1\ k\Omega$, the maximum frequency is 1,001 times the minimum frequency. This represents a much wider tuning range than is available from conventional resistively tuned resonant circuits.

The equivalent negative resistance signifies that power is generated by the circuit at the resonant frequency. If R_o is less than the source resistance R_s, enough power is generated to sustain oscillations, in which case the amplitude-limiting network is used. If R_o exceeds R_s, the oscillations are not sustained and the circuit acts as a tuned amplifier.

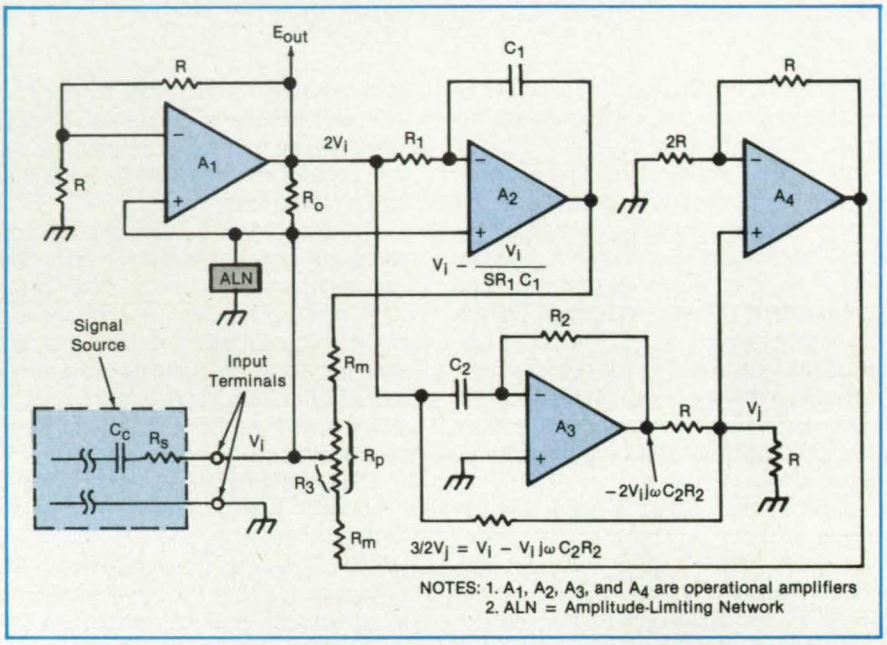


Figure 1. The **Oscillator/Amplifier Circuit** is built up from feedback circuits containing operational amplifiers, capacitors, fixed resistors, and one variable resistor.

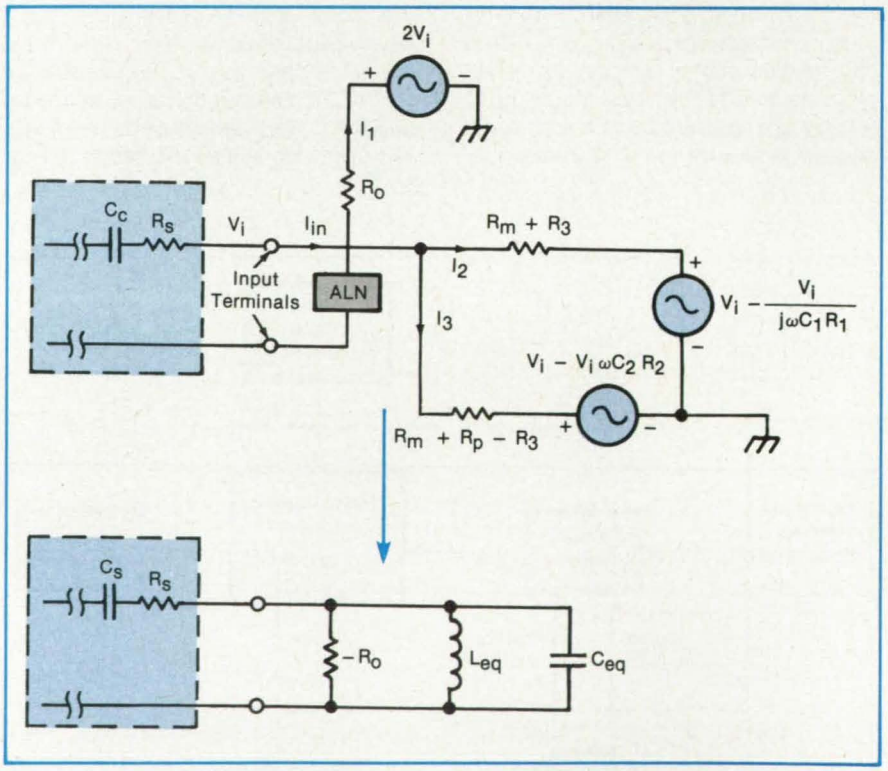


Figure 2. These **Equivalent Circuits** have the same input characteristics as those of Figure 1. The input admittance exhibits a resonance at the resonant frequency of synthetic reactive elements C_{eq} and L_{eq}.

$$Q = \omega L_{eq}/R_s = 1/\omega C_{eq} R_s = (1/R_s)[C_1 R_1 (R_m + R_3)(R_m + R_p - R_3)/C_2 R_2]^{1/2}$$

The output is taken from the output terminal of A_1.

This work was done by L. Kleinberg and J. Sutton of **Goddard Space Flight Center**. *No further documentation is available.* *GSC-12960*

Books and Reports

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

More Abstracts on Effects of Radiation on Electronic Devices

A previously published bibliography is augmented.

A second volume of a bibliography summarizes the literature on radiation effects on new electronic devices. Like the first volume, the second covers material published in the period 1984–85. The radiation effects include those of protons, electrons, neutrons, gamma rays, and cosmic rays at energies up to about 20 GeV.

The second volume contains 219 abstracts from unclassified sources. The abstracts are organized into four sections: (1) dose-rate effects, new technology, post-irradiation effects, and test environments.

Usually, the type of device to which an abstract applies is identified; for example, complementary metal/oxide semiconductor transistor, metal/semiconductor field-effect transistor, or surface-barrier detector. Where the original abstract is lengthy or vague, it has been condensed or modified for inclusion in the bibliography, to maximize its utility for radiation test engineers.

This work was done by Frank L. Bouquet of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the document, "Bibliography of Total Dose Radiation Effects on Electronics, Volume II", Circle 28 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, NASA's Resident Office-JPL [see page 19]. Refer to NPO-16959.

New Products

EAO Switch Corporation, Milford, CT, introduces the Lightbit LB 85 fiber optic switching system for hazardous location control. The system operates optomechanically by transmitting a light-impulse switching command from an electric switch located outside the hazardous environment. The command passes through the plastic optic cable where it performs the desired switching operation via a fiber optic switch — either a pushbutton, limit switch or microswitch that makes or breaks the beam of light. **Circle Reader Service Number 413.**

At 20 watts per cubic inch, **Inland Motor**'s BLM 1000 CB offers high power density in a commercial brushless servo amplifier. The modular unit requires no extra cooling. EMI/RFI is attenuated by the enclosure, and the FET-based PWM design gives quiet operation at better than 90% efficiency. Complete short circuit protection assures the user of trouble-free operation. A high performance integral current loop provides bandwidth in excess of 5 kHz. **Circle Reader Service Number 437.**

Isotec, Inc. (Dayton, OH) introduces the ANA/MS system, a dedicated Nitrogen 15 and Carbon 13 isotope ratio mass spectrometer. The compact system consists of a fully automated sample preparation unit and a mass spectrometer with capillary interface. Able to analyze 12 samples per hour, the system uses the Dumas Combustion method for direct analysis of biological, agricultural and environmental samples with no Kjedahl preparation required. **Circle Reader Service Number 476.**

Electronic Systems

Hardware, Techniques, and Processes

Gain-Compensating Circuit for NDE and Ultrasonics

More information can be retrieved from high-loss materials.

Langley Research Center, Hampton, Virginia

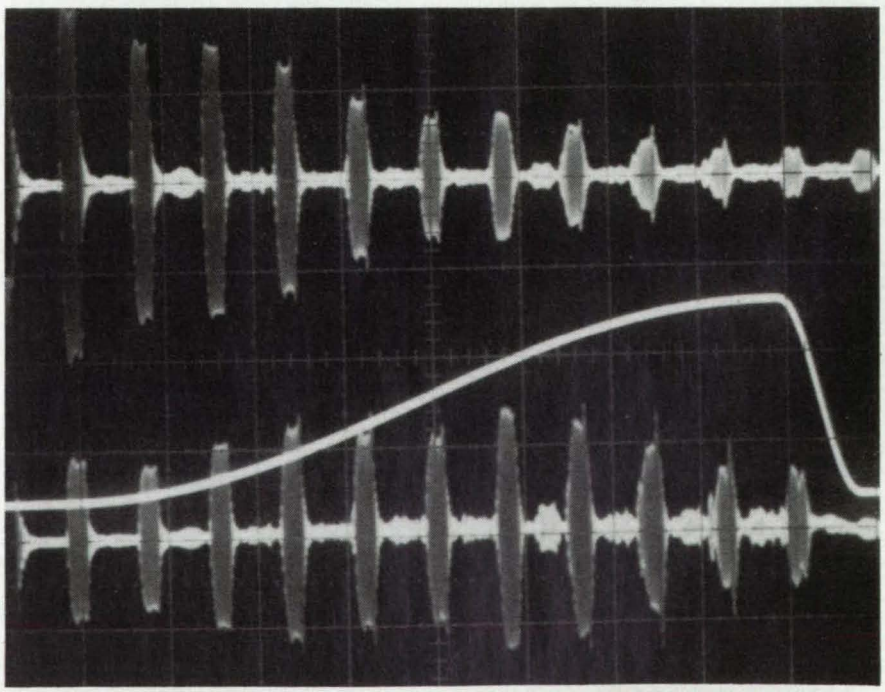
A high-frequency gain-compensating circuit has been designed for general use in nondestructive evaluation (NDE) and ultrasonic measurements. The circuit controls the gain of an ultrasonic receiver as a function of time to aid in measuring the attenuation of samples with high losses; for example, human skin and graphite/epoxy composites. The circuit features a high signal-to-noise ratio (100 dB), a large signal bandwidth (in excess of 50 MHz), and a large dynamic range (greater than 50 dB). The control bandwidth of 5 MHz ensures the accuracy of the control signal.

The ultrasonic signal is applied to one channel of a dual-channel analog multiplier with the other channel input grounded. Both outputs are then fed to a differential amplifier to remove distortion introduced in the control section of the multiplier. The output of the differential amplifier is then amplified further to bring the overall system gain to the desired level.

The system can be operated in several different modes, depending on the control input signal used: a linear ramp can be used to control the gain in a linear fashion; an exponential ramp can be used to compensate for ultrasonic attenuation, which usually decays exponentially (see figure); and a pulse waveform can be used to make the circuit function as a gate. Any commercial ultrasonic receiver can be used as a "front end" for the system. Control signals, which must fall between 0 and 3 volts, can be supplied by a function generator.

The circuit currently is being used for a number of applications. In one case, its use enables the retrieval of more information from ultrasonic signals sent through composite materials that have high losses. Another application is in the use of ultrasonics to measure skin-burn depth in humans. The circuit affords the large bandwidth necessary for adequate resolution of the burn depth while compensating for the large high-frequency ultrasonic attenuation of human skin.

This work was done by Peter W. Kushnick of PRC Kentron, Inc. for **Langley Research Center**. *For further information, Circle 15 on the TSP Request Card.*
LAR-13543



A **Typical Pulse-Echo Pattern** received after an ultrasonic tone burst has been sent through an aluminum sample is shown in the top trace. The tone-burst pattern decays nearly exponentially. The middle trace is the control signal designed to offset the exponential decay. The bottom trace shows the effect of compensation for the exponential decay.

Trellis-Coded Modulation for Fading Channels

Modulation and coding are designed together for best performance.

NASA's Jet Propulsion Laboratory, Pasadena, California

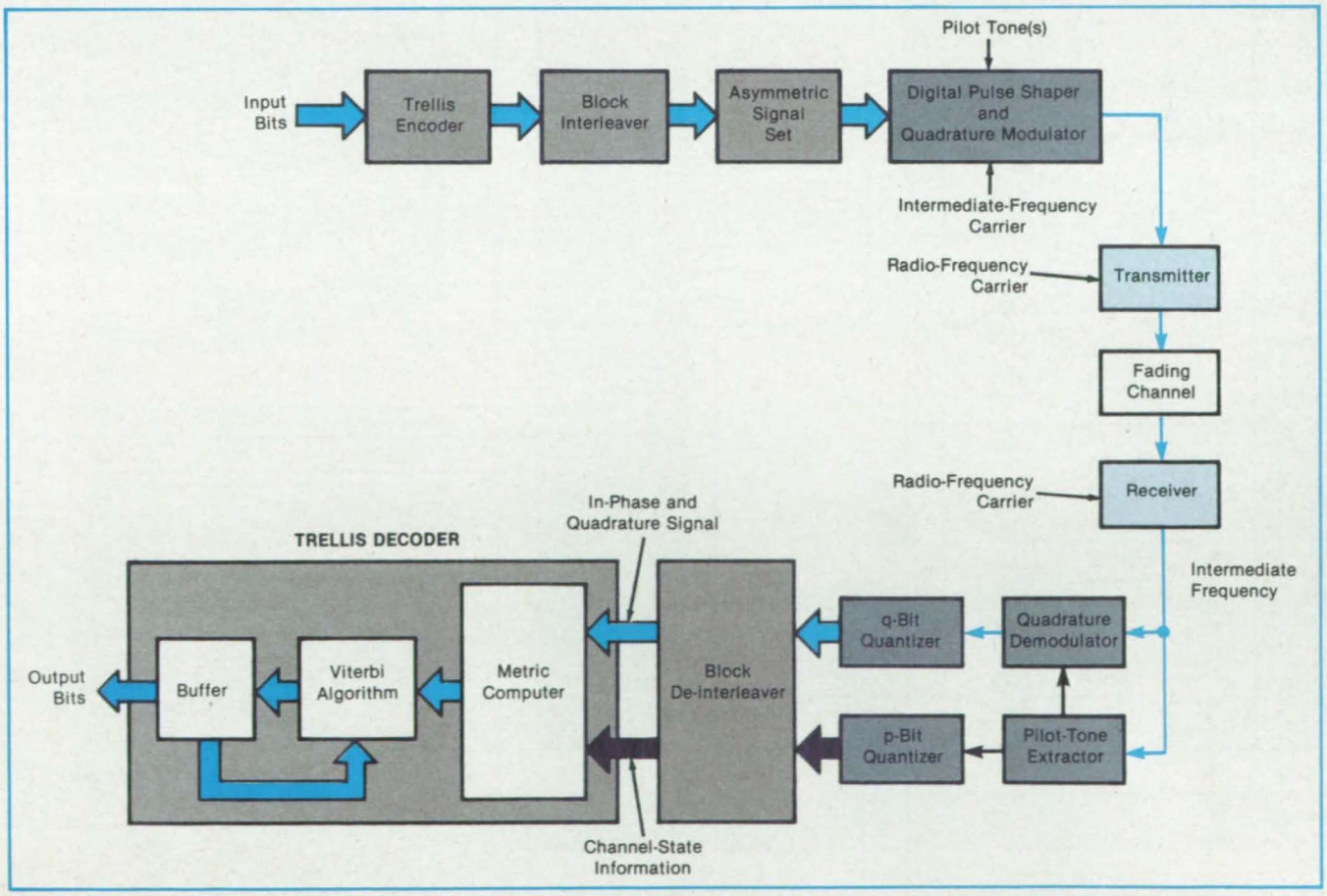
In a proposed communication system, digital signals would be transmitted efficiently over a fading channel by a combination of trellis coding and multiple-phase-shift keying (MPSK) with the addition of asymmetry to the signal set. The coding and modulation schemes are not designed separately as in previous systems but are integrated to yield bandwidth-efficient modulation and forward-error-correction coding. The system concept helps to satisfy the need for the reliable high-quality transmission of voice and data between land-mobile units via satellites, where limitations of power and bandwidth are imposed simultaneously. The concept may also be applicable to ionospheric communications between fixed or mobile units.

The system is illustrated in the figure. Input bits representing data or digitally encoded speech are passed through a rate-$n/(n+1)$ trellis encoder, which is normally implemented with a combination of n shift registers and appropriate modulo-2 adders (exclusive-OR gates). The encoder-output symbols are then block-interleaved to break up burst errors caused by amplitude fades of duration greater than one symbol time.

Groups of $n+1$ interleaved symbols are mapped (with a read-only memory) into the MPSK signal set according to the set-partitioning method. The pulses of the in-phase and quadrature components of the mapped signal point are digitally shaped to limit adjacent channel interference and to control intersymbol interference. The signals then modulate the quadrature carriers for transmission over the channel. If pilot-tone calibration techniques are used to recover the faded carrier at the receiver, then the pilot tone (or tones) must be added to the data-modulated signal before transmission.

In the receiver, the effect of fading on the phase of the incoming signal is corrected by a phase-locked loop or pilot-tone calibration technique. The faded, noise-corrupted in-phase and quadrature signal components are demodulated with the extracted pilot tone(s), q-bit quantized for soft-decision decoding, and then block-deinterleaved. The metric chosen for the Viterbi algorithm in the decoder depends upon whether or not channel-state information (CSI) is provided. A measure of CSI can be obtained from the power in the recovered pilot tone(s). Furthermore, the number of bits of quantization, p, for this operation can be much smaller than q since the accuracy of the CSI has only a secondary effect when compared with that of the soft decisions themselves.

Finally, the tentative soft decisions from the Viterbi decoder are stored in a buffer, the size of which is a design parameter. In particular, for the case of speech transmission, the total coding/decoding delay must be kept below about 60 ms so as not to be objectionable to the listener. Thus, for a



Coded Voice or Data Signals would be transmitted efficiently over a fading channel in which signal power and bandwidth are restricted. This system would be useful primarily in mobile communications.

given input bit rate, the decoder buffer and interleaving frame sizes must be limited so as to produce at most a 60-ms delay.

This work was done by Marvin K. Simon and Dariush Divsalar of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 59 on the TSP Request Card.*
NPO-16904

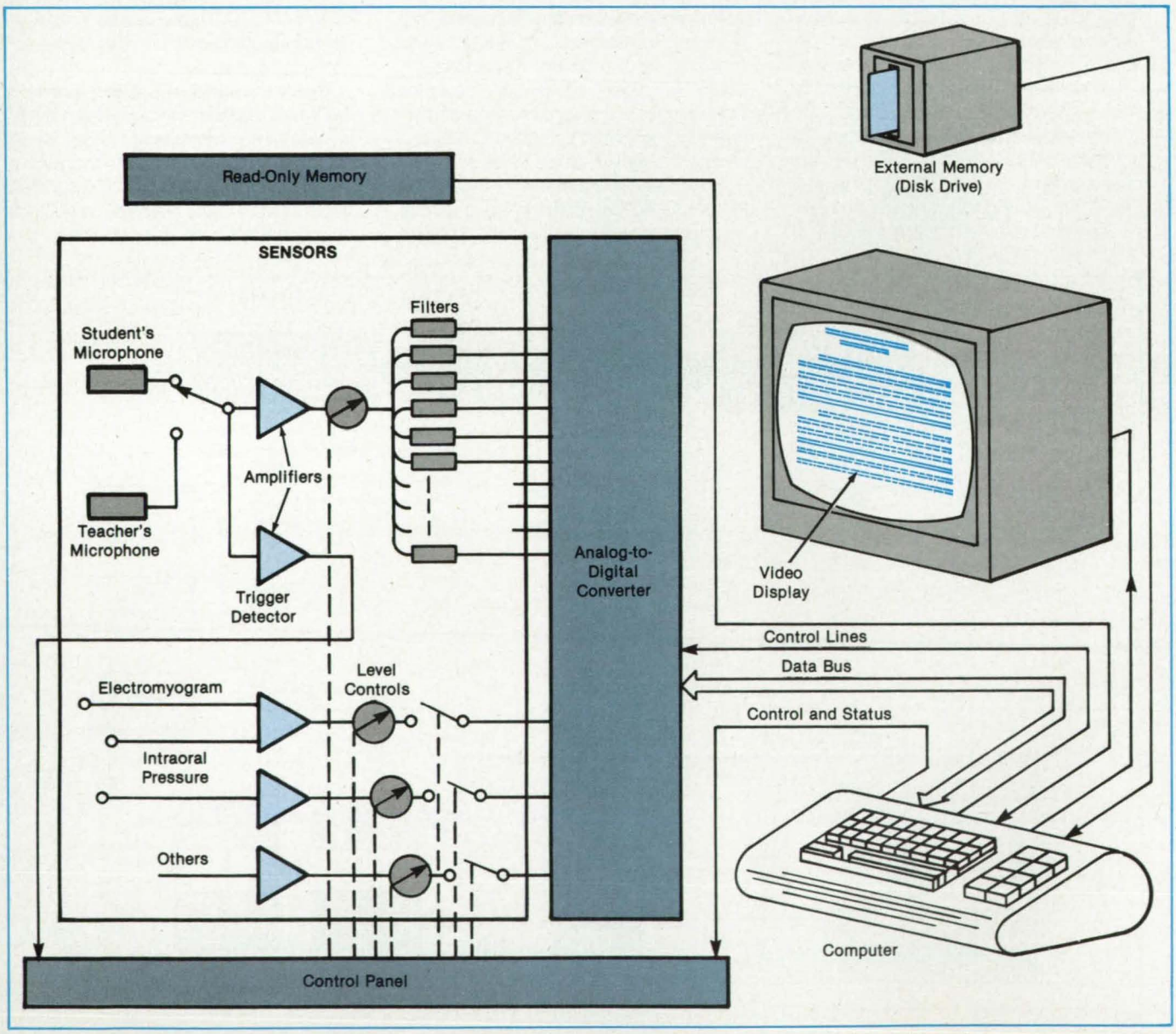
Visual Speech-Training Aid for the Deaf

This system enables a student to compare his/her sound with the "correct" sound.

Ames Research Center, Moffett Field, California

Teaching the deaf to speak could be aided by an electronic system that would provide a striking colored, pictorial representation of a sound; i.e., the energy at different frequencies as a function of time. Other modalities, such as nasality, intra-oral pressure, and lip-muscle contraction, could be pictorialized simultaneously. The use of standard components, including a personal microcomputer, would help to reduce the cost below that of prior voice-training systems.

The proposed system is shown schematically in the figure. The sensors block includes a microphone (or two, if a separate one is to be available to a teacher) and additional modules to provide other modalities as required. These may include electromyogram electrodes and amplifiers, pressure or flow sensors for nasality detection or intra-oral pressure measurement, or others. These components provide a set of electrical analog outputs characterizing the desired pa-



In this **Speech-Training System**, microphone output is separated by filters into narrow frequency bands, changed into digital signals, formatted by a computer, and displayed on a television screen. Output from other sensors can be displayed simultaneously, or the screen can be split to allow the sound produced by a student to be compared with that of the teacher.

rameters of the student's speech.

The microphone output is directed to a set of analog bandpass filters that separate the frequency range of 100 Hz to 5 kHz into a series of narrow frequency bands. A triggering circuit detects the initial sound and initiates the display process.

Following the sensors block is an analog-to-digital conversion section, which samples, in turn, the filters and the channels containing the additional modalities and converts their outputs to digital form usable by the computer. The computer converts the data in the various channels to a usable format and causes it to be displayed on the video monitor. The normal format is expected to be a time-resolved spectrum, with the horizontal position of a point representing time, the vertical position representing the frequency, and the color or color/intensity combination representing the energy contained in that frequency band. Other modalities would be displayed similarly and simultaneously on adjoining tracks.

Software, incorporated into the system as read-only memory connected to the external-memory port of the computer, controls the sampling and analog-to-digital conversion process and the display. The control panel allows the teacher or other user to control such functions as the choice of modalities, analog settings to individual preferences or characteristics, display time or erase by command, and single- versus split-screen options.

Varied and interesting visual displays would be provided to encourage vocalization by a deaf infant. In this case, only the sounds of the subject would be displayed. The spectrum should be displayed for only a few seconds to encourage continued vocalization.

A teaching situation requires more direct control of the operation, including choice of the modalities to be displayed and retention of the spectrum for as long as required, with erasing on command. If it is desired to display teacher and student spectra simultaneously for comparison, a split-screen presentation may be used, in which case two microphones may be used and separate erase controls provided for the two portions.

With the provision of additional memory, stored or animated pictures may be incorporated; for example in one portion of the split-screen format. Schematic or pictorial diagrams of the vocal system may be provided to show sound-producing mechanisms (i.e., tongue positions) for each phoneme. Animation may be provided to demonstrate phoneme transitions or the formation of such transitory sounds as plosives.

This work was done by Robert J. Miller of **Ames Research Center**. *For further information, Circle 78 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center [see page 19]. Refer to ARC-11526.

Noncontacting Thermometer

An instrument would measure interior and surface temperatures.

Marshall Space Flight Center, Alabama

A proposed laser/ultrasonic thermometer would measure the bulk and surface temperatures of a part without physical contact — unlike a pyrometer, which measures only the temperature of the surface. No sensors or wire connections would be needed on the part, which may be moving or stationary. Problems of bonding sensors, of mutual diffusion of materials between the sensor and the part, and of disturbances of fluid and heat flows by the sensor would thus be avoided. A single thermometer could be used to measure many parts remotely; for example, the blades of a rotating turbine.

According to the concept, a light pulse from a laser would be directed at the part, generating in it an ultrasonic pulse composed of both surface and bulk acoustic waves. The phase variations induced in a separate laser beam by reflection from the waves on the surface would be used to measure the start of a pulse and the echoes returning both along the surface and to the surface through the bulk of the part.

Since the time of passage of an acoustic pulse through the bulk is a function of the bulk temperature, the average bulk temperature could be determined directly from the echo delay. In addition, if the surface acoustic wave across the part were to be measured, the surface temperature could be determined. The duration, repetition rate, and other parameters of the pulses and the position of the excitation beam on the part could be selected so that both the surface and the bulk temperatures could be measured by the same instrument.

This work was done by Lynn M. Wyett of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 19]. Refer to MFS-29277.

New Products

The PME 2SB, a fast, dual ported dynamic RAM board providing high density storage for VMEbus systems and full implementation of the VME Subsystem Bus (VSB) is available from **Plessey Microsystems**, Pearl River, NY. The block transfer mode of the PME 2SB allows fast transfer of paged data between VMEbus and VSB. It can be configured as a one, two, four or eight Mbyte memory board, and includes data read-ahead on block transfers and pipelined address and data cycles, enabling data transfer rates in excess of 20 Mbytes per second across either bus. **Circle Reader Service Number 484.**

Linseis Corp. (Princeton,NJ) introduces the LP-12, a 1-12 channel microprocessor-controlled trend recorder. The 12-color print head is driven by a stepping motor accurate to .25%. Printing frequency ranges from 1-99 seconds/point regardless of the number of channels selected. The recorder can be connected to a computer through an optional RS-232/IEEE 488-bus, and can accept either AC or DC input. **Circle Reader Service Number 336.**

Gould Inc. Test and Measurement (Cleveland, OH) introduces an 8-channel thermal array recorder with a fixed array of thermal writing styli providing a recording width up to 200mm with 8 dots/mm resolution. The TA2000 recorder's linear thermal array head and digital design improve reliability by eliminating moving parts. The lack of mechanical inertia increases frequency response. In addition, plain thermal paper can be used. A simple front panel with a cover for infrequently-used special function keys provides convenient access to recorder controls. **Circle Reader Service Number 395.**

Contact East's new spring/summer catalog contains thousands of products for aviation design and test engineers, mechanics and inspectors involved with electronic and electrical equipment. To receive the free catalog and a one-year subscription, **Circle Reader Service Number 424.**

Physical Sciences

Remote Optical Combustion Analyzer

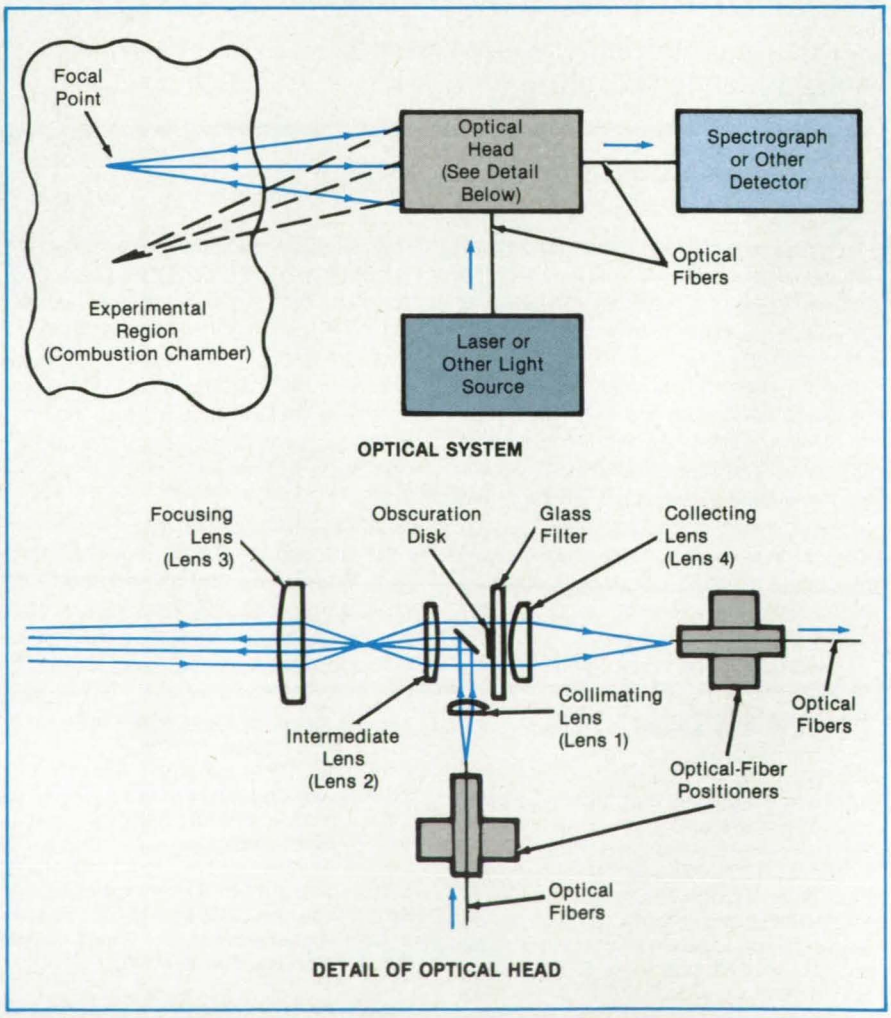
Delicate instruments are kept far from the combustion process.

Marshall Space Flight Center, Alabama

A rugged optical head enables remote, nonintrusive measurements of temperatures and chemical compositions in hostile environments — in combustion chambers, for example. The head brings laser light to the system under test and carries system-scattered light to a spectrograph or other instrument.

The head is mounted securely on an optical port in the test system. Optical fibers transmit light from the laser to the head and from the head to the spectrograph. Light from the laser diverges from the fiber tip and is collimated by lens 1 (see figure). The nearly parallel light rays from lens 1 are turned by a prism so that the light bundle coincides with the optical axis of the head. The laser radiation is then brought to an intermediate focus by lens 2 and finally is refocused on the measurement volume by lens 3. Lenses 2 and 3 can be translated with respect to each other so that the measurement region surrounding the final focal point can be moved along the optical axis of the head to the desired location within the system chamber. The axis of the measurement volume can be slued by prisms or mirrors.

Radiation backscattered from the measurement volume is collected and collimated by lenses 3 and 2. Most of the backscattered light passes around the prism and through the filter, which blocks



The **Optical Head Beams Light** from a laser source to a test chamber, then collects the backscattered light from the chamber and sends it to spectrographic equipment. The lenses, prisms, and optical-fiber tips can be moved so that the focal point can be precisely positioned in the test chamber.

the unwanted wavelengths. The light then enters lens 4, which focuses it into the optical fiber leading to the spectrograph. An obscuration disk can be used to restrict the depth of field of the optics.

The light delivered to the spectrographic equipment is analyzed to determine its spectral distribution or intensity. From these data, the temperature and chemical composition of the material in the measurement volume can be determined.

Currently-available glass optical fibers are well suited to the transmission of near-infrared light. When data are needed at green and blue wavelengths, fibers are less efficient carriers but nevertheless are usable if the fiber lengths are less than about 100 meters. Fluorescence measurements require higher photon energies, and the probing radiation therefore must be in the ultraviolet region. Even though fiber-transmission characteristics are not favorable at these short wavelengths, the measurement scheme may still be useful if a source of sufficiently high power is available to overcome the attenuation in the fibers, if the fibers are not degraded by the high power dissipation in them, and if a relatively low photon flux is acceptable in the measurement volume.

This work was done by A. C. Eckbreth and J. A. Shirley of United Technologies Research Center for **Marshall Space Flight Center**. *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center *[see page 19].* *Refer to MFS-28146.*

Cascaded-Blackbody Heat Radiators

Textured fins increase the effective emissivity.

Marshall Space Flight Center, Alabama

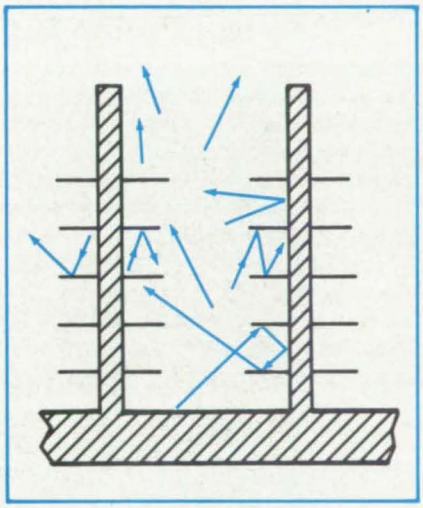


Figure 1. **Fins With Finned Surfaces** form large cavities lined with smaller cavities to produce a cascaded-blackbody effect.

A new class of heat radiators are made of metal or other conductive fin stock, the fins of which are textured or covered with smaller fins (see Figure 1). Measured from the outside, the effective emissivity of a projected radiator surface is greater than, and somewhat independent of, the emissivity of a flat surface made of the same material. Thus, special coatings to enhance emissivity are not required, and the emissivity will not be degraded significantly in the long term by environmental effects. Intended originally to radiate excess heat away from spacecraft, the new radiators can also be used on Earth to dissipate heat in vacuum systems.

With its finned structure, each radiator effectively consists of large cavities, the walls of which are lined with small cavities. In a manner reminiscent of anechoic chambers and conventional "blackbody" furnaces, multiple reflections, absorptions, and reradiations occur on the myriad of cavity walls. Thus, when viewed as a whole, the radiator behaves more nearly like a black body than does a flat surface of the same material. The blackbody effect is enhanced by cascading the effects of the small cavities in the walls of the large cavities.

The radiator surface can be made by bonding metal powder, metal felt, knitted wire, or smaller fin stock to a solid fin-stock substrate. An experimental version was made of composite copper powder on parallel-finned copper stock. For measurements of its effective emissivity, it was placed in a vacuum close to (but not touching) two water-cooled, flat-plate calorimeters and heated electrically. The same test was also performed on two similar radiators, one made of flat copper plate and the other of simple parallel-finned copper stock. As shown in Figure 2, the composite finned radiator performed better than the other two at temperatures from about 200 to 600 °C. The comparison of performance is uncertain at lower temperatures because the specimens underwent some vacuum cleaning when heating began and the first measurements were taken.

For effective heat dissipation, the new radiators must not be allowed to face other heat sources because the same cascaded-blackbody effect that increases the emissivity also increases the absorptivity. Thus, for example, a spacecraft radiator

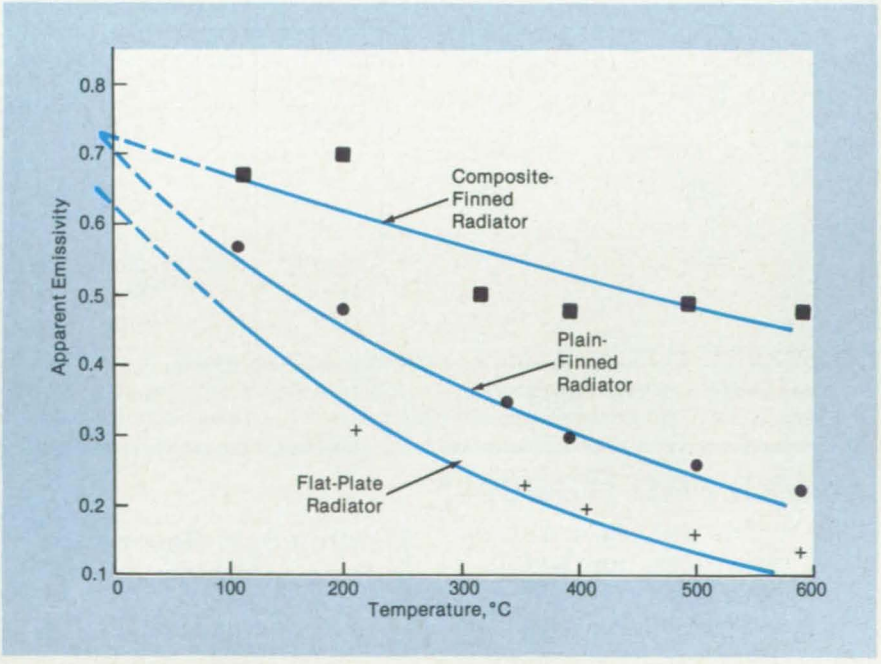


Figure 2. The **Apparent Emissivities** of three radiating surfaces of the same material were measured. The highest emissivity is exhibited by the most highly textured surface.

must be pointed away from the Sun and the Earth, and a laboratory vacuum radiator must be pointed toward a cool, absorptive surface.

This work was done by Michael D. Keddy, G. Yale Eastman, and Donald M. Ernst of Thermacore, Inc., for **Marshall Space Flight Center**. *For further information, Circle 134 on the TSP Request Card. MFS-26033*

ESR Analysis of Polymer Photo-Oxidation

Electron-spin resonance identifies polymer-degradation reactions and their kinetics.

NASA's Jet Propulsion Laboratory, Pasadena, California

The processes of photo-oxidation and aging in polymeric materials have been observed at the molecular level by using the electron-spin-resonance (ESR) technique combined with in situ ultraviolet irradiation of the polymers in atmospheres with different oxygen concentrations. Unlike the traditional approach to the study of such aging processes, which has been to monitor such macroscopic mechanical properties as stress and strain, the new technique enables the derivation of a kinetic model of the specific chemical reactions involved in the degradation of a particular polymer. The detailed information provided by the new method should enable the prediction of aging characteristics long before the manifestation of macroscopic mechanical properties.

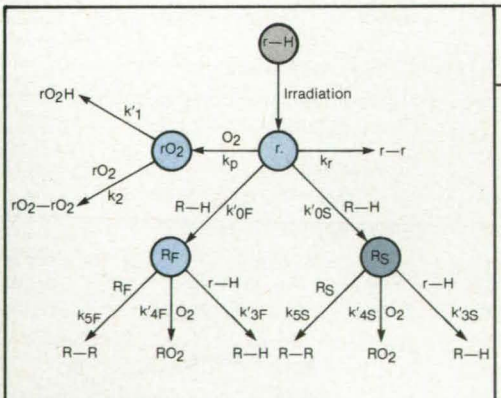
In the experiments, 25-mg samples of poly(n-butyl acrylate) were deposited as thin layers on the insides of glass tubes. The tubes were sealed after introducing oxygen at partial pressures from 1 to 760 torr (130 to 100,000 Pa). Each sample was placed inside an ESR microwave cavity with a grid opening for ultraviolet irradiation from an enhanced xenon lamp, the spectrum of which extended down to a wavelength of 250 nm.

Photo-oxidation was stimulated by turning the ultraviolet light on and off at preset intervals. During each irradiation period, there was a subperiod during which the population of radicals produced by photo-oxidation rose, followed by a subperiod of constant illumination during which the radical populations remained constant, followed by a subperiod of no illumination during which the radical populations decayed. For kinetic studies of a particular reaction product, the magnetic field of the ESR spectrometer was set at the corresponding peak of the radical spectrum.

The kinetic model and its rate constants derived from the ESR measurements on poly(n-butyl acrylate) are shown in the figure. While the peroxy and tertiary radicals are the major radical intermediates as required by the previously accepted mechanism, the model deduced from these measurements shows significant differences in the kinetics of the major intermediates and in the mechanism of their formation. The macromolecular peroxy radical is formed both directly from the intermediate short-lived radicals and in a parallel reaction of O_2 with the tertiary radicals.

There are at least two different types of tertiary radicals, one smaller and more mobile than the other. Under the illumination conditions used, cross-linking by recombination of peroxy radicals is the major degradation pathway; the cross-linking of tertiary radicals is important only in oxygen-starved samples.

This work was done by Soon Sam Kim, Ranty Hing Liang, Fun-Dow Tsay, and Amitava Gupta of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 35 on the TSP Request Card. NPO-16847*



Note: r-H denotes the polymer before irradiation.

Radicals	Steady-State Populations	Rate Processes	Rate Constants at 25°C
r. (Intermediate)	$[r\cdot]_{eq} = 2.4 \times 10^{-6}$ m/L	Reaction with O_2	$k'_p = 700$ L m^{-1}s^{-1}
		Recombination	$k_r = 8 \times 10^5$ L m^{-1}s^{-1}
R_F and R_S (Tertiary)	$[R_F]_{eq} = 4.4 \times 10^{-6}$ m/L	Formation of R_F	$k_{0F} = 5 \times 10^{-1}$s^{-1}
	$[R_S]_{eq} = 2.9 \times 10^{-6}$ m/L	Formation of R_S	$k_{0S} = 1 \times 10^{-1}$s^{-1}
		Abstraction by R_F	$k'_{3F} = 1.3 \times 10^{-1}$s^{-1}
		Abstraction by R_S	$k'_{3S} = 8 \times 10^{-3}$s^{-1}
		Reaction of R_F with O_2	$k'_{4F} = 700$ L m^{-1}s^{-1}
		Reaction of R_S with O_2	$k'_{4S} = 300$ L m^{-1}s^{-1}
		Recombination of R_F with self	$k_{5F} = 5 \times 10^4$ L m^{-1}s^{-1}
		Recombination of R_S with self	$k_{5S} = 3 \times 10^3$ L m^{-1}s^{-1}
rO_2 and RO_2 (Peroxy)	$[rO_2\cdot + RO_2\cdot]_{eq} = 8.0 \times 10^{-6}$ m/L	Abstraction	$k'_1 = 2 \times 10^{-2}$s^{-1}
		Recombination with self	$k_2 = 5 \times 10^4$ L m^{-1}s^{-1}

The **Photo-oxidation of Poly(n-Butyl Acrylate)** produces intermediate radical species. This reaction sequence and the associated rate constants were deduced from ESR measurements of the polymer during and after illumination with ultraviolet light.

Books and Reports

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

Electron-Spin Resonance in Boron Carbide

Samples exhibit Curie-law behavior in the temperature range of 2 to 100 K.

A technical paper presents studies of electron-spin resonance (ESR) of samples of hot-pressed B_9C, $B_{15}C_2$, $B_{13}C_2$, and B_4C. Boron carbide ceramics are refractory solids with high melting temperatures, low thermal conductivities, and extreme hardnesses. They show promise as semicon-

ductors at high temperatures and have unusually large figures of merit for use in thermoelectric generators.

At 2 K, the ESR spectra for all four compositions can be explained by a single Lorentzian absorption with a relatively narrow line width and free-electron gyromagnetic ratio. The ESR line width of B_4C remains narrow between 2 and 295 K, whereas those of the other three samples (which contain smaller proportions of carbon) increase by a factor of 20 over the same temperature range. Above the temperature of 20 K, the line shape of the ESR signal in the latter three samples can be expressed as a sum of two Lorentzians with different line widths.

The integrated intensities of the ESR signals in all four samples follow a Curie law below 100 K, with a Curie constant corresponding to spin concentrations of 1.8 to 3.6×10^{19} per gram. No prior experiments with boron carbides showed this simple behavior over a temperature range where the temperature increased by a factor greater than 50 (i.e., over the range 2 to at least 100 K), a result tentatively attributed to the high quality of the samples used. Although these values are in agreement with data on the static magnetic susceptibilities of samples cut from the same hot-pressed billets, they are about two orders of magnitude less than the carrier densities estimated from transport measurements. This suggests that the carriers are spinless bipolarons.

At room temperature the ESR spectra include both absorption and dispersion terms, indicating significant electrical conductivity at microwave frequencies. The estimated microwave resistivity, 0.3 Ω·cm, agrees well with the dc value of 0.5 Ω·cm.

This work was done by Charles Wood, Eugene L. Venturini, Larry J. Azevedo, and David Emin of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Electron Spin Resonance Study of Hot-Pressed Boron Carbide," Circle 116 on the TSP Request Card.*
NPO-16884

New Products

A collimated laser diode system from **D.O. Industries, Inc.** (Rochester, NY) can replace HeNe lasers for many applications, at a substantially reduced cost. The stand-alone Gala Laser System uses GaAlAs lasers with output power levels from 4 to 25 milliwatts and wavelengths from 750 to 830nm. Several output beam diameters are available through D.O. Industries' diffraction limited laser objective lenses. A round output beam can be obtained with an optional prism system or cylindrical lens assembly. **Circle Reader Service Number 328.**

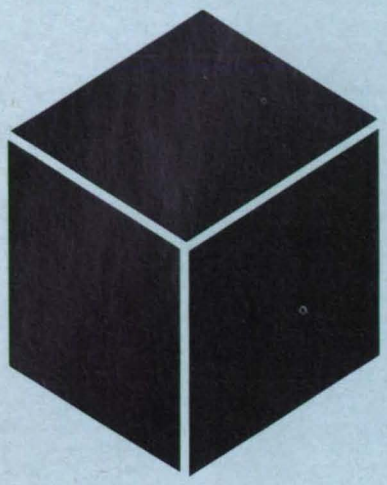
Power Technology, Inc., Little Rock, AR, introduces the Model PD-3, a stable, quiet, high voltage power supply for use with silicon photodiodes in the avalanche or the Geiger mode. The PD-3's output voltage temperature coefficient is user programmable from 0.1V per degree Centigrade to greater than 10V per degree Centigrade. Output voltage is also user programmable from 15V to 620V at 200 microamperes. **Circle Reader Service Number 314.**

EG&G Electronic Components Division, Salem, MA, announces its new 5000 series of thyratrons, 4-1/2 inch diameter tubes yielding twice the power switching capability of three-inch thyratrons. **Circle Reader Service Number 502.**

Lake Shore Cryotronics, Inc. (Westerville, OH) introduces its new series of Advanced Cryogenic Temperature Controllers. The Model DRC-91C is a high performance temperature controller suited for low and medium temperature cryogenic research and materials analysis in the 1.4 K to 800 K range (-272° to 527°C). The controller employs a series of easily-installed input cards that accomodate virtually any type of cryogenic sensor. Two input cards with sensors may be used concurrently, allowing temperature to be monitored at more than one point or with more than one sensor type. An optional scanner provides temperature monitoring of up to six sensors. **Circle Reader Service Number 426.**

The Model 805 temperature controller is an affordable versatile instrument designed to manage a broad array of controlled temperature requirements — in low temperature (1.4K) physics, in low to moderate magnetic field environments, and in medium temperature applications to 800 K (527° C). **Circle Reader Service Number 489.**

Materials



Hardware, Techniques, and Processes

Catalytic Oxidation of CO for Closed-Cycle CO_2 Lasers

Stoichiometric mixtures are converted completely.

Langley Research Center, Hampton, Virginia

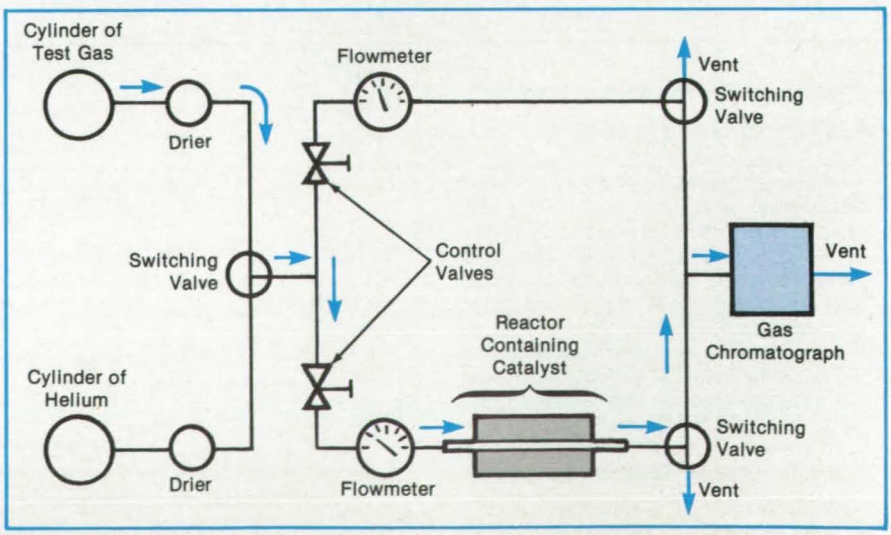
High-energy pulsed CO_2 lasers have a potential for measuring many different features of the atmosphere of the Earth and are particularly useful on airborne or space platforms. For this type of application, the laser must be operated in a closed cycle to conserve gas, especially if rare nonradioactive isotopes of carbon and oxygen are used. However, the laser discharge decomposes a fraction of the CO_2 to CO and O_2, causing a rapid loss in power and leading to erratic behavior. To maintain operation, the CO and O_2 must be recombined to form CO_2.

Recombination can be caused by passing the gas mixture over a heated, solid catalyst. Although many catalysts can oxidize CO to CO_2, some are unsuitable for laser operation because they need an oxidizing atmosphere of about 20 percent O_2. However, in the CO_2 laser, the O_2 concentration must be kept below a few tenths of a percent to maintain laser power. Previous work has shown that a 1-percent Pt/SnO_2 catalyst tested with a gas mixture of 1 percent CO and 0.5 percent O_2 showed considerable removal of CO and O_2. Therefore, an effort was undertaken to develop a basis for the design of a 1-percent Pt/SnO_2 catalyst bed for a closed-cycle CO_2 laser and to determine the reaction mechanism of CO and O_2 on the Pt/SnO_2 catalyst surface.

The figure shows one of the experimental systems used to obtain kinetic data on the reaction of a stoichiometric mixture of CO and O_2 on a 1-percent Pt/SnO_2 catalyst. The gas mixture, or test gas, was sampled at either the test-gas cylinder (reactor bypass) or the reactor outlet and analyzed by a gas chromatograph. The test gas was a mixture of 1 percent CO and 0.5 percent O_2 in ultrapure (99.999 percent before mixing) helium. About 0.2 percent neon was added to this mixture as an internal calibration standard.

In the surrogate laser system using 0.925 g of the 1-percent Pt/SnO_2 catalyst (BET* surface area per unit mass of 6.7 m^2/g), complete conversion of the stoichiometric gas mixture occurred at 100 °C and a flow rate of 10 standard cubic centimeters per minute. From these data, it was determined that a reactor in a closed-cycle CO_2-laser system using 925 g of catalyst at 100 °C should operate indefinitely with a circulating gas flow of 10,000 standard cubic centimeters per minute. An analysis of the kinetic data suggested a rate law for the reaction that is overall first order. However, further experiments with nonstoichiometric gas mixtures of CO and O_2 are planned to determine the order of the reaction with respect to the CO concentration and the order of the reaction with respect to the O_2 concentration in the rate law.

*BET refers to the Brunauer, Emmett, and Teller method of measuring the real surface area of a solid by nitrogen ad-



The **Test Gas**, consisting of CO and O_2 in He, is used to simulate the production of CO and O_2 from CO_2 in a laser. Thus, the apparatus serves as a surrogate laser system to obtain kinetic data for the reaction on the catalyst.

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Circle Reader Action No. 335

sorption.

This work was done by I. M. Miller, D. R. Schryer, R. V. Hess, B. D. Sidney, G. M. Wood, Jr., and P. A. Paulin of **Langley Research Center** *and B. T. Upchurch and K. G. Brown, of Old Dominion University.*

Further information may be found in NASA TM-86421/NSP [N85-25445], "Optimization of the Catalytic Oxidation of CO for Closed-Cycle CO_2 Laser Applications."

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-13505

Processable Polyimides Containing ATBN Elastomers

Void-free moldings are obtained without serious sacrifice in other properties.

Langley Research Center, Hampton, Virginia

A new synthesis produces a high-temperature linear aromatic polyimide that can be processed in the imide form to yield tough, void-free components without serious sacrifice in other properties. Linear aromatic condensation polyimides are materials of prime choice for use as adhesives, composite matrix resins, films, coatings, and/or moldings where durability at temperatures as high as 200 to 300 °C is needed. Because of their outstanding properties, they are finding increasing use in aircraft and spacecraft applications.

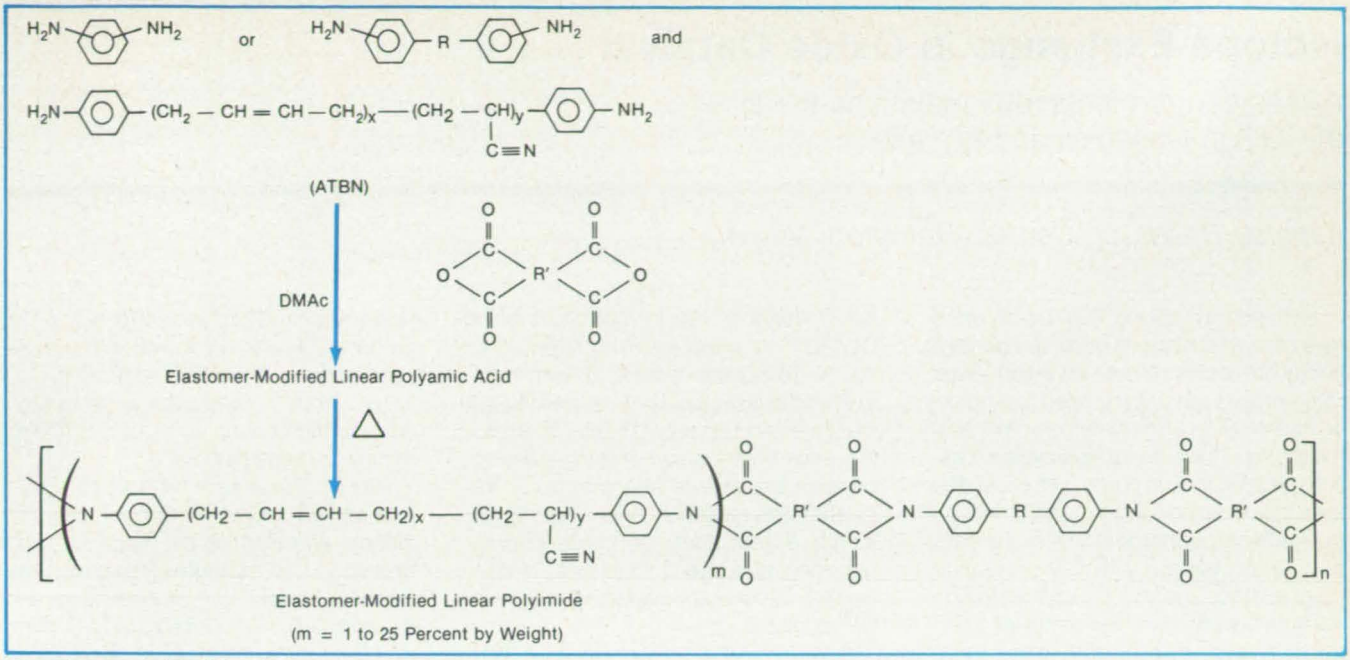
A major drawback hindering wider use of linear polyimides is that they are extremely tedious to process compared to other engineering plastics. Traditionally, a fully cured linear aromatic polyimide is intractable. Polyimide adhesives, laminates, or molded parts are generally processed in the amic acid form and later converted to the fully cured polymer. Because of the volatiles generated during final cure, the preparation of large, void-free components becomes exceedingly difficult, if not impossible.

By incorporating relatively small amounts of amine-terminated butadiene/acrylonitrile (ATBN) elastomer into the linear polyimide backbone, an otherwise hard-to-process polymer can be processed. The preparation of the elastomer-containing amic acid prepolymer involves the reaction of an aromatic diamine and an aromatic ATBN elastomer with an aromatic dianhydride in a polar solvent such as N,N-dimethylacetamide (DMAc) at room temperature. The reaction scheme is shown in the figure, where R is a divalent radical, R′ is an aromatic tetravalent radical, x is an integer of 1 or greater, and y is an integer of 0 or greater.

Although the aromatic diamine 4,4′-oxydianiline was specified, other aromatic diamines could be used. Similarly, other ATBN rubbers could be employed, and other dianhydrides are applicable in the synthesis. In addition to DMAc, other solvents are suitable for preparing the elastomer-modified polyamic acid resin.

The conditions under which the elastomer-modified polyimide powder was processed to form a void-free molded part [250 °C temperature, 4,000 to 6,000 psi (28 to 41 MPa) pressure] were found to be optimum for this particular system. Optimum conditions may vary depending upon the aromatic diamine, the elastomer, the dianhydride, or the solvent used.

A control polyamic acid resin, BTDA + ODA, containing no elastomer was prepared, precipitated, and staged to the imide prior to processing. The control molding powder did not flow. A second control powder sample crumbled as it was removed from the mold. It is evident that the presence of the ATBN elastomer in the polyimide matrix makes possible its processing, enhancing its ability to melt and flow. It is anticipated that the ATBN-modified polyimide of this synthesis will prove useful as a means of improving processing capability in the preparation of polyimide moldings, molded laminates, adhesive joints, or coatings for applications on aircraft and spacecraft, or for any other commercial applications where lightweight, high-temperature



The **Elastomer-Modified Linear Polyamic Acid** is prepared in a reaction at room temperature, then polymerized by heating.

materials are required.

This work was done by Anne K. St. Clair and Terry L. St. Clair of **Langley Research Center** *and Stephen A. Ezzell of Virginia Polytechnic Institute and State University. For further information, Circle 122 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 19]. Refer to LAR-13178.

Pretreatment of Platinum/Tin-Oxide Catalyst

The addition of CO to a He pretreatment doubles the catalytic activity.

Langley Research Center, Hampton, Virginia

In a sealed, high-energy, pulsed CO_2 laser, CO and O_2 form as the decomposition products of CO_2 in the laser discharge zone. These products must be recombined, because an oxygen concentration of more than a few tenths of a percent causes a rapid deterioration of power, ending in unstable operation. A promising low-temperature catalyst for combining CO and O_2 is platinum on tin oxide (Pt/SnO_2). A new development increases the activity of the catalyst so that less is needed for the recombination process.

A catalyst pretreatment adopted at Langley Research Center was to expose a 120-mg sample of 1 percent platinum on tin oxide (1 percent Pt/SnO_2) to high-purity flowing helium for 1 hour at 225 °C. Then the sample was exposed to a gas mixture of 1 percent CO and 0.5 percent O_2 in He, flowing at 5 standard cubic centimeters per minute and 100 °C. The steady-state activity, measured in terms of the percent conversion of CO and O_2 to CO_2, occurred after 900 minutes at a level of 38 percent.

The new development is to replace the He used in the pretreatment with a mixture of 1 percent CO in He. With this new pretreatment, the steady-state activity after 500 to 900 minutes is between 74 and 78 percent or about twice the value obtained for the pretreatment with He alone.

In addition to the above development, a simple process to reactivate the catalyst for long-term use was devised. After about 50 hours, a small decrease in activity was noted. To counteract this decay, the temperature of the catalyst bed was raised to 225 °C while the reactant gas was flowing, held for 1 hour, then lowered to 100 °C. This procedure restored the activity of the catalyst to a level above its initial steady-state value.

This work was done by Robert V. Hess, Patricia A. Paulin, Irvin M. Miller, David R. Schryer, Barry D. Sidney, and George M. Wood of **Langley Research Center**, *Billy T. Upchurch of Chemicon, and Kenneth G. Brown of Old Dominion University. For further information, Circle 91 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Langley Research Center [see page 19]. Refer to LAR-13540 and LAR-13541.

Isotope Exchange in Oxide Catalyst

A replacement technique maintains the level of CO_2^{18} in closed-cycle CO_2 lasers.

Langley Research Center, Hampton, Virginia

High-energy, pulsed CO_2 lasers using rare chemical isotopes must be operated in closed cycles to conserve gas. Such rare isotopes as CO_2^{18} are used for improved transmission of the laser beam in the atmosphere. However, closed-cycle operation results in a rapid power loss caused by the disassociation of CO_2 into CO and O_2 in the electrical discharge of a laser. To maintain laser power, the CO_2 must be regenerated, and the O_2 concentration must be kept below a few tenths of a percent. These conditions can be achieved by recombining the CO and O_2.

One method for recombining CO and O_2 is to use a solid catalyst. To conserve energy, the catalyst must be active at or below 100 °C, the temperature inside the laser envelope. Platinum on tin oxide (Pt/SnO_2) meets this requirement. However, reactions of CO_2^{18} and O_2^{18} with Pt/SnO_2^{16} result in the formation of some $CO^{16}O^{18}$ at temperatures from 25 to 100 °C. To maintain isotopic integrity of the CO_2^{18} in the laser gas mixture, the catalyst must also contain only O^{18} atoms at reactive oxide sites. Instead of using a very expensive procedure like preparing the catalyst with reagents containing only O^{18} atoms, a less costly technique involves removing all active O^{16} atoms at or near catalyst surface and replacing them with O^{18} atoms.

A sample of 1 percent Pt/SnO_2 was heated to 300 °C in flowing Ne and then chemically reduced in flowing H_2 for 5 minutes. Removal of O^{16} (as H_2O^{16}) was monitored with a mass spectrometer. The sample was then reoxidized with 3 percent O_2^{18} in Ne for 50 minutes, cooled in flowing Ne to 100 °C, and then exposed to a stoichiometric mixture of 2 percent CO^{18} plus 1 percent O_2^{18} in Ne for 15 minutes. The product CO_2 was monitored with a mass spectrometer. The observed isotopic purity (CO_2^{18}/total CO_2) of the product CO_2 equaled the isotopic purity of the CO^{18} in the reactant gas mixture.

This work was done by Robert V. Hess, Irvin M. Miller, David R. Schryer, Barry D. Sidney, and George M. Wood, Jr., and Ronald F. Hoyt of **Langley Research Center**, *Billy T. Upchurch of Chemicon, and Kenneth G. Brown of Old Dominion University. For further information, Circle 98 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Langley Research Center [see page 19]. Refer to LAR-13542.

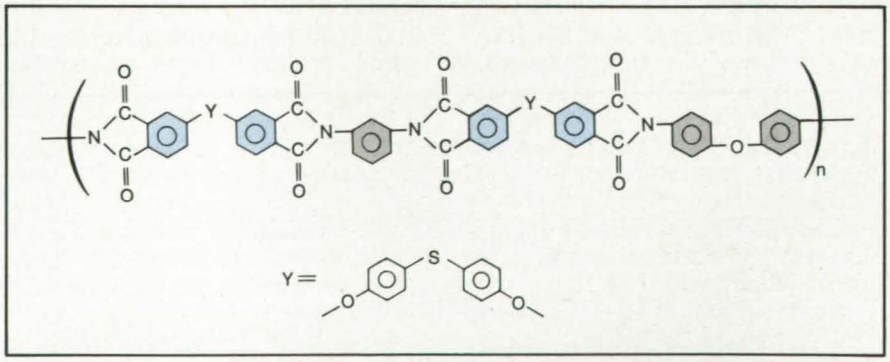
Copolyimides With Flexibilizing Groups

Copolymers have improved flexibility, processability, and melt-flow characteristics.

Langley Research Center, Hampton, Virginia

Aromatic polyimides are generally difficult to process because they exhibit only a limited degree of flow even at high temperatures and when subjected to high pressure. Because aromatic polyimides possess such desirable properties as good thermal stability, resistance to solvents, and high glass-transition temperature, there is a definite need for readily processable varieties. In the current technique, copolyimides are derived from the reaction of aromatic dianhydrides with a meta-substituted phenylene diamine and a bridged aromatic diamine. The incorporation of meta-substituted phenylene diamine derived units and bridged aromatic diamine derived units into the linear aromatic polymer backbone results in a copolyimide of improved flexibility, processability, and melt-flow characteristics.

Three copolyimides of varying copolymer molar ratios were prepared using three dianhydrides. The dianhydrides and diamines were dissolved in an inert solvent at a temperature between 10 and 30 °C. The reaction was allowed to proceed until a solid poly(amide-acid) soluble in the solvent was formed. The poly(amide-acid) was separated from the solvent and heated at 150 to 400 °C to form a solid copolyimide.



A **Copolyimide** of the new type exhibits synergistic improvements in flow properties due to flexibilized diamine-derived units incorporated into the polymer backbone.

The copolymers thus formed consist essentially of two recurring polyimide moieties, one comprising an aromatic dianhydride derived unit and a bridged diamine derived unit and the other comprising an aromatic dianhydride derived unit and a meta-substituted diamine derived unit (see figure). The two diamine derived units are flexibilizing groups, which,

when combined and incorporated into the backbone of a linear aromatic polyimide, lead to unexpected synergistic improvements in softening, thermoplastic, and flow behavior of the resulting copolymers.

This technique produces copolyimides with a combination of flexible linkages that cause the polymers to exhibit flow properties that make them particularly well suited for use in a wide range of products including adhesives, molding resins, laminating resins, dielectric coatings, and protective coatings. These improved properties make the copolymers especially useful as thermoplastic hot-melt adhesives.

This work was done by Terry L. St. Clair, Harold D. Burks, Donald J. Progar, and K. Mason Proctor of **Langley Research Center**. *Further information may be found in NASA TM-86416 [N85-31296/NSP], "Synthesis and Characterization of Copolyimides with Varying Flexibilizing Groups."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487–4650. Rush orders can 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 19]. Refer to LAR-13354.

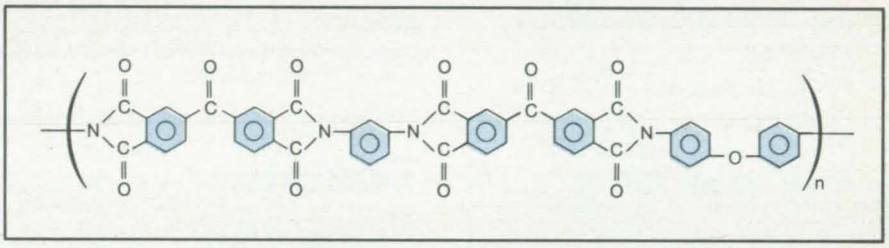
High-Temperature Copolyimide Adhesive

Thermoplastic copolyimide polymer is made from inexpensive, commercially available materials.

Langley Research Center, Hampton, Virginia

Thermoplastic polyimides show potential for use as matrix resins and adhesives for aircraft applications. One such thermoplastic polyimide, LARC-TPI, was developed at Langley Research Center in the late 1970's. The thermoplastic behavior of this polymer has been attributed primarily to the flexibility of the aromatic diamine used in its preparation: 3,3′-diaminobenzophenone, a meta-linked, bridged diamine, which was not commercially available at that time and which is now generally not available at a reasonable cost. Therefore, a program was begun to find a way to prepare a thermoplastic polyimide with properties similar to those of LARC-TPI using only commercially available materials.

The system that shows the most promise to date is a random copolyimide with the structure shown in the figure. The copolyimide, designated STPI/LARC, was prepared from the reaction of 3,3′4,4′-benzophenonetetracarboxylic dianhydride (BTDA), equimolar quantities of *m*-phenylenediamine and 4,4′-oxydianiline, and a small amount of phthalic anhydride to control the molecular weight. The incorporation of two types of flexibilizing diamines in the polymer affords a polyimide with thermoplastic properties and adhesive performance similar to those of LARC-TPI.



This **Random Copolyimide,** called STPI/LARC, is prepared from commercially available materials. It is being investigated for possible use as an adhesive or matrix resin for aircraft applications.

Test data on a commercially available LARC-TPI and on the experimental STPI/LARC show both polymers to possess exceptional lap shear strengths at room temperature and at elevated temperatures up to 204 °C, both before and after aging at 204 °C. However, the LARC-TPI strengths were, in general, higher than the corresponding STPI/LARC strengths. After exposure to boiling water for 72 hours, bonded specimens of both polymers exhibited similar percentage losses of strength in tests at room temperature and at 177 °C. In contrast, when tested at 204 °C after the exposure to boiling water, the STPI/LARC retained a much higher percentage of its original strength than did the LARC-TPI (68-percent vs. 40-percent retention). This phenomenon was most likely the result of STPI/LARC having a glass-transition temperature higher than that of LARC-TPI (283 °C vs. 260 °C).

An attractive feature of the STPI/LARC is that it is prepared from relatively inexpensive, commercially available chemicals. Therefore, this flexible, thermoplastic copolyimide shows considerable potential as an adhesive — based on the results of this initial study and on its ease of preparation and relatively low cost.

This work was done by Donald J. Progar, Terry L. St. Clair, Sharon E. Lowther, and Karen S. Whitley of **Langley Research Center**. *Further information may be found in NASA TM-86447 [N85-31297/NSP], "STPI/LARC: A 200 °C Polyimide Adhesive."*

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-13509

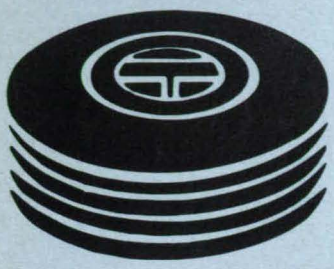
New Products

Klinger Scientific Corporation of Richmond Hill, NY announces its Type TR series of precision all-steel rotation stages. Designed for use in either a horizontal or vertical orientation, the TR stages offer smooth, manually controlled rotation through 360 degrees. A clutch assembly permits rapid coarse adjustment. Fine adjustment with a sensitivity of several arc seconds is micrometer-driven. Precision etched verniers on the body of each unit permit readability to 1 arc minute. The largest of the series, the TR160, can handle loads up to 80 kilograms. **Circle Reader Service Number 509.**

Quantachrome Corp. (Syosset, NY), introduces the Multipycnometer, designed for accurately measuring the true volume and density of a wide range of sample sizes for any powdered or bulk solid material. The Multipycnometer can analyze samples ranging in volume from 0.5 cm^3 to 135 cm^3. This is accomplished through three different size sample cells and three different calibrated reference volumes. **Circle Reader Service Number 386.**

Palmetto, a division of Greene, Tweed & Co., in Denton, MD based their new mechanical seal on a cartridge design that eliminates troublesome springs, bellows or carbon faces. Simpleseal is designed for applications in strong acids to caustic streams, including abrasive slurries. A rugged, easily-installed flexible sealing element provides a leak-free seal. A small screwdriver and an Allen wrench are the only tools required for adjustment and rebuild. **Circle Reader Service Number 310.**

Computer Programs



COSMIC: Transferring NASA Software

COSMIC, NASA's Computer Software Management and Information Center, is the one central office established to distribute software that is developed with NASA funding. COSMIC's role as part of NASA's Technology Utilization Network is to ensure that NASA's advanced software technology is made available to industry, other government agencies, and academic institutions.

Because NASA's software development efforts are dynamic and ongoing, new programs and updates to programs are added to COSMIC's inventory on a regular basis. *Tech Briefs* will continue to report information on new programs. In addition, the 1986 edition of the *COSMIC Software Catalog* is available with descriptions and ordering information for available software. Several new programs for control systems/robotics, expert systems, thermal analysis, turbomachinery design, structural analysis, and computer graphics are offered.

For additional information on any programs described in this issue of *Tech Briefs*, circle the appropriate number on the TSP card at the back of the publication. If you don't find a program in this issue that meets your needs, you can call COSMIC directly at (404) 542-3265 and request a review of programs in your area of interest. There is no charge for this information review.

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John A. Gibson, Director

Computer Programs

These programs may be obtained at a very reasonable cost from COSMIC, a facility sponsored by NASA to make raw 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.

Mathematics and Information Sciences

Acquisition-Management Program

Data are maintained on contracts, grants, and purchases.

The NASA Acquisition Management Subsystem (AMS) program is an integrated NASA-wide standard automated-procurement-system program that was developed in 1985. AMS is designed to provide each NASA installation with a procurement data-base concept with on-line terminals for managing, tracking, reporting, and controlling contractual actions and associated procurement data.

The subsystem provides control, status, and reporting for the following areas of procurement: bidders source system; purchase-request tracking; award information for purchase orders, contracts, and grants; contract and grant administration; and contract and grant closeout. The purpose of this standardization is to decrease the costs of procurement and of the operation of automatic data processing; increase procurement productivity; furnish accurate, on-line management information; and improve customer support.

AMS can provide detailed procurement information from the start of the procurement through contract award, contract administration, and subsequent contract closeout: it is a daily working tool for the procurement and technical team in the day-to-day accomplishment of tasks. Summary-level data for procurement managers are also available. To satisfy NASA Field Center procurement organizations and NASA Headquarters reporting requirements, a historical data base of all procurement actions is maintained. In addition to being the acquisitions management subsystem for each NASA installation, the AMS also serves as a feeder system for the NASA Headquarters Financial and Contractual System (FACS) and the Federal Procurement Data System (FPDS) for the Office of Management and Budget.

Other procurement organizations will probably need to modify the AMS code to suit their procurement nomenclature and procedures. AMS installation and modification requires a thorough understanding of the ADABAS DBMS and the NATURAL programming languages.

AMS is written in the ADABAS NATURAL language and has been implemented on an IBM 4381 Group 2 machine with 4 megabytes of memory and operating under OS MVS/SP3. AMS is designed to

Do You Feel Lucky???

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AFFORDABILITY: Our **Janus/Ada** "C" Pak is available for $99.95 and contains the **Janus/Ada** Compiler and Linker, designed specifically for microcomputers and consumer tested since 1981. Our customers can upgrade to our development and embedded systems "paks" with 100% credit for this starter package. Our **Janus/Ada** Extended Tutorial is available for the same low price. We feature commercial and educational "site" licensing for all of our packages.

ADA STANDARDIZATION: **Janus/Ada** source code can be ported to any validated Ada system and compiled. We offer a variety of tools and consultations to assist you in this process, if needed.

JANUS/ADA USERS: Over 5,000 seperate sites use the **Janus/Ada** compiler for training, embedded systems and applications each day. We supply our tools to the U.S. Armed Forces, Fortune 500 companies and over 400 educational institutions, as well as to individuals like you.

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Circle Reader Action No. 467

use an IBM 3705 TCU to support IBM 3270 terminals. The subsystem requires the following IBM software: ACF-VTAM, JES2, and CICS. It also requires the following Software AG software: ADABAS, NATURAL SECURITY, and PREDICT.

This program was written by Don E. Avery, A. Vernon Vann, Richard H. Jones, and William E. Rew of **Langley Research Center**. *For further information, Circle 151 on the TSP Request Card.*
LAR-13588

Assembly-Line Simulation Program

Costs and profits are estimated for models based on user inputs.

The Standard Assembly-Line Manufacturing Industry Simulation (SAMIS) program was originally developed to model the manufacturing processes used in a hypothetical U.S. facility that manufactures silicon solar modules for use in electricity generation. The SAMIS program has been generalized to the extent that it should be useful for simulating processes in many different production-line manufacturing companies. SAMIS provides an accurate and reliable means of comparing alternative manufacturing processes. It can also be used to assess the impact of changes in such financial parameters as the costs of resources and services, inflation rates, interest rates, tax policies, and the required rate of return on equity.

The most important capability of SAMIS is its ability to estimate the prices a manufacturer would have to receive for its products to recover all of the costs of production and make a specified profit. To do so, it "constructs and staffs" a simulated company, based on a set of manufacturing-process descriptions developed by the user. The results of the simulation are financial reports that detail the direct and indirect requirements, including quantities and costs, of the processes that comprise the company.

Because of the large amount of data that may be needed to describe a company and its manufacturing processes, the user interface for SAMIS has received a great deal of design attention. Every available action and every datum has an associated "help" message. Menus and color are used to advantage.

SAMIS is available in two versions. The IBM 370 version, Release 4.0, is written in SIMSCRIPT II.5 with a central-memory requirement of approximately 2 megabytes. SAMIS was first developed in 1978; Release 4 has been available from COSMIC since 1982.

The IBM PC version of SAMIS is written in TURBO PASCAL, Version 2.0, and requires at least 256 kilobytes of random-access memory, a minimum of 1.5 megabytes of hard-disk space, an 8087 math coprocessor, and an IBM color-graphics adapter. Executable and source codes are provided. The IBM PC implementation of SAMIS, Release 6.0, includes the PC-IPEG program for rapid analyses of the effects of financial parameters on the product price; the SAMPEG mode of operation for rapid analyses of the effects of process parameters on the product price; and the full, thoroughly validated SAMIS simulation mode for detailed analyses. Release 6.0 also includes changes to accommodate the depreciation method in the accelerated cost recovery system (ACRS), and a cost-account catalog updated to 1985.

This program was written by Robert G. Chamberlain, Silvino Zendejas, and Shan Malhotra of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 163 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 19]. Refer to NPO-16779.

Programs To Aid FORTRAN Programming

Program-development time is decreased while program quality is increased.

The FORTRAN Programming Tools (FPT) are a series of programming tools used to support the development and maintenance of FORTRAN 77 source codes. Included are a debugging aid, a central-processing-unit (CPU) time-monitoring program, source-code maintenance aids, print utilities, and a library of useful, well-documented programs. These tools assist in reducing development time and encouraging high-quality programming. Although intended primarily for FORTRAN programmers, some of the tools can be used on data files and other programming languages.

BUGOUT is a series of FPT programs that have proven very useful in debugging a particular kind of error and in optimizing CPU-intensive codes. The particular type of error is the incorrect addressing of data or code as a result of subtle FORTRAN errors that are not caught by the compiler or (necessarily) at run time. A TRACE option also allows the programmer to verify the execution path of a program. The TIME option assists the programmer in identifying the CPU-intensive routines in a program to aid in optimization studies.

Program coding, maintenance, and print aids available in FPT include routines for the following:

- Building standard format subprogram stubs;
- Cleaning up common blocks and NAMELIST's;
- Removing all characters after column 72;
- Displaying two files side-by-side on a VT-100 terminal;
- Creating a neat listing of a FORTRAN source code, including a table of contents, an index, and page headings;
- Converting files between VMS internal format and standard carriage-control format;
- Changing text strings in a file without using EDT; and
- Replacing tab characters with spaces.

The library of useful, documented programs includes such things as the following:

- Time and date routines;
- A string-categorization routine;
- Routines for converting between decimal, hex, and octal representations;
- Routines to delay process execution for a specified time;
- A Gaussian elimination routine for solving a set of simultaneous linear equations;
- A curve-fitting routine for least-squares fits to polynomial, exponential, and sinusoidal forms (with a screen-oriented editor);
- A cubic-spline fitting routine;
- A screen-oriented array editor;
- Routines to support parsing; and
- Various terminal-support routines.

These FORTRAN programming tools are written in FORTRAN 77 and Assembler for interactive and batch execution. FPT is intended for implementation on DEC VAX-series computers operating under VMS. This collection of programming tools was developed in 1985.

This program was written by Arthur E. Ragosta of **Ames Research Center**. *For further information, Circle 53 on the TSP Request Card.*
ARC-11676.

Program for Automated Real-Time Monitoring

Process-control decisions are made by applying rules to process data streams.

The Expert System Executive is a computer program that demonstrates the feasibility of automated real-time monitoring. Real-time data monitoring is a decision-making process involving knowledge of the system being watched and inferences based upon the observed data. Using the Executive, the knowledge of a system is formally coded as a set of rules specifying actions to be taken under various conditions. The program makes inferences

about the observed data based on the rules.

The Executive has been tested by monitoring the Space Shuttle onboard navigation console, using flight data from an entry simulation. The test rule base pertaining to onboard state vectors is included in the program documentation. By supplying an appropriate set of rules, the program can be adapted to such other real-time applications as plant operations. Each rule must contain a schedule of conditions and the action to be executed when all its conditions are true.

When provided with a set of rules and real-time data, the Executive continuously compares the current status to the rule conditions, determines which rules are applicable and which are not, and performs the required action for the applicable rules. The Executive has three principal data structures: (1) an array containing the rules, (2) an array containing the conditions, and (3) the queues containing the conflict set. The principle constraint on the Executive, as with all real-time programs, is execution speed.

The Expert System Executive is written in the C language, which is a highly-efficient compiled language that allows faster execution on conventional equipment than do programs based on LISP. The C language is also an efficient manipulator of large data structures, which are used in the pattern-matching algorithm.

The Expert System Executive is written for interactive execution and has been implemented on an HP 9000-series computer (system 1805). This program was developed in 1984.

This program was written by Glenn R. Goodrum of **Johnson Space Center**. *For further information, Circle 110 on the TSP Request Card.*
MSC-20908

New Products

Multiflow Computer, Inc., Branford, CT, introduces its Trace family of low cost, general-purpose, field-upgradable VLIW supercomputers that run a broad range of scientific, engineering and other computer-intensive applications at very high speeds. Trace systems are single processor machines based on Very Long Instruction Word (VLIW) architecture and Trace Scheduling compacting compilers; they automatically deliver supercomputer performance from standard sequential FORTRAN and C programs at supermini prices. **Circle Reader Service Number 508.**

Alsys, Inc. (Waltham, MA) announces the immediate availability of an Ada compiler for the Compaq Deskpro 386. The Alsys 386 Compiler runs under DOS 3.1 and supports the use of protected mode, allowing Ada application programs to break the DOS 640K barrier. Direct access up to 16 MB of main memory is supported. **Circle Reader Service Number 498.**

Genrad, Inc. (Concord, MA) introduces their 3200V Computer System, a 32-bit host providing users with a computing platform for the Company's test generation and data management applications. Based on the DEC MicroVAX II, the 3200V runs the MicroVMS operating system, and is configured specifically for GenRad's 32-bit software application packages, including the ATG-32, a new automatic test generation software for Genrad's 227X family of in-circuit/functional test systems. **Circle Reader Service Number 434.**

Anorad Corporation's (Hauppauge, NY) Anoline Brushless Motor, a non-contact linear DC servo motor, offers smooth motion directly. It is able to control infinite table travel lengths and provide accelerations of 4 g's to velocities of 100 inches per second without backlash or stepping action. Electronically switching the winding connections eliminates wear, carbon dust and sparking and gives faster response, smooth table travel, better heat dissipation, and lower rotor inertia. **Circle Reader Service Number 499.**

Mechanics

Hardware, Techniques, and Processes

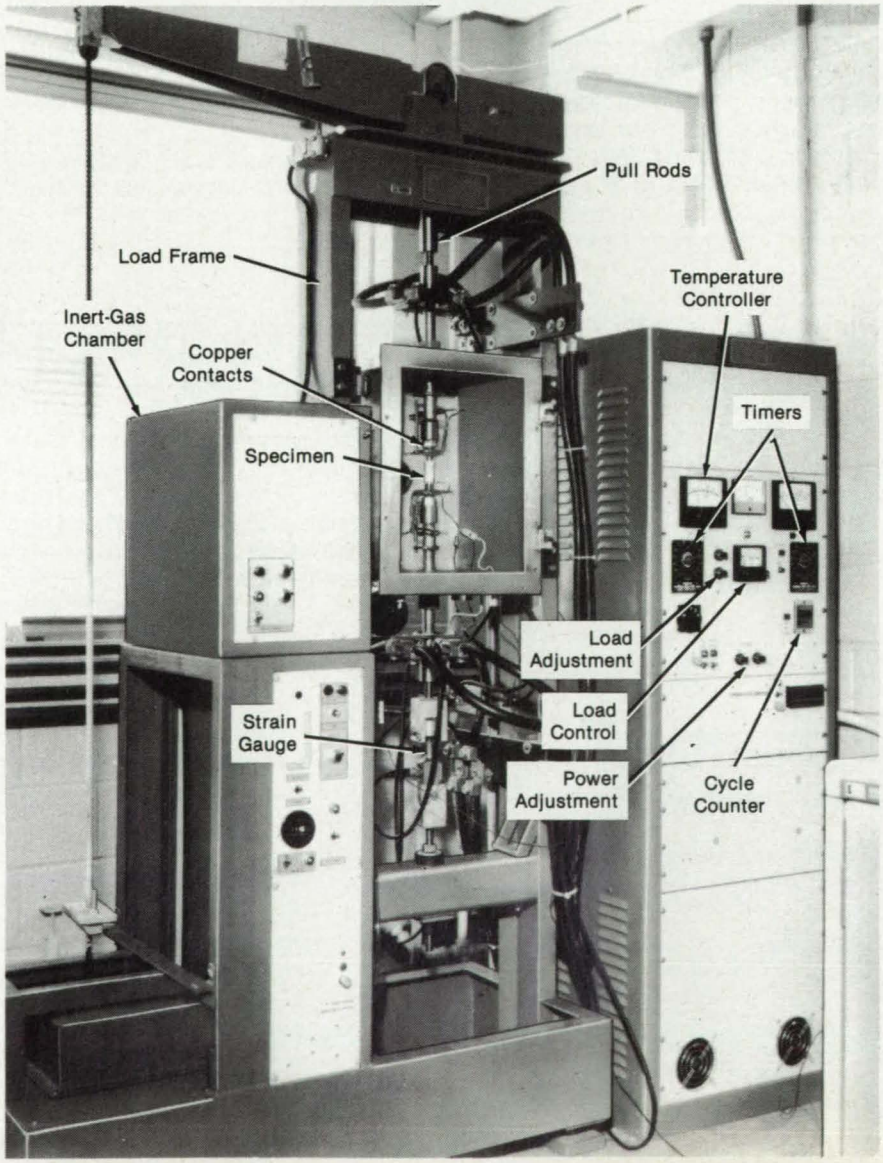
Fatigue-Testing Apparatus for Metal Matrix Composites

Thermal and mechanical load cycling are simulated in realistic fatigue tests.

Lewis Research Center, Cleveland, Ohio

Metal matrix composites have demonstrated a potential for use as high-temperature structural materials. The successful application of these materials often depends on their ability to withstand cyclic loading. Thermal/mechanical fatigue is one of the primary failure modes considered in the design analysis of high-temperature components. In the testing of these materials it is desirable to simulate, as closely as possible, the actual conditions of use. A thermal/mechanical fatigue-test facility was thus required for the simulation of the loading and environmental conditions projected for a metal matrix composite component during use.

The efficient joining of metal matrix composite components to supporting structures is a major concern facing users of these materials. A need exists to evaluate the thermal/mechanical fatigue behavior of composite/metal joint attachments and to simulate as closely as possible the conditions the joint at-



This **Thermal/Mechanical Fatigue-Testing Apparatus** simulates the cyclic loads that cause fatigue in metal matrix composites and composite/metal joint attachments.

tachments will experience in service.

The Lewis Research Center has designed and developed two thermal/mechanical fatigue test facilities, one to test metal matrix composite specimens at temperatures up to 2,600 °F (1,430 °C) and another to test composite/metal attachment bond joints at temperatures up to 1,400 °F (760 °C). The thermal/mechanical fatigue facility (see figure) designed for testing metal matrix composites permits specimen-temperature excursions from room temperature to 2,600 °F (1,430 °C), with controlled heating and loading rates. A strain-measuring device measures the strain in the test section of the specimen, during each heating and cooling cycle, with superimposed loads. Data are collected and recorded by a computer.

The second facility was designed to test composite/metal attachment bond joints and to permit heating to a maximum temperature of 1,400 °C (760 °C) within 10 min and cooling to 300 °F (150 °C) within 3 min. A computer controls the specimen temperatures and load cycling. This facility has unique capabilities not found in other laboratories.

This work was done by Leonard J. Westfall and Donald W. Petrasek of **Lewis Research Center**. *Further information may be found in NASA TM-87187 [N86-15378/NSP], "Thermal-Mechanical Fatigue Test Apparatus for Metal Matrix Composites and Joint Attachments."*

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-14457

Growing Single Crystals of Compound Semiconductors

Defects would be reduced by preventing melt/furnace contact and by suppressing convention.

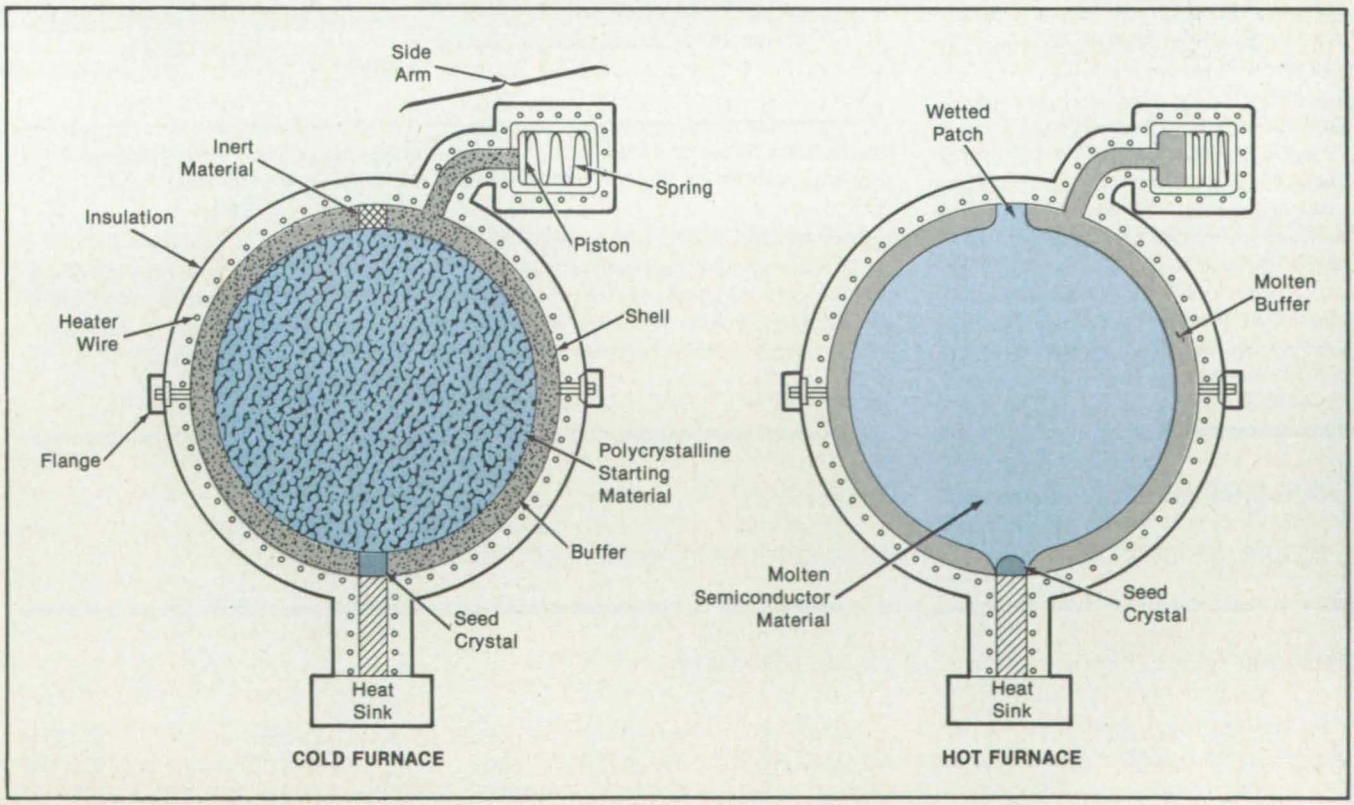
Marshall Space Flight Center, Alabama

Large crystals of compound semiconductors with few defects would be grown by a proposed new method. Such materials as gallium arsenide and cadmium telluride would be produced, perhaps with a quality suitable for very-large-scale integrated circuits or for large focal-plane arrays of photodetectors. The method can be used on a small scale in Earth gravity, but would need microgravity to provide crystals large enough for industrial use.

The method reduces thermal strain induced in the semiconductor material by the container as the material solidifies during growth. Such strain is the primary cause of defects in contained growth. The method employs a buffer layer between the semiconductor material and the container. The buffer layer melts at a lower temperature than does the material but is immiscible with the material and isolates it from the effects of the container wall.

A spherical furnace shell would serve as the container (see figure). The shell has a high thermal conductivity so that it provides a uniform-temperature boundary for the semiconductor material. Resistance heating wires surround the shell. An outer layer of insulation prevents excessive heat loss from the furnace. The inside of the shell is coated with a refractory material.

The charge is prepared by casting or pressing the semiconductor into a sphere



A **Polycrystalline Sphere of Gallium Arsenide**, or other compound semiconductor to be processed, rests in a furnace. After heating, the molten sphere floats in a layer of molten buffer material, which isolates the semiconductor from the furnace wall. During cooling, a spherical solid front advances from the seed to the top of the furnace.

slightly smaller than the inside of the furnace. The buffer material, in powder form, is pressed around the sphere. Holes are left in the buffer coating at the poles to accommodate a seed crystal (at the bottom) and a support plug (at the top).

The seed crystal — a single crystal of the semiconductor material — is inserted in a heat sink in the bottom half of the furnace shell. The charge is then placed in the bottom half of the shell, and the top half of the shell is assembled over it. The support plug, anchored at the center of the top shell, fits in the top hole in the buffer layer. The plug is made of an inert material that is wettable by the molten charge.

The furnace is heated so that first the buffer, then the charge, melts. The seed is cooled through the heat sink so that it remains solid. At equilibrium, the semiconductor melt is surrounded by a thin layer of the buffer melt except at the seed and support locations. When the furnace has been heated to equilibrium, single-crystal growth is begun in the semiconductor melt by slowly lowering the furnace temperature and adjusting the heat flow from the seed.

Expansion and contraction during heating and subsequent cooling are taken up by the flow of the buffer into and out of a side arm. This flow protects the growing or grown crystal from container-induced strains. The side arm also includes a spring-loaded piston that serves as a pressure regulator. It applies enough pressure to the semiconductor melt to prevent evaporation of components and thus maintains the required composition.

The crystal grows in a spherical shape that is tangent to the furnace wall in the vicinity of the seed crystal. The convexity of the growing crystal further reduces trapping of defects, tending to push them away from the solidifying mass.

Defects are further reduced because convection created by surface-tension gradients in the melt and buffer is suppressed: the uniform shell temperature minimizes lateral temperature gradients at this liquid/liquid interface. In addition, the thinness of the buffer layer and its wetting of the shell tend to dampen flow.

This work was done by Robert J. Naumann, Sandor L. Lehoczky, and Donald O. Frazier of **Marshall Space Flight Center**. *For further information, Circle 30 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 19]. Refer to MFS-28137.

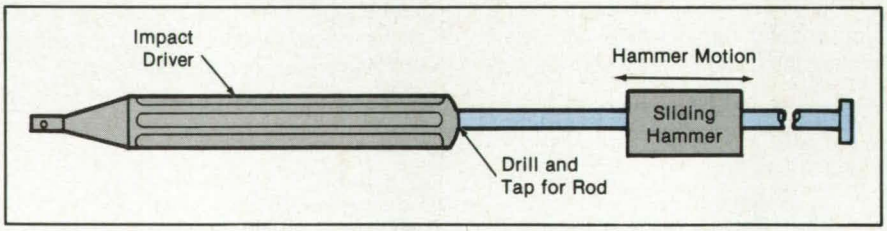
Impact Driver With Integral Sliding Hammer

Accidental injury and damage are less likely.

Lyndon B. Johnson Space Center, Houston, Texas

A tool combines an impact driver with a sliding dead-blow hammer. It can be used for any purpose for which an ordinary impact driver would be used — tightening fasteners or driving starter holes for a drill, for example. At the same time, the tool protects the user from accidental injury and the surrounding equipment from damage that might occur from an ordinary arm-wielded hammer. It promises to be especially useful in underwater work, where the viscous nature of the medium makes accurate free hammering difficult.

The tool is an off-the-shelf impact driver that has been modified by the addition of a rod and sliding hammer (see figure). The user merely slides the cylindrical hammer back and forth on the rod, thereby subjecting the head of the driver to repeated blows. A disk at the outer tip of the rod prevents the hammer from disengaging.



The **Hammer Slides on a Rod**, making it impossible for the user to miss hitting the impact driver squarely on the head. The rod is 12 to 18 inches (30 to 46 centimeters) long.

This work was done by Bilby J. Wallace of OAO Co. for **Johnson Space Center**. *No further documentation is available. MSC-20582*

Cryogenic Shutter

A simple design includes no bearings or other rubbing components.

Goddard Space Flight Center, Greenbelt, Maryland

An electrically actuated shutter is designed to operate many thousands of times at cryogenic temperatures. When open, the shutter allows light at wavelengths between 1 and 300 μm to enter an instrument that measures background cosmic radiation. When closed, the shutter blocks outside radiation from the instrument and positions a mirror to reflect light from an internal source to the instrument so that it can be calibrated.

The shutter is designed to operate at least 50,000 times at 2 K, the operating temperature of the instrument. It draws less than 1 mW from the power supply. It is designed so that, if a power failure should occur, the shutter will remain in or assume the open position so that measurements

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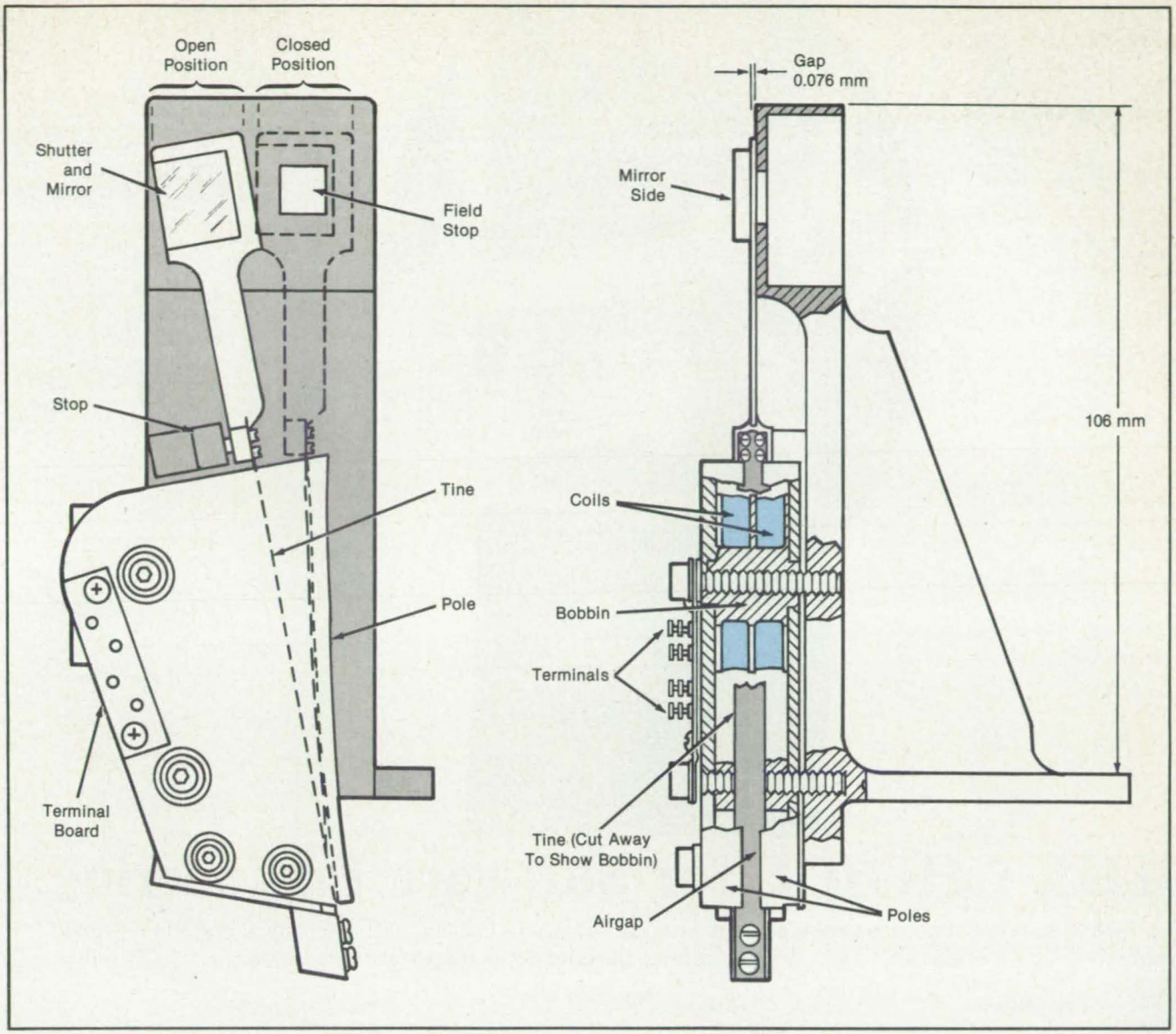


The **Shutter on the Moving End of the Tine** swings to cover the field stop when actuated by superconducting coils on the bobbin of an electromagnet. It comes to rest against a pole piece and assumes the cantilevered-beam contour of the piece. When the coils are de-energized, the tine returns to its relaxed, open position.

can continue, albeit without calibration.

Ordinary motors or solenoids could not be used in the actuating mechanism because of the low-power, low-temperature constraints. A further constraint was that the mechanism had to fit within a small predetermined volume.

The mechanism is magnetically operated. The magnet core consists of two curved pole pieces and a metal bobbin made from highly purified iron with low hysteresis and high saturation flux density. An aluminum flat mirror is attached to a flexible tine made of high-strength tool steel.

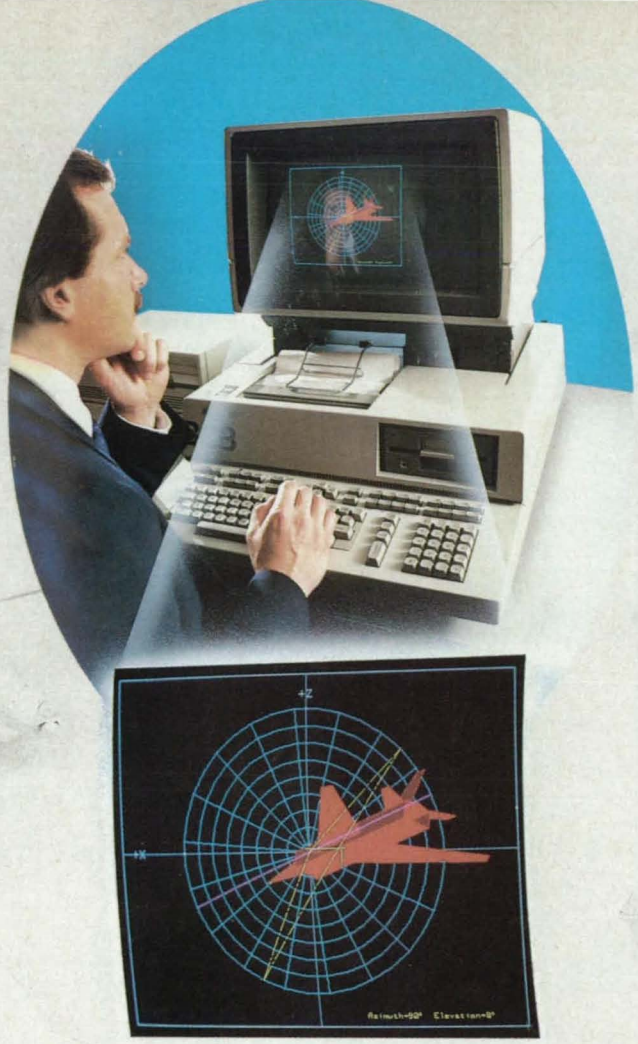
The bobbin is wound with two coils of superconducting niobium/titanium wire and vacuum-impregnated with Formvar (or equivalent) polyvinyl formal so that the windings are supported. Either of the two coils can actuate the shutter if the other fails.

The bobbin is sandwiched between the two pole pieces, each of which has the shape of a cantilevered beam uniformly loaded in bending. When the bobbin winding is energized, the tine takes the shape of the pole pieces, closing the shutter. The initial energizing current is 45 to 50 mA and lasts for 200 ms. It then drops to 12 mA to hold the tine and shutter in place. To prevent magnetic sticking, a 80-μm-thick nonmagnetic plating of copper and gold on the pole pieces maintains a small gap between the actuated tine and the pole pieces. When current is removed from the windings, the spring action of the tine returns the shutter to the open position.

The clearance between the instrument field stop and the closed shutter is 76 μm — close enough to block almost all of the incoming radiation. For futher blockage, a shutter retainer on three sides of the field stop provides a noncontacting labyrinth seal.

This work was done by Allen Tyler and Casey de Kramer of **Goddard Space Flight Center**. *For futher information, Circle 129 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Goddard Space Flight Center [see page 19]. Refer to GSC-13068.



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Hardness Tester for Polyur

A rubber-hardness tester is modified and recalibrated.

Marshall Space Flight Center, Alabama

A rubber-hardness tester (durometer) has been modified for use on rigid polyurethane foam. Previously, the inspection of parts made of rigid polyurethane foam involved subjective criteria — for example, a part was rejected if the color was lighter than normal or the part felt spongy. The modified tester provides an objective basis for the evaluation of improvements in foam manufacturing and inspection. A typical acceptance criterion requires a minimum hardness reading of 80 on the modified tester.

The tester (see Figure 1) has a 1-cm^2 spring-loaded pressing foot. In use, the tester is pressed onto the sample until the base of the instrument is flush with the material surface. The force exerted by the material on the foot is indicated on the dial: this is the hardness reading. In the unmodified instrument, the dial reading varies linearly from 0 at a minimum force (preload) of about 88 g weight (0.86 N) to 100 at a force of 142 g weight (1.37 N). For proper operation, the material must be at least ¾ in. (20 mm) thick.

By trial and error, increased values of spring stiffness and preload were selected so that the tester gave hardness readings at 75 to 95 percent of full scale with PDL-4034 (or equivalent) foam. The calibration plot of the modified tester shows a preload of about 0.25 lb (about 1 N) and a full-scale reading at a force of about 5.6 lb (about 25 N).

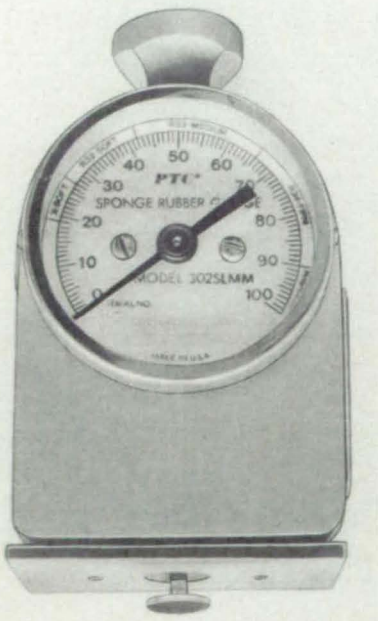


Figure 1. This **Durometer** is pressed into rubber or other resilient material to measure its hardness.

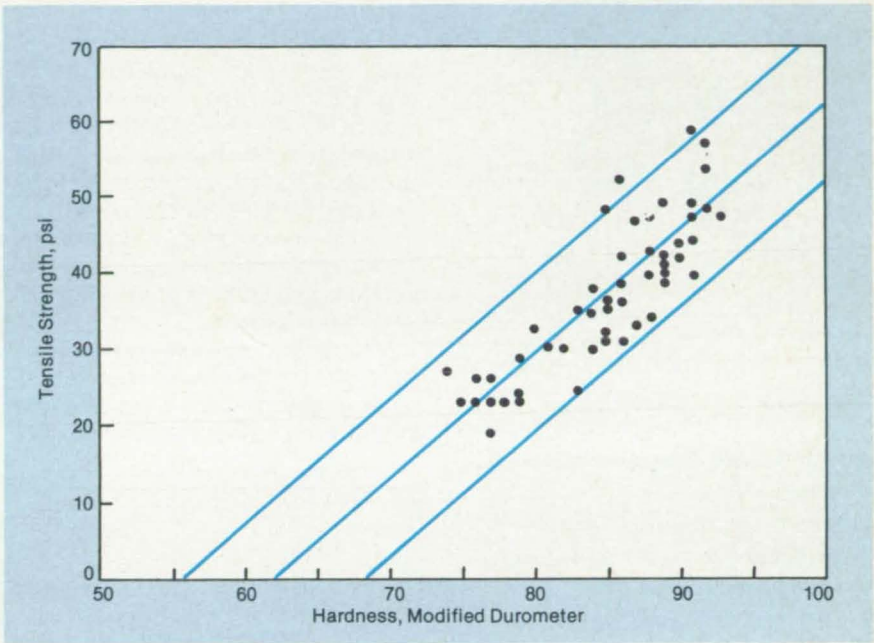
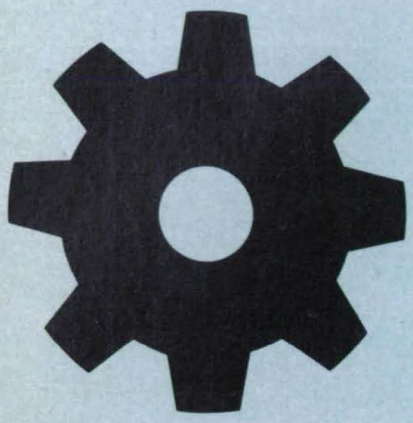


Figure 2. The **Tensile and Compressive Strengths and Hardness** were measured on samples of a commercial polyurethane foam that were prepared under different conditions.

With adequate correlation tests, the modified tester can be used to measure indirectly the tensile and compressive strengths of the foam. As shown in Figure 2, a direct correlation was found between these quantities and the modified-durometer hardness for the PDL-4034 (or equivalent) foam.

This work was done by D. L. Hauser, D. F. Buras, and J. M. Corbin of Martin Marietta Corp. for **Marshall Space Flight Center**. *For further information, Circle 135 on the TSP Request Card.*
MFS-28147

Machinery



Hardware, Techniques, and Processes

Forced-Flow Evaporative Cooler

Centrifugal force maintains thermal contact in unusual gravitational conditions.

Lyndon B. Johnson Space Center, Houston, Texas

An evaporative cooler absorbs heat efficiently under unusual gravitational conditions by using centrifugal force and vapor vortexes to maintain good thermal contact between the heat-transfer surface and the vaporizable coolant. This system would be useful for cooling electronic or other equipment under the low gravity encountered in spacecraft or under the multiple-gravity conditions frequently experienced in high-performance airplanes.

Although evaporative cooling is normally one of the most efficient cooling techniques, ordinary versions of this technique do not work well under unusual gravitational conditions. Under zero gravity, the liquid phase of the coolant floats within its flow path within an evaporator, without necessarily making a good thermal contact with the inner evaporator surface through which heat transfer must occur. In high gravity, the coolant liquid is driven in a particular direction, losing contact with a major portion of the evaporator heat-transfer surface. In both cases, heat-transfer efficiency is decreased.

In one version of the proposed cooling system (see Figure 1), the coolant passes through a conductive tube of rectangular cross section, wound into a flat spiral. The

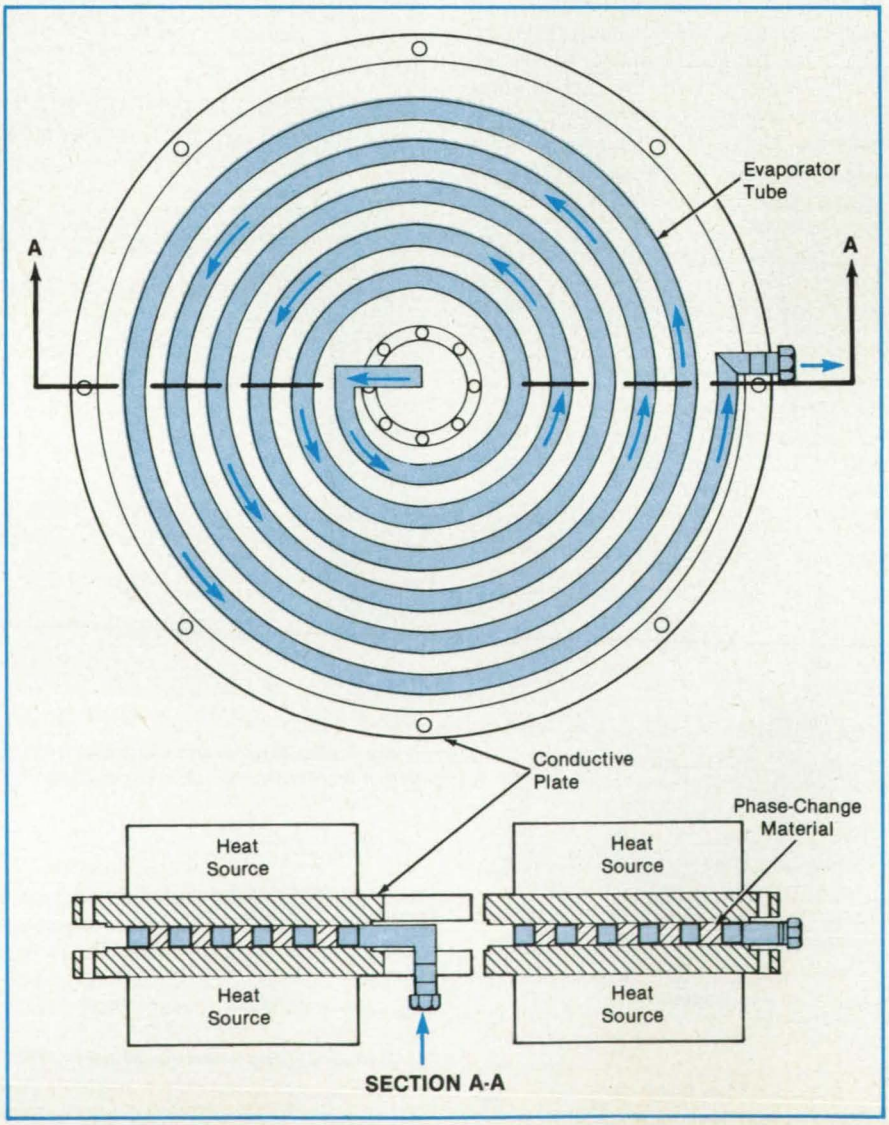


Figure 1. The **Coolant Flows in a Spiral Tube** sandwiched between two plates.

tube is sandwiched between two conductive plates in direct thermal contact with the equipment to be cooled. The coolant enters the tube at the center of the disk and leaves it at the outer edge, or vice versa. In a similar, alternative configuration, the coolant-carrying tube has a reverse bend near the center of the spiral, effectively creating two interleaved spirals. In this configuration, the coolant both enters and leaves on the outside of the disk.

The flow of coolant along the spiral generates substantial centrifugal force. Consequently, the liquid coolant, being denser than the vapor, moves radially outward, pressing against the radially outer wall of the tubing. It has been determined that once liquid coolant strikes the radially outer wall of the tubing, it circulates around the interior of the tubing, covering the entire inner wall (see Figure 2) and thereby providing a high degree of thermal contact.

Where the heat input varies during an operating cycle — for example, as a consequence of the turning on or off of one or more electronic circuits being cooled by the system — the space between adjacent coils within the disk and between the conductive plates could be filled with a phase-change material; for example, hexadecane or other paraffinic material. During periods of rapid heat input, this material would melt, absorbing a relatively large amount of heat during a short time. During low heat loads, the material would be solidified by the excess cooling capacity of the evaporator, thereby regaining its ability to act as a supplemental coolant during high heat loading.

The evaporative cooler could also be used to cool or condense a second heat-transfer fluid. In one version, conduits containing the hot fluid to be cooled are in thermal contact with the conductive plates. Alternatively, hot fluid could be circulated through the channel between the turns of the evaporator tube.

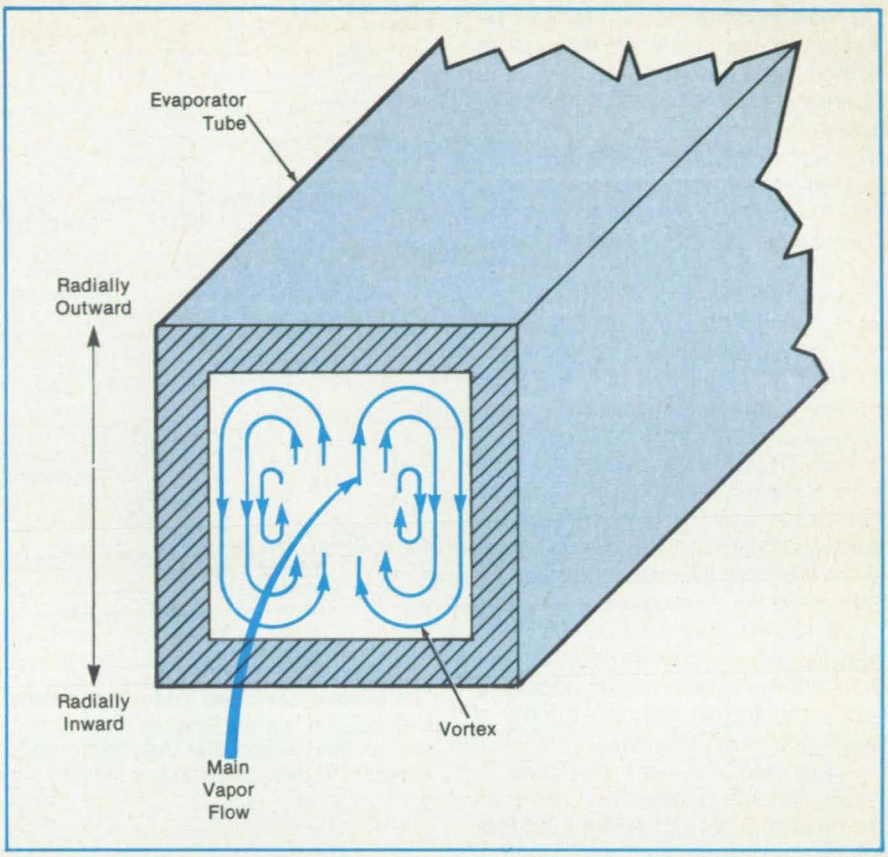


Figure 2. **Liquid Circulates Around the Inner Tube Surface**, driven by counterrotating vapor vortexes. This flow regime is aided by a relatively rapid flow of vapor-phase coolant through the tubing; this vortex-creating mechanism is particularly important in the case of high gravitational loads.

This work was done by Wilbert E. Ellis of **Johnson Space Center** *and Richard E. Niggemann of Sundstrand Corp. For further information, Circle 161 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Johnson Space Center [see page 19]. Refer to MSC-21078.

Blender for Antimisting Kerosene

A demonstration unit meters polymeric additives into jet fuel during refueling.

NASA's Jet Propulsion Laboratory, Pasadena, California

A blender continuously disperses a controlled amount of flammability-reducing additive into a stream of jet fuel. The resulting mixture consists of a homogeneous suspension of additive polymer particles in the fuel. The particles dissolve within 15 to 30 min, without agitation, forming the airplane fuel known as antimisting kerosene, which promises to reduce the danger from fire in crashes.

The blender delivers up to 10 gal/min (0.6 L/s) of the liquid mixture. It was developed as a demonstration of the mixing concept and as a source of fresh antimisting kerosene for laboratory experiments. The apparatus can readily be enlarged to provide mixing at an aircraft-fueling site — the delivery mode envisioned for worldwide use of antimisting kerosene.

The apparatus consists of subsystems for pumping and metering the jet fuel, for pumping and metering the additive (a polymer slurry), and for injecting the additive into the fuel (see figure). A gear-type fuel pump was chosen because it delivers a smooth flow and is insensitive to changes in the inlet and exit pressures. It is driven by a variable-speed motor. A turbine flowmeter downstream from the gear pump provides a series of pulses with a repetition frequency proportional to the flowrate.

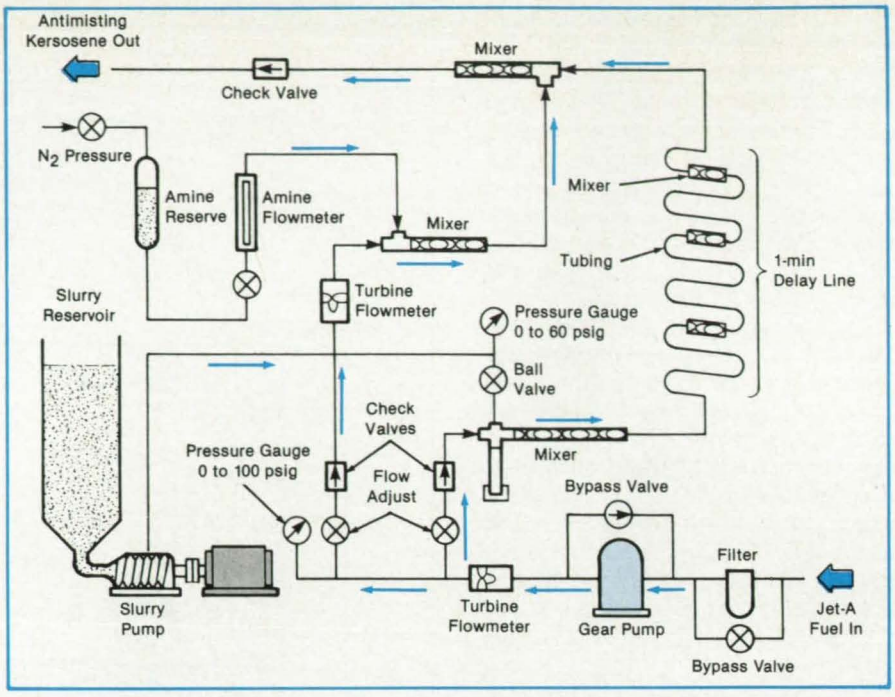
The additive is pumped by a rotary screw especially suited for slurries. It is powered by a speed-controlled motor through a 20:1 speed-reducing gearbox. A flexible hose delivers the slurry from the pump to the slurry-injection tube. The slurry flow is calibrated as a function of the motor speed and the pressure just up-

stream of the injection tube.

It is important that the slurry particles be dispersed in the fuel immediately after injection. Otherwise, blobs of slurry form, leaving the fuel with reduced flammability protection. Accordingly, an inline static mixer is positioned just downstream of the injection point. The mixer has no moving parts but contains helical elements that direct the flow alternately clockwise and counterclockwise. The mixing-tube diameter is selected to provide a Reynolds number high enough for effective mixing (5,000 to 30,000) without excessive pressure drop [10 lb/in.^{2} (70 kPa) maximum]. Additional mixers are placed downstream.

Optionally, the blender also mixes a metered amount of amine into the polymer/fuel suspension about 1 min after the polymer has been injected, because experiments show that the delayed amine injection enhances the dissolution of the additive in the fuel. The delay line is a tube 120 ft (36 m) long of 1-in. (2.5-cm) diameter, with static mixers placed at 20-ft (6-m) intervals. The amine is dispensed from a pressurized chamber through a needle valve and a rotameter.

This work was done by Pradip G. Parikh, Virendra Sarohia, and Andre H. Yavrouian of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 87 on the TSP Request Card.*
NPO-16968



The **Blender Combines Three Components**: fuel, polymer, and amine. The amine is first blended with fuel in one leg, then mixed with the polymer/fuel suspension in the other leg far enough downstream that the polymer particles have been in the fuel medium for about a minute. The delay is necessary to bring out the beneficial effect of the amine.

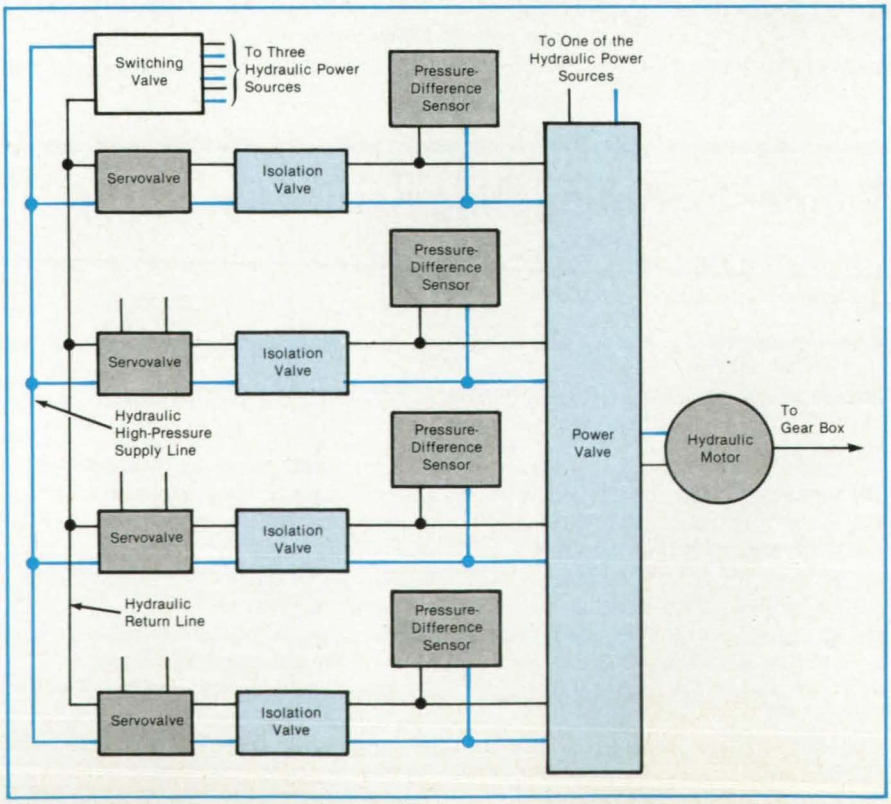
Fault Detection and Isolation for Hydraulic Control

Pressure sensors and isolation valves act to shut down a defective servochannel.

Lyndon B. Johnson Space Center, Houston, Texas

A redundant hydraulic system indirectly senses a failure in any of its electrical control channels and mechanically isolates the hydraulic channel controlled by the faulty electrical channel so that it cannot participate in operating the system. With the failure-detection and -isolation technique, the system can sustain two failed channels and still function at full performance levels.

The technique was developed for two similar hydraulic systems on the Space



Any Combination of Two servovalves will operate the power valve. While a channel is failing and its servovalve differential pressure is rising, the good channels will fight against its spurious commands. When the overpressure in the failed channel stabilizes, the sensor and isolation valve cut it off from the rest of the system.

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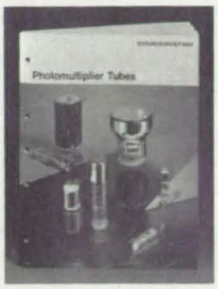

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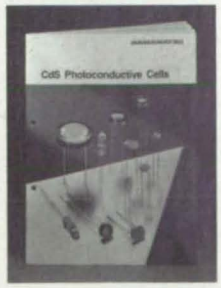
PHOTODIODES — Silicon, PIN Silicon, GaAsP, GaP, Avalanche This 44-page catalog provides spectral range, response time, temperature characteristics, linearity and specifications for UV to IR silicon, visible to IR silicon, GaAsP and GaP photodiodes.



PHOTOCONDUCTIVE CELLS CdS, CdSe This 16-page catalog describes performance characteristics and specifications of various photoconductive cells used in exposure meters, auto dimmers, musical instruments, flame monitors, street light controls and other applications.

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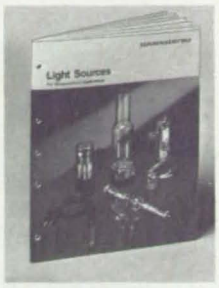

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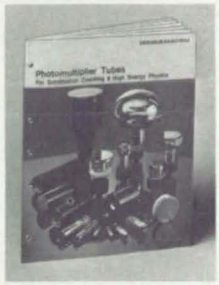

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Shuttle: one for the rudder and one for the speed brake. In both systems, command signals are sent to a power drive unit, which sets the positions of aerodynamic control panels. The scheme may be useful on aircraft or other systems with hydraulic servovalves where failure cannot be tolerated.

In either system, four servovalves feed each power valve, which sums their hydraulic control signals (see figure). The power valve in turn controls a hydraulic motor that drives the rudder or speed brake through a gearbox. The power valve and motor are triply redundant. A switching valve selects one of three hydraulic power sources to supply power to the servovalves.

One of the peculiarities of these systems is that if an electric control channel fails, the servovalve output pressure will be high on one leg — about 3 times as high as normal. A differential-pressure sensor continuously monitors the output pressure of each servovalve. When a sensor detects this large pressure difference, it activates an isolation valve on the servovalve output, and the channel is removed from service.

If another electrical channel should fail, the pressure difference in the output of the affected servovalve will again rise — this time to twice the normal value. Again the sensor will detect the high differential pressure and activate the associated isolation valve. Even with two channels out of service, the power drive unit will be able to operate the rudder and speed brake normally.

This work was done by Sundstrand Energy Systems for **Johnson Space Center**. *For further information, Circle 160 on the TSP Request Card.*
MSC-20760

Solenoid Valve With Self-Compensation

Paired upstream and downstream seals balance sealing forces.

Ames Research Center, Moffett Field, California

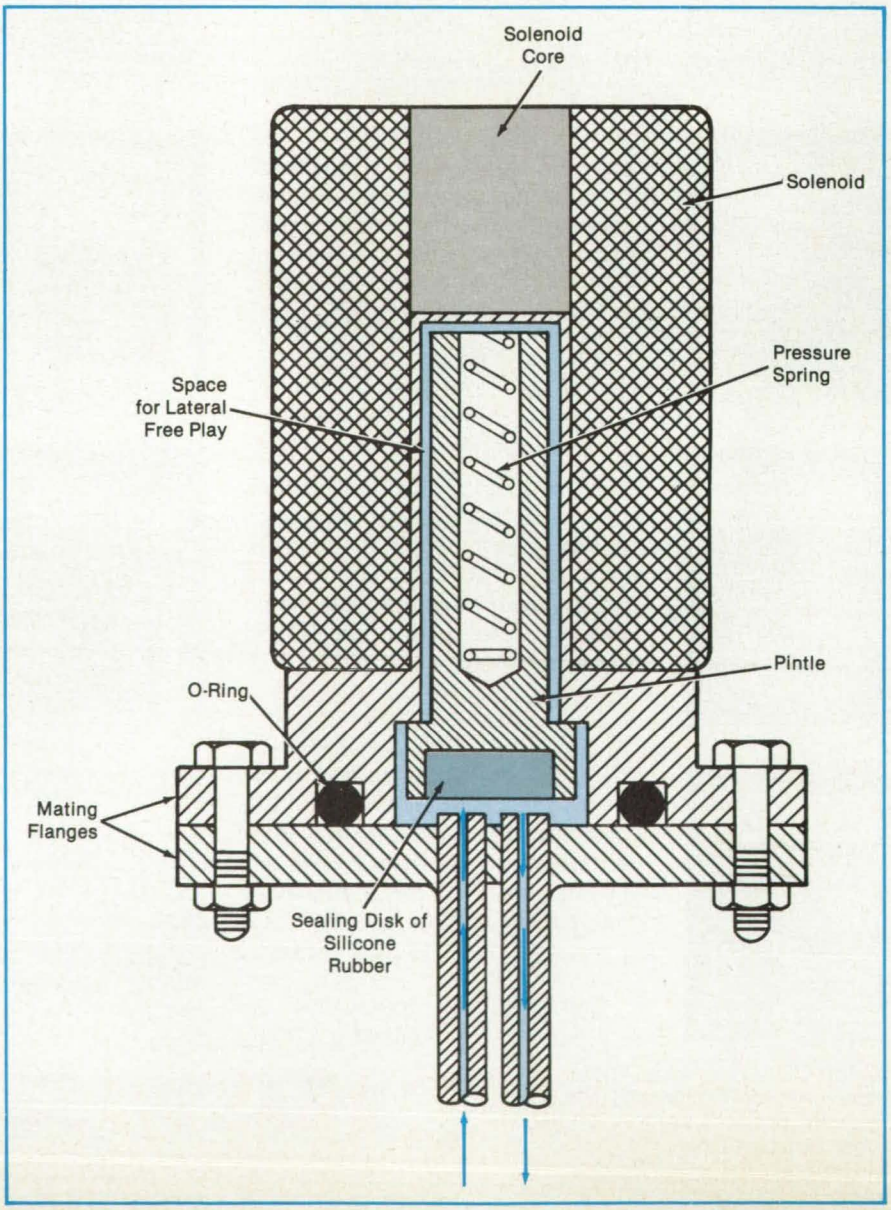
By using a dual upstream and downstream seal, a new solenoid-operated miniature shutoff valve provides self-compensation of the differential pressure forces that cause jamming or insufficient valve closure as in single-seal valves. Furthermore, the dual-seal valve is bidirectional. The normally closed valve shown in the figure operates reliably at pressures up to at least 1.5 MPa. By appropriate reversal of the solenoid and spring action, a similar normally open valve could be designed.

The valve simultaneously seals both the inlet and outlet tubes by pressing a single disk of silicone rubber against the ends of both. When the valve is open, the pressures in the inlet and outlet tubes and in the body of the valve are all approximately equal. Thus, when the spring closes the valve, there is no significant differential fluid-pressure force acting across the valve disk. The result is positive, nonjamming sealing action.

Since the moving parts of the valve are all located entirely within the fluid-flow region, no sliding seals are required, and leakage to the exterior of the valve should not occur even after prolonged use.

This work was done by Fritz H. Woeller and Yutaka Matsumoto of **Ames Research Center.** *No further documentation is available.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center [see page 19]. Refer to ARC-11620.



The **Solenoid Valve** achieves self-compensation of differential pressure forces by sealing both the inlet and outlet tubes with the same side of a disk of silicone rubber.

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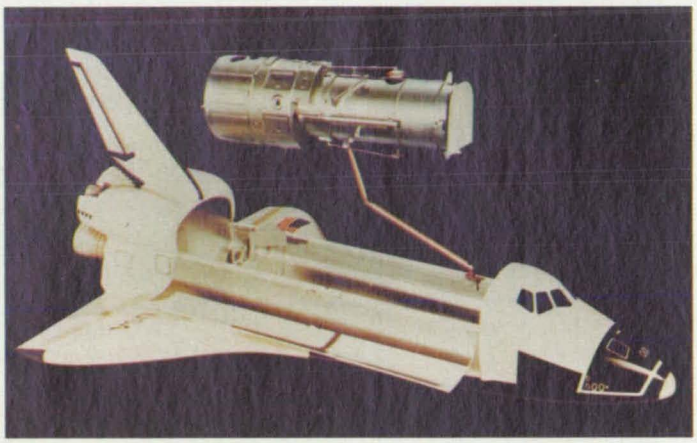

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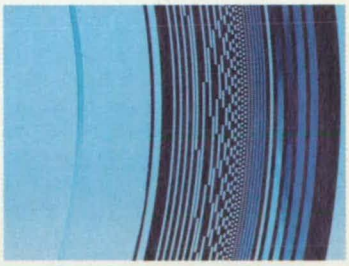

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Active Suppression of Rotor Vibrations

A feedback system enables operation at and beyond critical speeds.

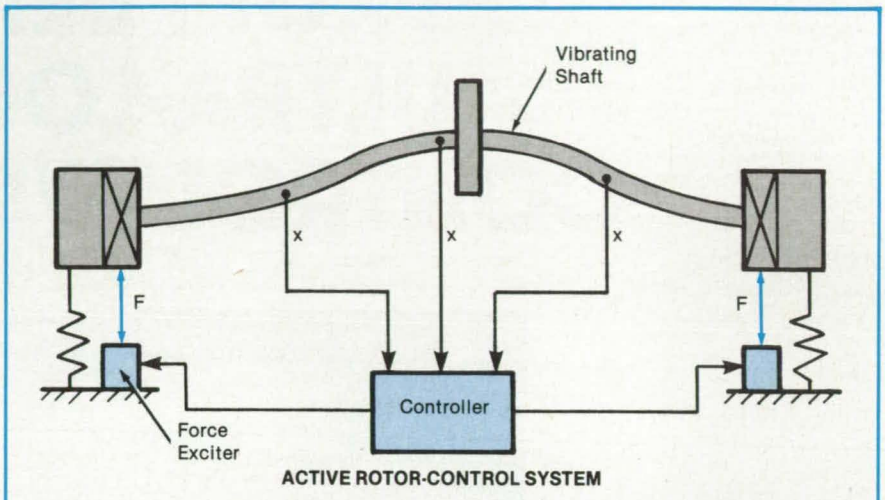
Lewis Research Center, Cleveland, Ohio

In active rotor control, vibrations of flexibly supported rotors are suppressed by the use of an electronic feedback control system. The feedback control system senses the vibration level of a rotor system and, in turn, provides damping such that vibration level is maintained within acceptable limits. This enables a rotor to operate through and above its critical speeds, increases bearing life, reduces the size and weight of rotating shafts, and generally enables rotors to operate more smoothly.

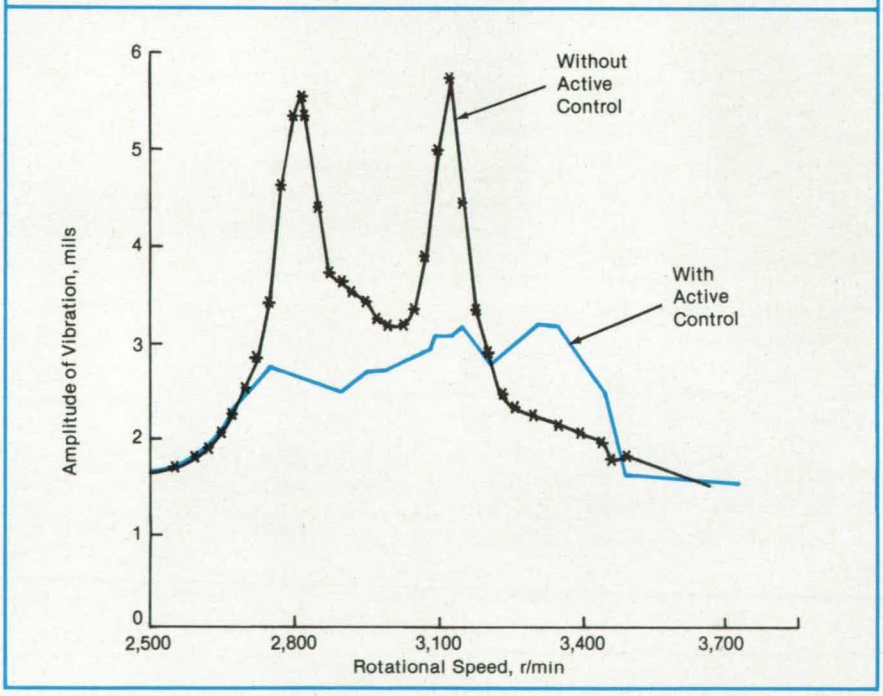
The significant features of the active rotor-control system shown in the figure are the electronic controller and the force exciters. The vibrational velocity ($\dot{x}$) is sensed, and the sensor output is sent to the electronic controller, which processes the velocity signal and commands the force exciters to provide the desired level of damping force (F) to the rotor support (see top of figure).

The electronic controller is programmed by entering feedback coefficients to provide any desired percentage of critical damping. The feedback coefficients are calculated by a computer program and are based on a modal analysis of the vibrating rotor system. Preliminary experiments on the active rotor-control system at Lewis Research Center have demonstrated that a high degree of damping is achievable, as shown at the bottom of the figure.

This work was done by Eliseo DiRusso of **Lewis Research Center**. *No further documentation is available.*
LEW-14488.



ACTIVE ROTOR-CONTROL SYSTEM



VIBRATION MEASUREMENTS

The **Active Rotor-Control System** reduces the amplitude of vibration over most of the experimental range of rotational speeds.

Adapting a Robot Hand to Specialized Functions

A special-purpose end effector is quickly joined to a general-purpose gripper.

Marshall Space Flight Center, Alabama

An adaptor enables mechanical and electrical connections to be made easily between a special-purpose end effector (robot hand) and the arm of a robot or remote manipulator. Use in prosthetic devices is also contemplated. With the

adaptor, the hand can be changed quickly from a device designed to grasp objects of various sizes and shapes to a device intended to do a specific task efficiently. Examples of such special-purpose end effectors are a drill and a set of jaws for gripping only one kind of object; for example, an electromagnetic hammer or a camera.

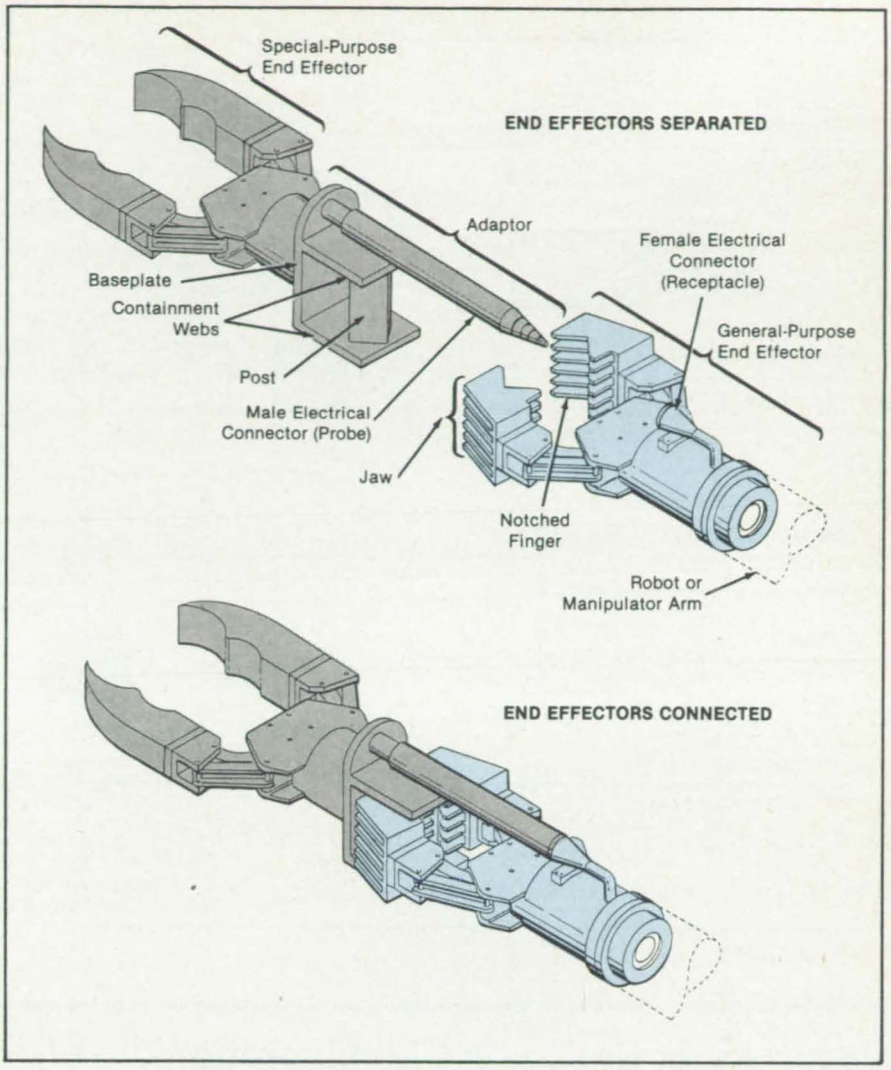
The general-purpose end effector is a pivoted pair of jaws with notched, interleaving fingers (see figure). The adaptor consists of an end plate, containment webs, a post, and an electrical probe. The special-purpose effector is mounted on the adaptor.

The adaptor is placed on the general-purpose end effector such that the jaws close on the adaptor post, gripping it securely; the notched fingers on the jaws prevent the post from twisting or rotating. Because the containment webs prevent the jaws from sliding vertically on the post, the adaptor is rigidly joined to the general-purpose effector.

The conical tip of the electrical probe aligns itself with the electrical receptacle on the general-purpose effector. Contacts on the probe mate with contacts in the receptacle and carry electrical signals from a controller to and from the special-purpose end effector.

This work was done by Keith H. Clark of **Marshall Space Flight Center**. *For further information, Circle 41 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 19]. Refer to MFS-25949.



The **Special-Purpose End Effector** is connected to the general-purpose end effector through an adaptor, forming a rigid unit. The special-purpose effector can be any of a variety of types; the one shown here picks up bundles of tubes.

Emergency Control for a Circulation-Control Helicopter Rotor

A digital system gives the pilot partial command when the primary system fails.

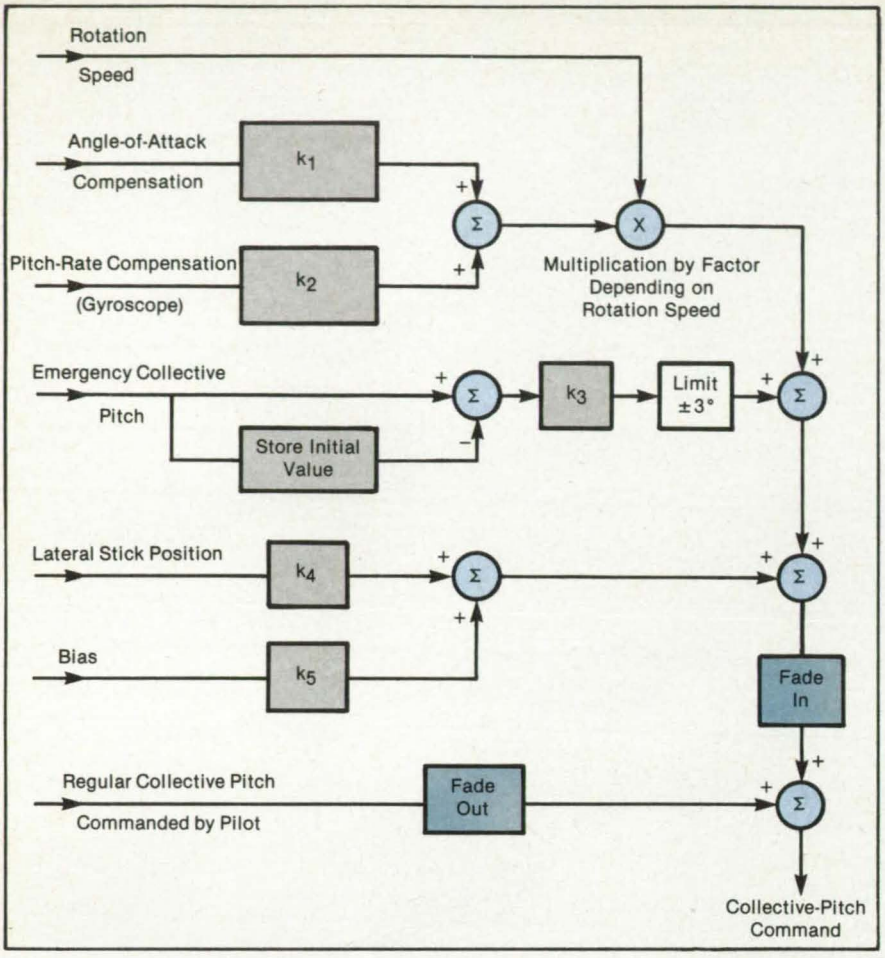
Ames Research Center, Moffett Field, California

An emergency system (see figure) provides digital control of a rigid circulation-control rotor for the experimental X-wing aircraft. In addition to centering collective-pitch control, the new command provides limited roll control via collective pitch and gyroscopic decoupling in pitch and aerodynamic decoupling.

The X-wing aircraft uses a rigid, stoppable, circulation-control rotor. In normal operation, lift and the pitch and roll moments on the rotor are controlled by varying the pressure and airflow from the rotor blowing holes. For roll control at higher forward flight speeds and for lift augmentation in hovering, conventional collective-pitch control is used. If the blowing control is lost, the rotating rotor can be a strong source of unwanted pitch and roll moments.

A digital type of backup system was chosen for simplicity and reliability; although an analog system could be built, it would be complicated and less reliable. The backup system is implemented via a second independent software program executed by the same quadruply redundant computers used for the prime system. The Backup Control Software (BUCS) is switched in when selected by the pilot or automatically when the third computer servers. The digital system treats the rotor in its unblown state so that the requisite software is also simple. When the primary control system fails, the emergency system fades out the existing collective-pitch command and fades in a new collective-pitch command. The new command consists of the sum of the collective-pitch bias, lateral-stick-position, angle-of-attack, and pitch-rate signals.

To compensate for changes in the roll moment caused by angle-of-attack changes, the digital backup sends an angle-of-attack signal to the collective-pitch control. To reduce gyroscopic coupling, the system



also feeds pitch-rate data to the collective-pitch control. Because both gyroscopic and angle-of-attack effects exist only in the rotary-wing mode the angle-of-attack and pitch-rate signals are amplified according to the rotor speed from zero amplification for a stopped rotor to maximum amplification at full rotational speed.

This work was done by William C. Fischer, Kenneth C. Arifian, and Tom H. Lawrence of United Technologies Corp. for **Ames Research Center**. *For further information, Circle 43 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center [see page 19]. Refer to ARC-11605.

The **Emergency-Control System** processes the collective-pitch pilot command, lateral-stick-position, angle-of-attack, and pitch-rate signals to generate a new collective-pitch signal that restores neutral lift and partial control of roll and collective pitch.

Refrigerator Based on Chemisorption

A reversible chemical reaction would generate pressurized oxygen for cooling.

NASA's Jet Propulsion Laboratory, Pasadena, California

A concept for a cryogenic refrigerator is based on the chemical absorption of oxygen by a praseodymium/cerium oxide (PCO) compound. The refrigerator would produce a cryogenic liquid for cooling infrared sensors. The concept could also be used for liquefying air and for separating oxygen from nitrogen in air.

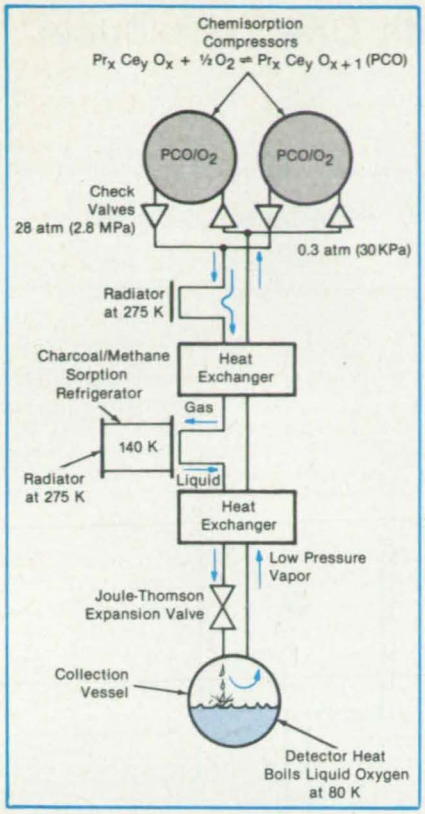
Gaseous oxygen would be compressed in a vibrationless, wear-free, fully reversible reaction cycle. The refrigerator would include two chemisorption compressors, a series of heat exchangers, a Joule-Thomson expansion valve, and a vessel to collect liquid oxygen (see figure). While one compressor is cooled so that it chemically absorbs oxygen at 0.3 atm (30 KPa), the other would be heated so that it releases oxygen at 28 atm (2.8 MPa). The compressors would alternate in heating and cooling. Flowing through the expansion valve, the pressurized oxygen would cool in the collection vessel at a temperature of 60 to 100 K. The boiling liquid oxygen in the vessel would absorb heat from the refrigeration load. Along with some uncondensed expanded oxygen, the boiled oxygen gas would return to one of the compressors.

When cool, PCO would combine with the oxygen flowing over it, forming PCO in a higher oxidation state. When heated to a temperature of 650 °C, the oxygenated PCO would dissociate. The absorbed oxygen would pass off as a gas, leaving the PCO to absorb more oxygen when it is recooled.

On leaving a compressor, the hot oxygen would be cooled to 275 K in a radiator. It would be cooled further by a recuperative heat exchanger and a charcoal/methane sorption refrigerator at 140 K. This would liquefy the high-pressure oxygen and allow efficient expansion to 80 K at 0.3 atm (30 KPa). The oxygen returning to the compressors would pass through the recuperative heat exchangers, absorbing heat from the inflowing oxygen.

The entire refrigerator system would require about 150 W (mostly as heat) to produce 1 W of cooling at 80 K. Although its efficiency would be lower than that of some mechanical units, multistage sorption systems using hydrides are considerably more competitive. With an oxide upper stage, the overall system weight and the power efficiency for closed-cycle solid hydrogen sublimation (7 K - 14 K) are significantly better than those of any other known refrigeration system. Furthermore, there are essentially no wear-related moving parts and thus virtually no vibration. Life expectancy of this JPL-developed refrigeration system is at least ten years and thus ideal for long-life space use.

This work was was done by Jack A. Jones of Caltech for **NASA's Jet Propul-**



In the **Chemisorption Refrigerator,** PCO alternately absorbs and desorbs oxygen, depending on whether it is cooled or heated. One of a pair of compressors accepts oxygen while the other releases it. The compressed oxygen is liquefied when precooked and expanded.

sion Laboratory. *For further information, Circle 52 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, JPL [see page 19]. Refer to NPO-16734.

New Products

Lixi, Inc. (Downers Grove, IL), has added a micro focus feature to its X-ray inspection system to show flaws in greater detail. The Micro Focus Lixi Fluoroscope magnifies X-ray images up to 130 times. Details visible using this system are solder integrity in surface mount devices, voids in the bonding of IC chips to substrates, and wire placement on chips. The Fluoroscope's portability and real-time X-ray imaging allow users to inspect parts during manufacturing. Readers are invited to send a good and a suspect sample to Lixi Inc., which will send pictures of both samples, showing hidden flaws as viewed through the Fluoroscope. **Circle Reader Service Number 312.**

Edwards High Vacuum (Grand Island, NY) introduces the Autoregenerator 1701, an automatic microprocessor-based cryopump system controller, which ensures that the correct pumping and valve sequences are followed with little intervention. The operator is thus free to concentrate on process activities. Regeneration can be initiated at any convenient time, for example at night or during weekends. The standard unit controls the cryopump system regeneration, and additional components allow the unit to manage all vacuum hardware through to the opening of the high vacuum valve. **Circle Reader Service Number 307.**

Crystal Systems, Inc. (Salem, MA) announces the availability of titanium-doped-sapphire for tunable solid-state lasers. Ti:Sapphire crystals, grown by the Heat Exchanger Method (HEM), exhibit highly uniform growth, uniform dopant concentration and crystalline perfection. The HEM Ti:Sapphire has a tunability range of 660 to 1140 nm. Systems using Ti:Sapphire may, for economic reasons, replace several dye lasers currently required to cover this portion of the spectrum. **Circle Reader Service Number 469.**

Fabrication Technology

Hardware, Techniques, and Processes

Acoustic Levitation With One Transducer

Higher resonator modes enable the simplification of equipment.

NASA's Jet Propulsion Laboratory, Pasadena, California

An experimental acoustic levitator for high-temperature containerless processing has a round cylindrical levitation chamber and only one acoustic transducer. Stable levitation of a solid particle or liquid drop is achieved by exciting the sound in the chamber to a higher-order (nonplanar) resonant mode that makes a potential well for the levitated particle or drop at some point within the chamber.

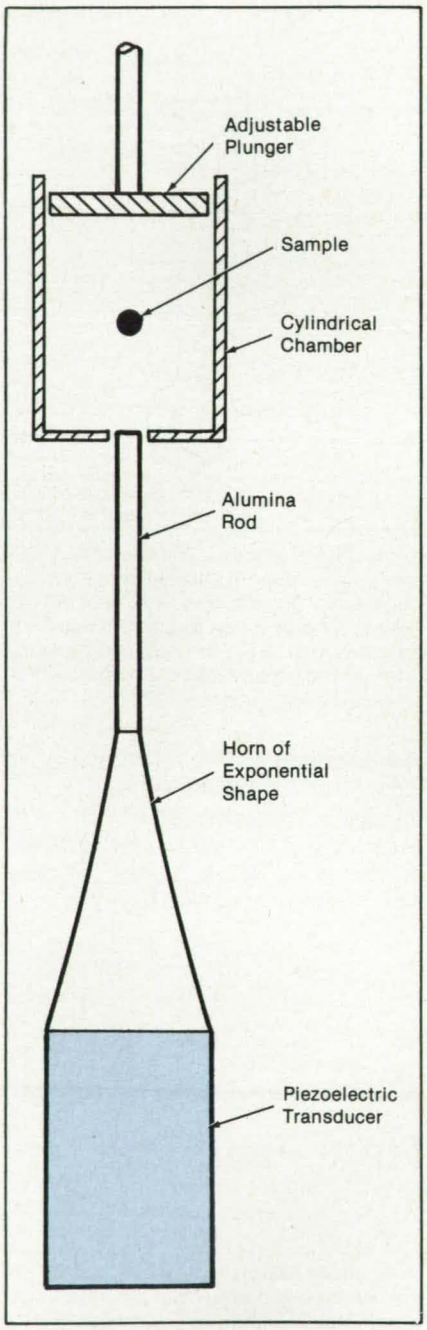
Previous levitation schemes have involved different types of chambers and transducers. In the triple-axis resonant method, a sample is levitated in the potential well formed by the superposition of three orthogonal plane standing waves from three transducers in a rectangular chamber. In the single-axis interference method, a sample is levitated in the potential well formed near an acoustic reflector by the interference between the reflected waves and the waves incident upon the reflector from a single transducer. The new method is related to the single-axis interference method but takes advantage of reflections from all the walls of an enclosed chamber.

Theoretical studies of acoustic-resonance-positioning theory have been conducted to aid the design of single-mode levitators, with attention to such matters as the following:

- The magnitudes of the acoustic restoring forces;
- The optimum chamber dimensions to maximize the restoring forces; and
- The temperature dependence of the restoring forces.

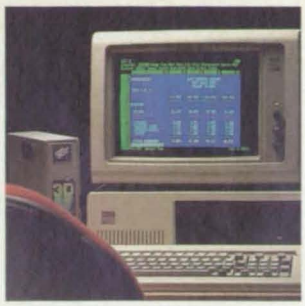
The translational and rotational stability of the sample would also normally be a matter of concern in such studies. However, in a single-mode levitator, the inherent phase coherence of the orthogonal force components automatically assures stability, and controlled sample rotation can be introduced by the excitation of more than one mode.

In the experimental single-mode levitator (see figure) a 20-kHz piezoelectric transducer is coupled to the high-temperature levitation chamber by a solid horn and an alumina rod. The speed of sound in this solid transmission medium varies only slightly with temperature, and the density is nearly constant; consequently, a relatively high degree of acoustic-energy transfer is maintained over a wide temperature range. The alumina rod withstands high temperatures and acts as an acoustic waveguide between the horn and the chamber.



The **Single-Mode Acoustic Levitator** requires only one transducer. A nonplanar acoustic-resonance mode provides translationally and rotationally stable levitation of the sample.

For stable levitation at 1,500 °C in argon, calculations indicate an optimum chamber



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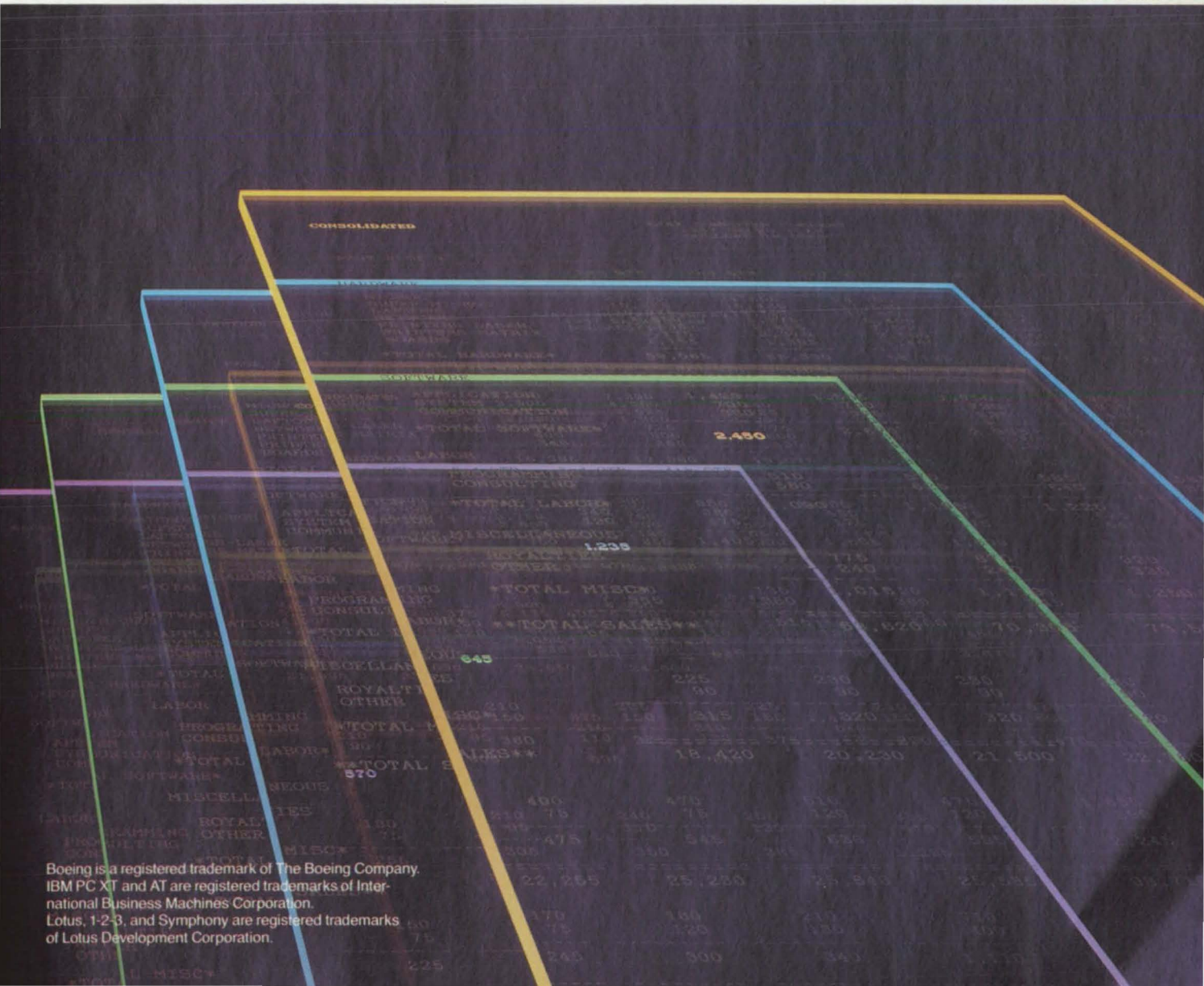


length of 3.8 cm and a radius of 2.9 cm, using the zero-order azimuthal, first-order radial, first-order axial mode. Other resonance modes could also be chosen. The correct chamber length for the excitation of a particular resonance mode is obtained by adjusting the plunger.

This work was done by Martin B. Barmatz of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 115 on the TSP Request Card.*
NPO-16867

Thermal Stresses in Silicon-Web Growth

A suitable temperature distribution may yield a stress-free ribbon.

NASA's Jet Propulsion Laboratory, Pasadena, California

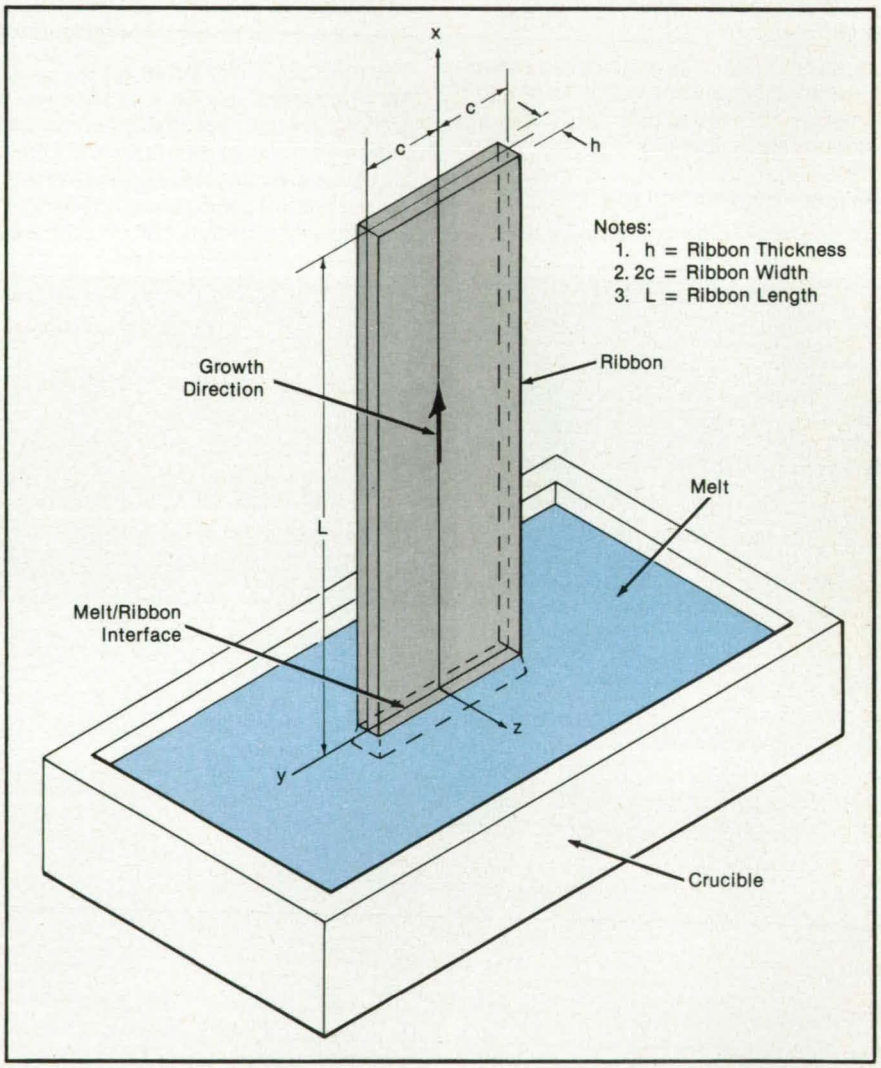
A mathematical model represents the thermomechanical behavior of a solid web of rectangular cross section as it is pulled from a melt of the same material. Although intended for application to the growth of silicon webs or ribbons, the model is general enough to be applicable to other materials as well. The model shows that a suitable temperature distribution may result in a stress-free ribbon.

The ribbon (see figure) is taken to be sufficiently thin to justify the approximation that there is no thermal gradient through the thickness (z direction). The temperature is allowed to vary only along the width (y direction) and length (x direction) of the growing web. The solid material is assumed to be orthotropic, with temperature-dependent coefficients of thermal expansion α_x, α_y, and α_{xy}.

The thermal strains cause thermal stresses, which give rise to plastic, elastic, and creep strains. The relationships among the stresses and strains is expressed in a matrix equation. Considering only the situation after the initial thermal transients have dissipated and the ribbon is growing at a steady rate, the equation is put in its steady-state form.

The steady-state equation has a zero-stress solution, which can be realized in one or more ways depending on the temperature distribution and the properties of the material. In particular, the equation shows that the ribbon will be free of thermally induced stresses if the material can deform freely and if the thermal loading is such that the thermal strains satisfy the strain-compatibility equations. Cases in which the zero-stress conditions are satisfied include the following:

- The thermal-expansion coefficients are independent of temperature and position, there are no restraints against free deformations, and the temperature either varies linearly with position or is uniform; and
- The thermal-expansion coefficients are independent of temperature, the material is isotropic ($\alpha_x = \alpha_y = \alpha$; $\alpha_{xy} = 0$) and homogeneous and $\nabla^2 T = 0$, where T = temperature.



A **Conceptual Ribbon of Rectangular Cross Section** is pulled from a melt. This simplified configuration is used to calculate the thermal conditions for a stress-free ribbon.

In the second case, assuming that the temperature at the edge of the ribbon is prescribed to be that required by the manufacturing process, if the temperature distribution within the ribbon can be made to satisfy $\nabla^2 T = 0$, the ribbon will grow without stress. The required distribution is found by solving $\nabla^2 T = 0$ as a boundary-value problem.

This work was done by Ben K. Wada of Caltech for **NASA's Jet Propulsion Laboratory** *and Senol Utku and Sujit Kumar Ray of Duke University. For further information, Circle 34 on the TSP Request Card.*
NPO-16824

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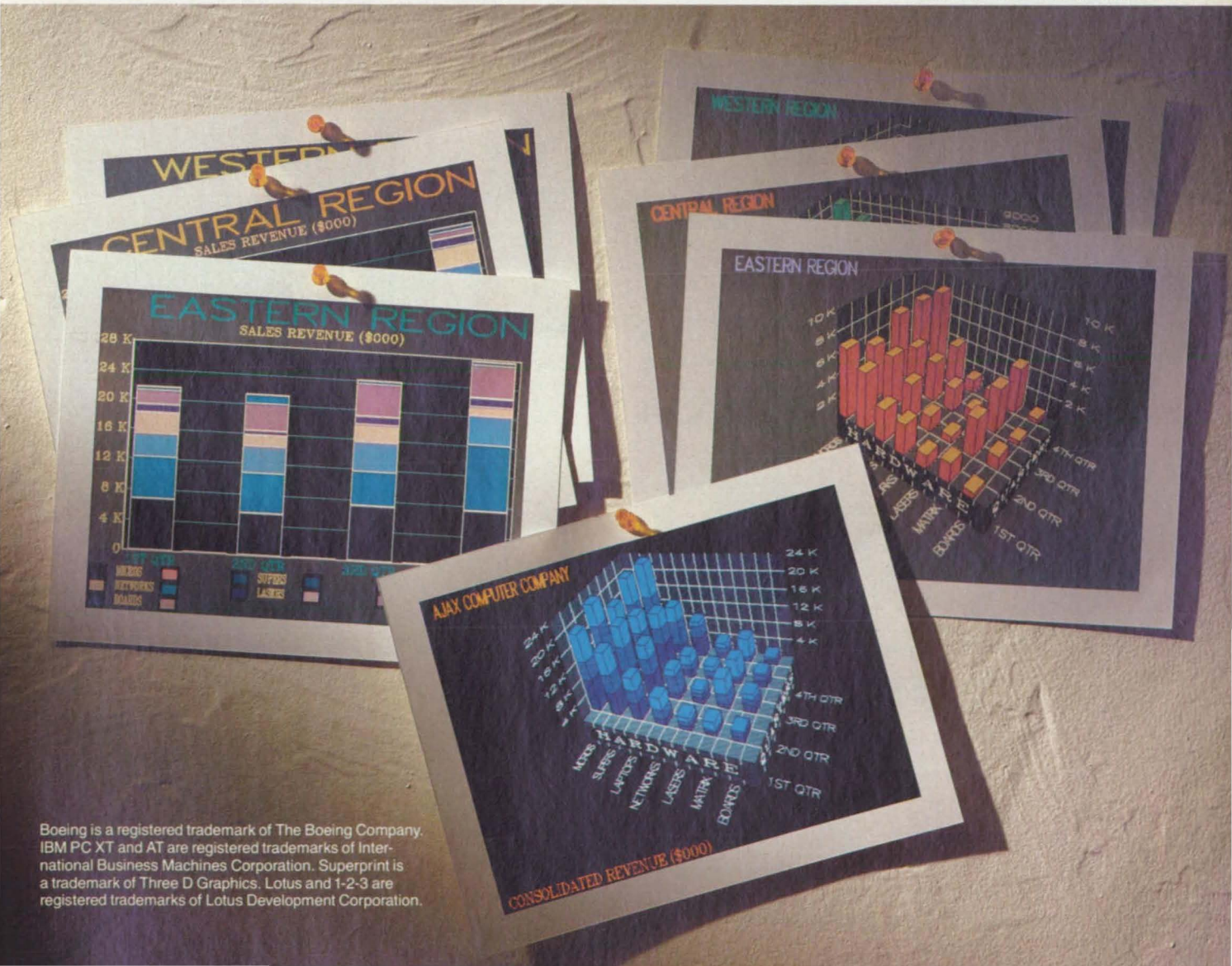


Economical Joint for Truss Structures

Mass-produced flat parts can be easily assembled.

Marshall Space Flight Center, Alabama

A joint for a three-dimensional truss is made of simple die-cut plates and inexpensive fasteners. Each truss joint consists of two identical interlocking plates that are bolted, welded, or glued together (see top of figure). The truss struts are bolted to the joint through holes in the plate. Alternatively, the ends of the struts could be forked so that they slip over the plates and are fastened to them by bolts or pins.

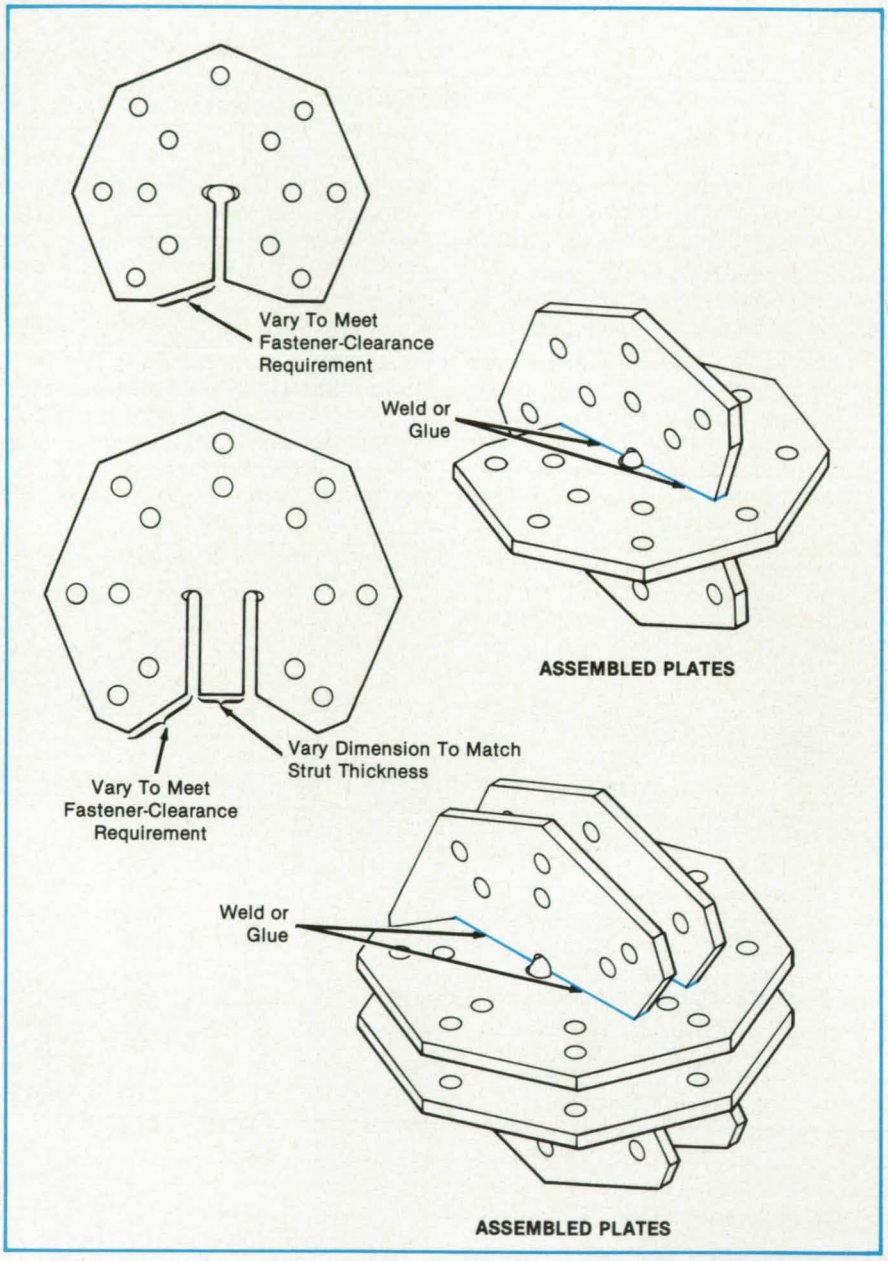
Plate stock of aluminum or steel, for example, can be used to make the joints. The plates are designed so that they can be stamped from the stock in large quantities with little waste.

The size of the plate, the shape of the slot, and the size and spacing of the holes can be changed to save weight, to ensure clearances of fasteners, or to match a particular truss configuration. The most economical plate style, however, is one that suits a variety of applications and can be turned out in great quantities.

A slightly more complex version of the joint includes four plates that again would be bolted, welded, or glued together (see bottom of figure). A strut is inserted between a pair of plates. It is held by bolts, pins, or rivets through plate holes.

This work was done by Carleton J. Moore of **Marshall Space Flight Center**. *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 19]. Refer to MFS-28160.



Simple Interlocking Plates contain holes for mounting truss members at 90° or other angles with each other. A more complex joint with four plates (lower right) allows members to be positioned between pairs of plates, possibly making assembly easier and giving greater rigidity.

Removing Silicon Monoxide From Nickel Mirrors

Adherent fragments are detached by gentle polishing.

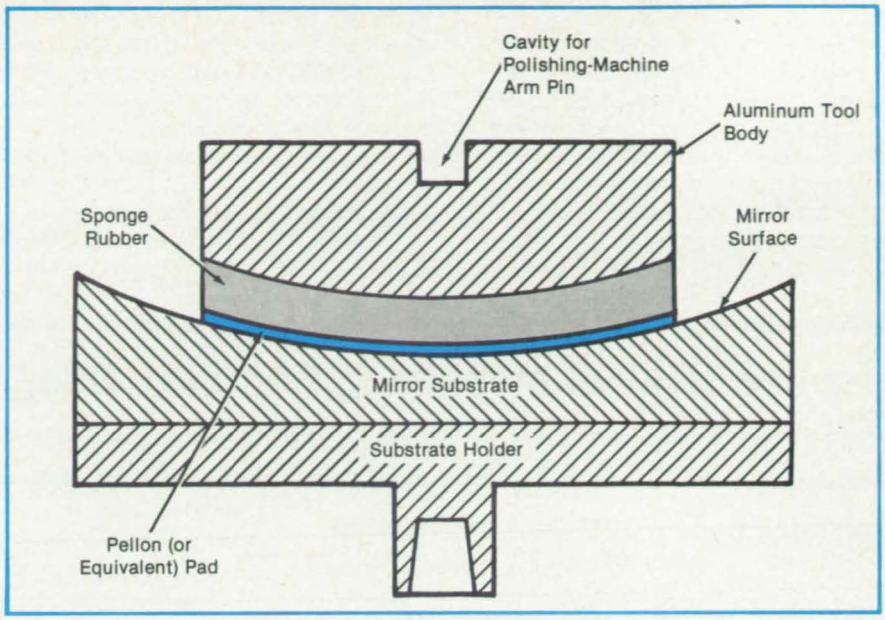
Goddard Space Flight Center, Greenbelt, Maryland

The combination of a polishing tool and polishing mixture is used to remove adherent fragments of silicon monoxide protective coatings from nickel/aluminum mirrors without altering the shapes or harming the polishes of the mirror surfaces. The polishing technique was developed to prepare stained mirrors for recoating to restore high reflectance.

A polished electroless-nickel-plated mirror is coated with vacuum-deposited aluminum to enhance its reflectance, then overcoated with glasslike silicon monoxide for durability. During extensive use, the surface becomes stained, losing reflectance. Before recoating, the surface layers are stripped off with a solution of sodium hydroxide, which penetrates through minute pores in the silicon monoxide and dissolves the aluminum. The silicon monoxide is insoluble and simply floats off the mirror surface as the aluminum is dissolved. However, fragments of the silicon monoxide adhere to the surface and must be removed because they cause unwanted scattering of light.

The polishing technique applies just enough force to remove the fragments. In contrast with conventional rigid tools, the new tool (see figure) is flexible: thus, it conforms to the existing mirror shape, rather than forcing it into a different, unwanted configuration. The tool is formed on an aluminum body with a diameter of about ⅔ that of the mirror. If the surface to be polished is convex or concave spherical, or planar, the tool body is machined to the mating concave, convex, or planar surface shape, respectively.

The tool surface is covered with sponge rubber ¼ in. (6 mm) thick, using a general-purpose adhesive (GC bond or equivalent). An adhesive-backed Pellon (or equivalent) pad is applied to the surface of the sponge rubber. The mirror can be used as a pressing tool for the polisher while the adhesive is curing.



A **Polishing Tool With a Compliant Surface** conforms to the mirror surface. It applies just enough force to remove adherent silicon monoxide without damaging the mirror surface.

The tool surface is saturated with a gently acting abrasive of three parts aluminum oxide (Linde B 0.05 μm or equivalent) and one part cream of tartar, with an abrasive additive of lathered barber's shaving soap, and with water as the abrasive carrier. The tool and mirror are set up on a conventional polishing machine. The eccentricity and the polishing force are adjusted to suit the location and degree of residual stain on the mirror surface.

This work was done by John J. Zaniewski of **Goddard Space Flight Center**. *No further documentation is available. GSC-13079*

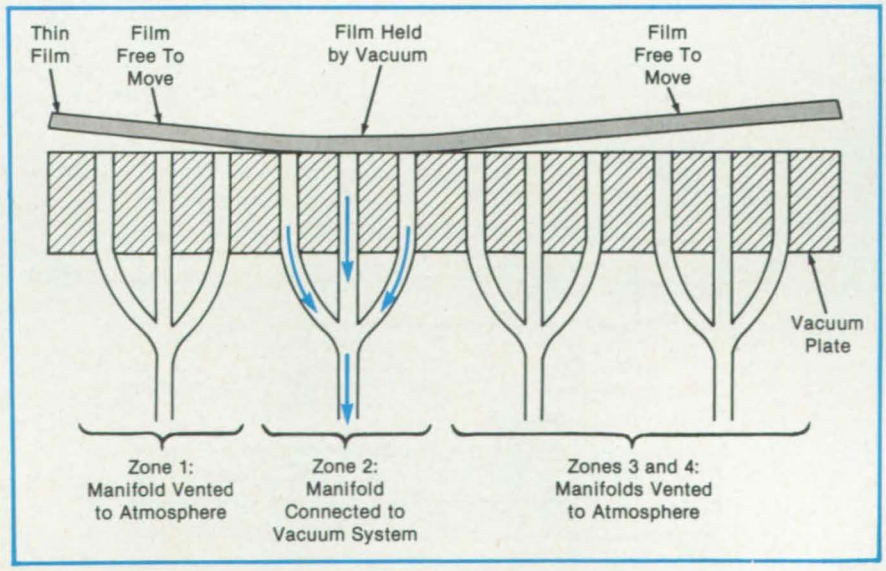
Vacuum Hold-Down System for Heat-Treating Thin Films

Vacuum is supplied alternately to different zones.

NASA's Jet Propulsion Laboratory, Pasadena, California

In an improved furnace concept for heat-treating thin films, the vacuum ports in the vacuum plate(s) that hold the films are connected together in zones so that the vacuum can be applied separately to each zone. This allows the material being held to shrink or expand while still being held in place. Unclamped zones expand or contract, relieving local stresses so that the entire sheet can accommodate thermally induced changes without cracking. Likely applications include the manufacture of thin semiconductor films for solar cells and of membranes for the electrolytic production of oxygen.

The vacuum is supplied in alternating pulses to each zone, with rotation to a different zone at every pulse or at an interval corresponding to several pulses, as desired (see figure). Each zone is connected to a separate vacuum manifold so that at least one zone at a time can be at ambient pressure, allowing the material overlying it



The **Vacuum Is Applied to One Zone** at a time, so that the film is held in place in one zone but free to move in the others.

to shrink or expand freely.

The zones may be arranged in many ways; for example, in concentric rings with the vacuum being applied radially, such that the clamping action "ripples" outward from or inward toward the center. Alternatively, the zones could be arranged as pie-shaped sectors, and the vacuum pulsed sequentially around a circle. The arrangement of the patterns and shapes is dependent on the material and shape of the film being held. Experimentation will find the best for each application. An experimental or universal version can be made by using a large number of small zones that can be connected together in larger groups to form various zone shapes.

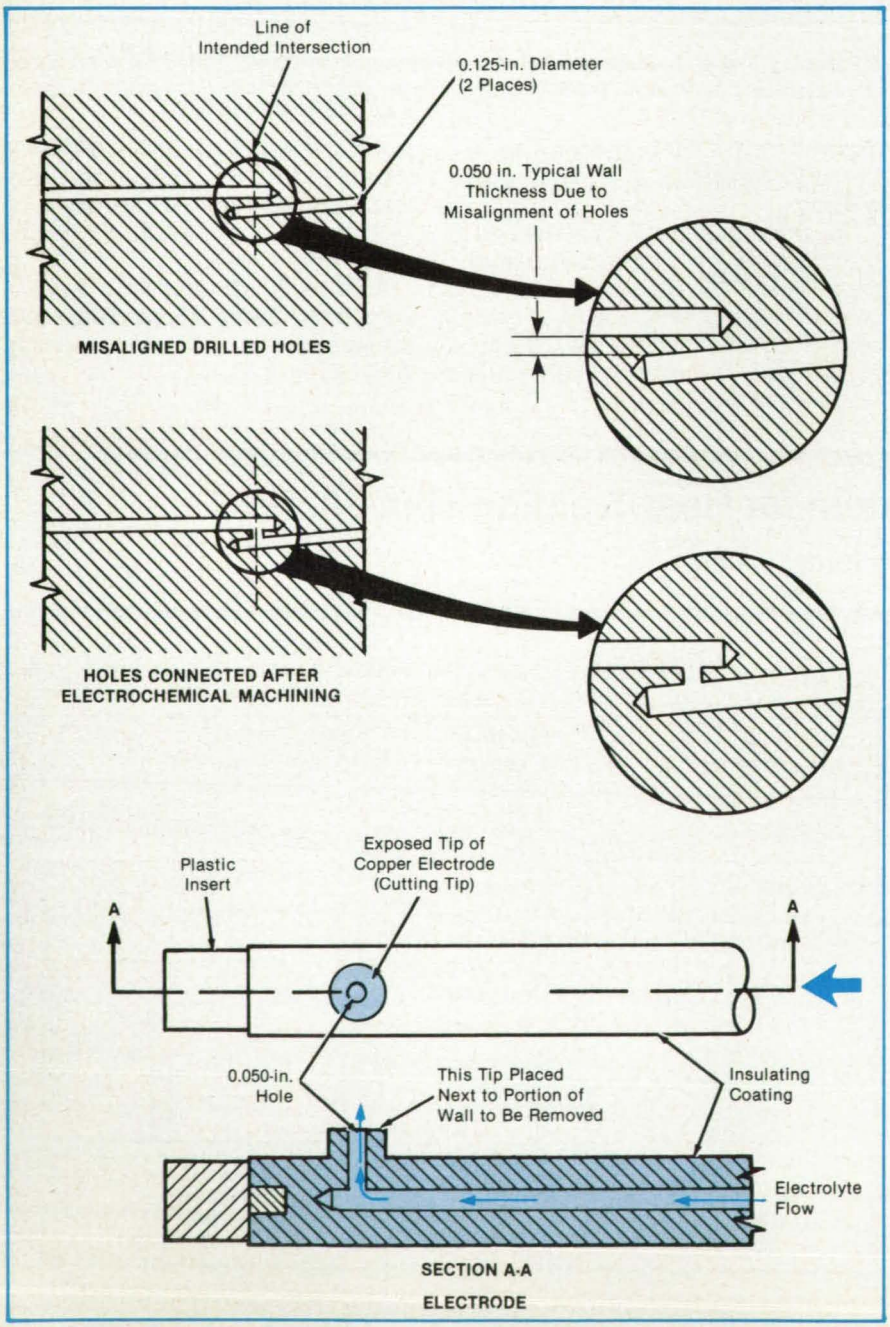
This work was done by Earl R. Collins, Jr., of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 21 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, NASA's Jet Propulsion Laboratory[see page 19] Refer to NPO-16892.

Electrochemical Machining Removes Deep Obstructions

An inexpensive technique can salvage expensive parts.

Marshall Space Flight Center, Alabama



Electrochemical machining (ECM) is an effective way of removing obstructing material between two deep holes that are supposed to intersect but do not because of misalignment of the drilling tools. ECM makes it possible to rework costly castings that would otherwise have to be scrapped.

ECM produces smooth surfaces and transition radii. It does not cause metallurgical damage and makes postprocessing treatments unnecessary. It is highly cost-effective because of its simple tooling, short setup time, and cutting speed.

An electrode is inserted in one of the holes with its tip near the obstruction (see figure). An electrolyte solution flows through the core of the copper electrode and out through a hole near the exposed tip while direct current passes between the workpiece (connected as the anode) and the tip of the electrode (the cathode in the electrochemical circuit). The action of the current and the electrolyte removes metal from the workpiece. Since the obstructing wall is thin [typically about 0.05 in. (1.3 mm)], it is quickly dissolved. The method is fast even for tough or hard alloys and complicated three-dimensional shapes.

This work was done by Mark J. Catania of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*
MFS-29118

Coolant Channels Drilled in a Metal Block failed to intersect because of the difficulty of aligning drill bits accurately in the long holes. The electrochemical-machining electrode can be inserted in either hole to remove the obstructing wall between the channels.

Simulating Building Fires for Movies

Realistic scenes are staged inexpensively.

Marshall Space Flight Center, Alabama

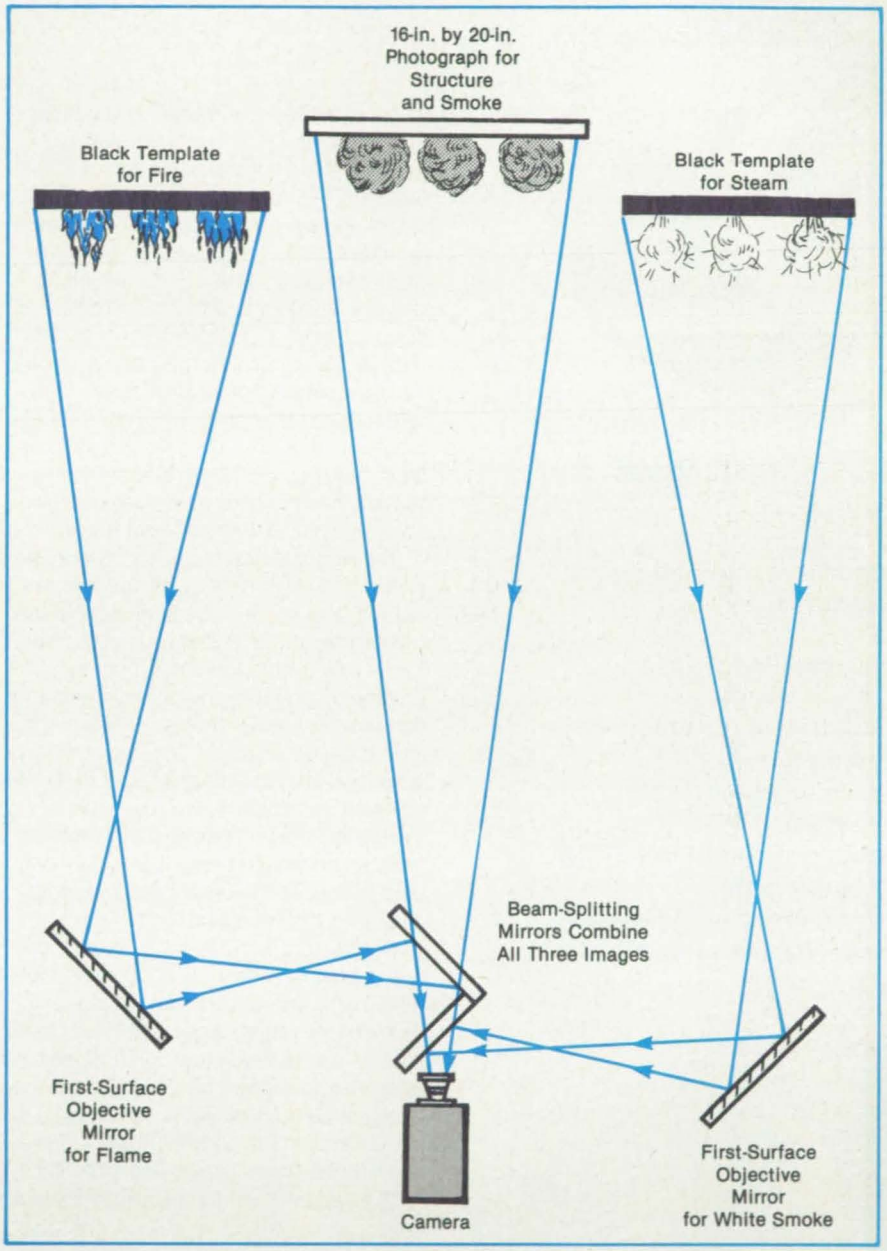
Fire scenes for cinematography are staged at relatively low cost in a method that combines several existing techniques. Nearly realistic scenes, suitable for firefighter training, are produced with little specialized equipment. Sequences of scenes can be set up quickly and easily, without compromising safety because the model is not burned.

The method involves the optical overlay shown in the figure. The images of separate models of fire, smoke, and steam are combined with the help of mirrors and a beam splitter. The model of the structure to be burned is made from a photograph mounted on cardboard. Windows, doors, vents, or any other openings where simulated fire, smoke, or steam must emerge are cut on three sides to form small doors. The fire and steam templates are black cardboard copies of the model, complete with all openings and identical to the photograph in size and shape.

To simulate fire, orange and red cellophane sheets are cut into thin strips, mounted above a fan behind a fire template, and illuminated from above and below. When the fan runs, the strips move, bouncing light through the openings in the template in irregular patterns and thereby giving the appearance of fire. Flames licking out of the top of an opening are simulated by cutting the top of the opening on the template in an irregular pattern higher than the top of the corresponding opening on the photograph.

Smoke and steam are generated and controlled in the same manner: the difference between the appearances of the two is created by a difference in lighting. A smoke generator creates a thick, nontoxic cloud of white smoke. The smoke is contained in a box, where it is heated to ensure proper rise and piped to two manifolds mounted behind the photograph and the black steam template. It then flows out through the desired opening. The airflow is controlled by walls and a hood, which pulls the smoke into an exhaust fan.

The appearance of black smoke is created by lighting the set from the front: an optical illusion is created wherein the video camera records the shadow of the white smoke, which appears black. The appearance of steam is created by lighting the smoke from above, causing it to appear white in the image.

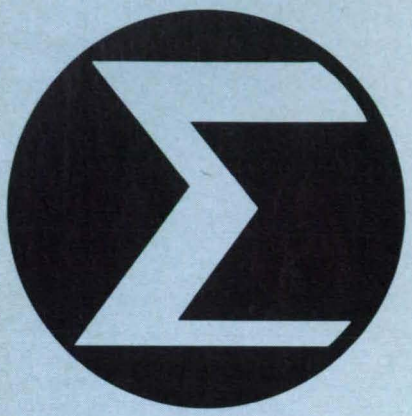


Images of Fire, Steam, and Smoke are superimposed on an image of a building to simulate the burning of the building.

Whereas the initial setup of the equipment requires construction, the amount of work required for later scenarios is minimal. Reconfigurations for individual scenes, done by opening and closing cutouts, take only minutes, thus speeding the filming process. In one application, 65 scenes of about 30-second duration were filmed in less than 4 hours.

This work was done by Ricardo C. Rodriguez and Randall P. Johnson of Essex Corp. for **Marshall Space Flight Center**. *No further documentation is available.*
MFS-26044

Mathematics & Information Services



Algorithm for Fluid Networks

Flow systems can be simulated to almost any degree of detail.

Lyndon B. Johnson Space Center, Houston, Texas

An algorithm performs either a transient integration or a steady-state relaxation of a network that represents an internal fluid system. The algorithm is valid for both single and two-phase flow of any fluid and includes both heat-transfer and work (volume-change) terms. The algorithm is general enough to simulate almost any flow system to almost any degree of detail desired. The algorithm has been encoded into the computer program FLUINT, which will work in conjunction with the SINDA-85 program to enable the analysis of pipelines; heating, ventilating, and cooling systems; and almost any other system that involves both fluid flow and heat transfer.

The algorithm treats a fluid network as a collection of lumps and connectors. Lumps are tanks, junctions, and plena where mass and energy are conserved. Tanks are control volumes that can exchange energy with the environment and can grow or shrink. They are governed by differential equations for mass and energy. Junctions are zero-volume tanks that can be used to model tees, small tanks, or measuring points. Plena are tanks with infinite volume that represent boundary conditions for open systems and do not appear directly in the equations.

Connectors include tubes and paths. Tubes have significant line inertia and are governed by a differential equation for momentum. Paths have insignificant inertia and are represented by an algebraic relationship between the flow rate and the pressure differential. Paths can be used to simulate pumps, valves, loss factors, capillary passages, leaks, and small lines.

The system of differential equations that describes a network is built by the algorithm and then solved. Each differential equation that goes into the final formulation is written in such a general form that a choice among Eulerian (first-order explicit), first-order fully implicit, and trapezoidal (second-order fully implicit) solution methods is made simply by the selection of a constant. Eulerian methods are not suitable unless extremely small transient time steps or many small steady-state relaxations are taken. The algorithm automatically uses the trapezoidal method, which is unconditionally stable and accurate to second order, unless network conditions require that the first-order implicit method be used. One such condition is that which can give rise to water-hammer events; namely, the presence of nonexpandable tanks filled with incompressible fluid.

One consequence of the assumption of incompressible tanks is that the pressure is no longer governed by a differential equation and hence can change discontinuously. The algorithm may therefore perform a pressure-propagation solution. This is required only occasionally to maintain the desired accuracy during sudden events, but it has proved to be a major contributor to the ruggedness of the algorithm.

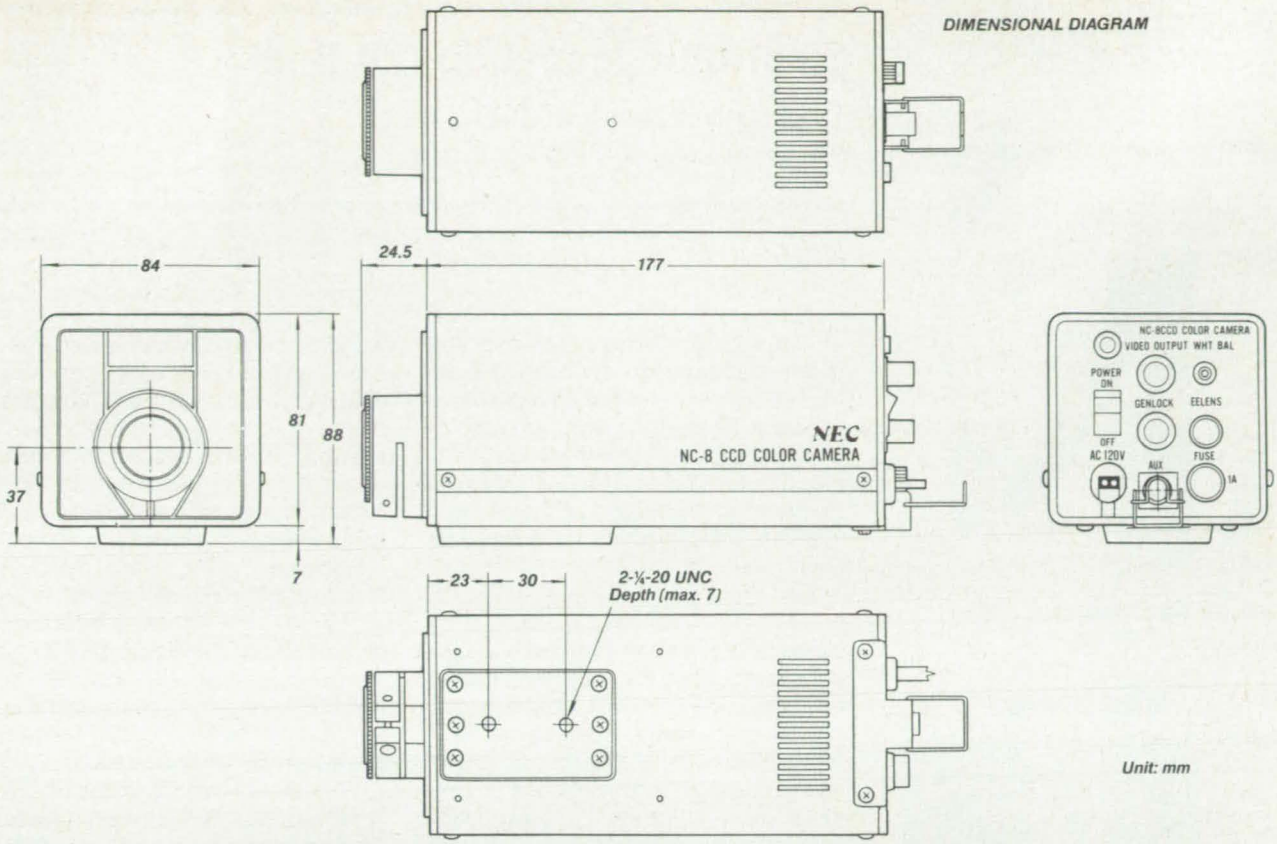
The algorithm would easily accommodate a compressible-liquid formulation for the resolution of water-hammer events. Other possible extensions of the algorithm include the effects of the flexibilities of containers, high-velocity flow, gravitation, acceleration, and the opening and closing of valves.

This work was done by Brent A. Cullimore of Martin Marietta Aerospace for **Johnson Space Center**. *For further information, Circle 90 on the TSP Request Card.*
MSC-21250

New Products

Sensotec's (Columbus, OH) transducer handbook includes over 150 different transducers and instrument models. The handbook covers a complete line of pressure transducers, load cells, torque transducers, accelerometers, linear displacement transducers and instrumentation. Included are sections on Terms and Definitions, Troubleshooting, and information on setting up the units, including shunt calibration. For a free copy, **Circle Reader Service Number 445.**

R.R. Software, Inc. has submitted the pre-validation results for its Janus/Ada compiler to NCR, in support of a recently assigned joint marketing agreement. The compiler was tested under ACVC 1.8, using NCR"s Worksaver processor series and MS DOS emulation within the C TOS environment. After NCR approves the results, R.R. Software, Inc. will officially apply to one of the Ada Validation Facilities (AVF); the chosen AVF will assess the pre-validation report and begin scheduling the actual validation. **Circle Reader Service Number 443.**



OUR DESIGN FITS YOUR SPECS.

NEC invites you to take a look inside the NC-8 single chip color camera — the camera designed with your specifications in mind. With the lightweight, flexible NC-8, you get high definition and resolution, very low lag and no burn in. It resists shocks, is immune to magnetic distortion, and because its pixels are arranged in a high precision matrix, there is no geometric distortion. It includes Gen Lock as a standard feature. It is equipped for any C-mount lens including auto iris.

This durable little camera is a match for any of your toughest video camera requirements and is easily adaptable to a wide variety of settings.

NEC, the world's largest manufacturer of semiconductors, offers an entire line of solid state industrial cameras—all high quality, hard-working products from a respected source.

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Specifications

Pickup	Interline transfer type CCD x1
Number of picture element	H427xV492
S/N ratio	47dB (illuminance channel, standard recording conditions, AGC: off)
Resolution	Horizontal: 280 lines Vertical: 350 lines
Sensitivity	1,600 Lux F4.0
Minimum illumination	10 Lux F1.4 AGC: ON (20% signal output level)
White balance adjustment	Manual/Remote
Lens mount	C-Mount
Power consumption	Approx. 6.5W (less than 9VA)
Weight	Approx. 1.4kg [3.1 lbs] (excluding lens)

NEC

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For more information about the NC-8, TI-22AII, TI-22PII and TI-26A industrial cameras, contact the Industrial Video Group, Broadcast Equipment Division, NEC America, Inc., 1255 Michael Drive, Wood Dale, IL 60191 Toll free 1-800-323-6656. In Illinois phone 312/860-7600.

Circle Reader Action No. 369

Life Sciences

Hardware, Techniques, and Processes

Electronic Inspection of Beef

Television imaging and ultrasound are promising testing methods.

NASA's Jet Propulsion Laboratory, Pasadena, California

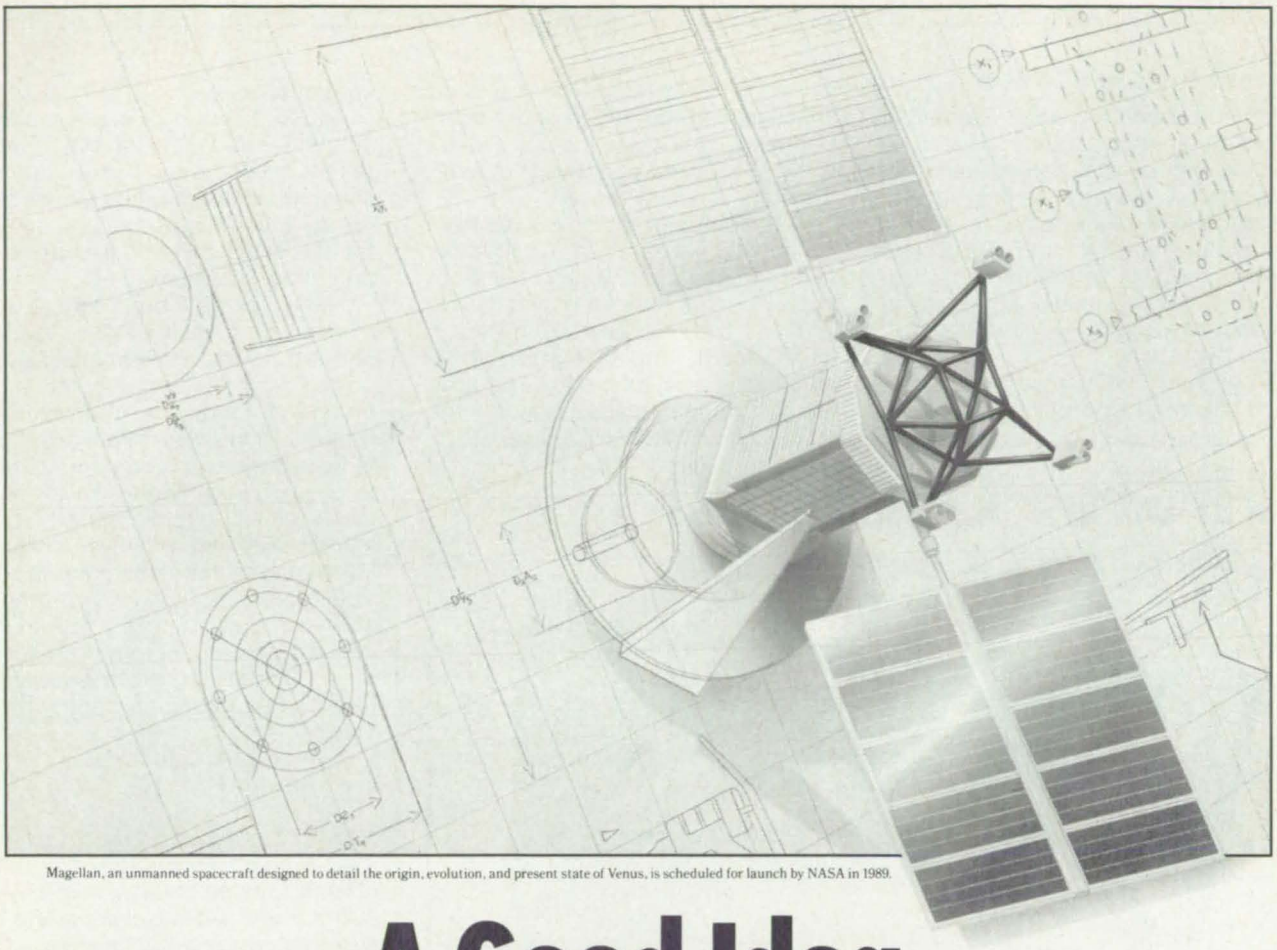
Two proposed methods for grading beef quality are based on inspection by electronic equipment: one method would use a television camera to generate an image of a cut of beef as the customer would see it; the other would use ultrasonics to inspect the live animal or unsliced carcasses. Both methods show promise for automated meat inspection.

Beef grading is currently a subjective process, dependent on the judgment of individual graders. Although experienced graders are generally consistent in their decisions, there are many marginal cases in which the decisions could go either way. A reliable automated process might eliminate arguable decisions and ensure that revenue is not lost by selling prime cuts for a low price and that consumer satisfaction is not compromised by selling lower-quality meat at premium prices.

The criterion for inspection by television would be the amount of marbling in a rib-eye steak (the longissimus dorsi muscle) cut at the 12th and 13th ribs. The degree of marbling would be calculated from the television image by image-analyzing techniques. A problem to be overcome with this inspection method is discoloration of the meat when it is exposed to the air or refrigerated. The discoloration makes it difficult to obtain consistent results.

The ultrasonic method is based on the multiple sound reflections created by internal discontinuities. With this method, a high-grade specimen with considerable fat marbling can be distinguished from a low-grade sample with little marbling.

This work was done by Victor J. Anselmo, Paul M. Gammell, and Jerry Clark of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 67 on the TSP Request Card.*
NPO-15477



Magellan, an unmanned spacecraft designed to detail the origin, evolution, and present state of Venus, is scheduled for launch by NASA in 1989.

A Good Idea Shouldn't Stay An Idea.

If an idea is good, it shouldn't stay an idea for long. At Martin Marietta Denver Aerospace they don't. Dreams, even the "impossible" ones—the long shots—can come true.

Each day, our engineers face a variety of interesting, challenging assignments—an unmatched repertoire of advanced launch and space propulsion systems, spacecraft, instruments and strategic defense systems.

Explore a career with us. You'll find a matrix organization that encourages broad, exciting responsibilities. Challenge and reward are the rule here. Your contributions receive recognition, your career moves forward. And your best ideas take shape.

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We have several opportunities for spacecraft controls specialists with 5 to 10 years of experience which includes digital computer modeling and flexible/rigid bodies.

Sr. Guidance and Control Hardware Engineers (PIE)

We need top hardware engineers with 5 to 10 years of experience in systems integration and a thorough knowledge of sub-contract work involving gyros, accelerometers, momentum wheels, star trackers, star scanners and related areas.

Structural Dynamics & Loads

Three to five years of experience in dynamics analysis and a strong background in loads cycle and acoustics analysis qualifies for these multiple opportunities. Acoustics/random vibration experience would be helpful.

Stress Analysis

We need top analysts with at least five years' experience in aero stress analysis. Experience with NASTRAN, advanced composites and structural test would be helpful.

AN EBI/SBI BACKGROUND INVESTIGATION MAY BE REQUIRED.

Please send your resume to Martin Marietta Denver Aerospace, Personnel Department, P.O. Box 179, G1311, P70061, Denver, Colorado 80201. No agencies, please. We're an Affirmative Action Employer actively seeking veterans and the handicapped. U.S. citizenship is required.

MASTERMINDING TOMORROW'S TECHNOLOGIES

MARTIN MARIETTA

Feedback

Quest for Excellence

I certainly agree with the President's goals of improved competitiveness and excellence and "swiftly transferring new technologies to the marketplace," which you reported in April's issue. But I don't think that the new program will "...help commercialize non-patentable results of federally funded research" without careful implementation.

Many years experience in technology transfer of federally funded R&D innovations has taught me that many (most) federal contractors and subcontractors who perform the lion's share of the R&D have no interest in most transfers for many reasons.

Foremost are that incentives have been missing as well as penalties for failure to document, report and/or to implement the transfers. With few exceptions, there has been grossly insufficient monitoring of contract R&D results for new technology by both the government agencies and by the contractors.

Although I do not claim a simple solution, we must not turn over to federal laboratories, contractors and subcontractors all rights to new technology without imposing a technology transfer check gate in the implementation rules and regulations.

The check gate must be placed in the system to assure that: a) valuable new technology is documented and reported promptly to guarantee patent protection for the inventions and early use for non-patentable innovations; b) valuable new technology is made available to companies and/or agencies that will exploit the new technology — not necessarily the originating organization which may have no interest in the innovation or invention; and, most importantly, c) potentially valuable new technology does not die in a file cabinet, unreported by a federal laboratory or contractor or subcontractor.

N. J. Bud Goldstone
Beverly Hills, CA

NASA does have a "check gate" in their system; Technology Utilization offices, located in each of the NASA Centers and NASA Headquarters, ensure that new technology is reported, reviewed and, when appropriate, published in ***NASA Tech Briefs****. Other federal agencies implementing or continuing their own technology transfer programs have looked to NASA's experience as a model.*

Medical Appliances

Everyday I'm met with the challenge of producing improved medical appliances for handicapped adults and children. In engineering these appliances, weight, flexibility and strength are very important. In the past, I have relied on salesmen to reveal new product knowledge, but their knowledge is limited and it's a time-consuming process. The information found in *NASA Tech Briefs* helps tremendously.

Dr. Art Copes
President
Orthotic Research Inc.
Gonzales, LA

More Spin-Offs

You are doing an excellent job. How about having several 'spin-offs' in which you publish similar magazines for DOE, TVA, NRC, DOT, etc. under contract?

Patrick A. March
Principal Engineer
Eclectic Technologies
Oak Ridge, TN

Capture the Glory!

Now you can own this collector's print, commemorating Columbia's exploits, at an exceptional introductory price.

Noted aviation artist Ken Kotik has captured *Columbia* in all its glory to commemorate the completion of four test flights and the first operational mission, STS-5. This fine print—truly a collector's item—depicts the orbiter in full color, side view, with every feature crisply detailed.

Arranged beneath the ship, also in full color, are the five distinctive mission patches. But what makes Ken Kotik's work most unique is his method of creating a 'historical panorama' via individual vignettes surrounding the side view of *Columbia*.

Educational as well as eye-appealing, these scenes, which are expertly rendered in a wash technique, include such subjects as the orbiter under construction at Rockwell, on the launch pad, at touch-down and during transit on its 747 carrier. Concise copy, hand-written by the artist, accompanies each vignette. (*Important:* The greatly reduced print reproduced here is intended only to show style—at the full 32" by 24" size, all copy is clearly readable.)

About the artist.

Ken Kotik, a 37-year old Colorado native, has been a professional commercial artist for the past 14 years. In his own words, he "eats, drinks and sleeps flying." It shows in the obvious care and attention he brings to each print or mural. When not at his drawing board creating artworks for such prestigious institutions as the Air Force Academy, Ken can be found at the controls of his Schweitzer sailplane, in which he competes nationally. A self-taught artist, he specializes in airbrush-applied acrylic techniques. *Space Shuttle Columbia: The Pathfinder* is his first work on the space program, and the original art has been accepted by the Smithsonian Air and Space Museum for its permanent collection.

About the artwork.

Space Shuttle Columbia: The Pathfinder was printed in five colors, after individual press proving, on exhibit-quality 80 lb text 'Hopper Feltweave' textured paper. The feltweave texture yields properties most desirable for framing and display.

About ordering.

Each *Columbia* print comes packed in a sturdy mailing tube and will be shipped upon receipt of your order at the introductory price of $9.95. Please allow two to three weeks for delivery. There is a one-time *first class* postage and handling charge of $2.50 for each order. (If you order three prints, for example, you still include only $2.50 for postage and handling to cover the entire order.) To ensure that you receive your prints without delay, fill out and mail the coupon today, *including check or money order only* and local tax where applicable. If coupon has been clipped, mail your order to: NASA Tech Briefs, Columbia Print Offer, 41 E. 42nd St., New York, N.Y. 10017.

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Subject Index

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ABOUT THE NASA TECHNOLOGY UTILIZATION PROGRAM

This document was prepared under the sponsorship of the National Aeronautics and Space Administration. NASA Tech Briefs is published ten times a year and is free to engineers in U.S. industry and to other domestic technology transfer agents. It is both a current-awareness medium and a problem-solving tool. Potential products...industrial processes...basic and applied research... shop and lab techniques...computer software...new sources of technical data...concepts...can be found here. The short section on New Product Ideas highlights a few of the potential new products contained in this issue. The remainder of the volume is organized by technical category to help you quickly review new developments in your areas of interest. Finally, a subject index makes each issue a convenient reference file.

Further information on innovations—Although some new technology announcements are complete in themselves, most are backed up by Technical Support Packages (TSP's). TSP's are available without charge and may be ordered by simply completing a TSP Request Card, found at the back of this volume. Further information on some innovations is available for a nominal fee from other sources, as indicated. In addition, Technology Utilization Officers at NASA Field Centers will often be able to lend necessary guidance and assistance.

Patent Licenses—Patents have been issued to NASA on some of the inventions described, and patent applications have been submitted on others. Each announcement indicates patent status and availability of patent licenses if applicable.

Other Technology Utilization Services—To assist engineers, industrial researchers, business executives, Government officials, and other potential users in applying space technology to their problems, NASA sponsors Industrial Applications Centers. Their services are described on pages 18-19. In addition, an extensive library of computer programs is available through COSMIC, the Technology Utilization Program's outlet for NASA-developed software. See special section on computer programs on page 42.

Applications Program—NASA conducts applications engineering projects to help solve public-sector problems in such areas as safety, health, transportation, and environmental protection. Two applications teams, staffed by professionals from a variety of disciplines, assist in this effort by working with Federal agencies and health organizations to identify critical problems amenable to solution by the application of existing NASA technology.

Reader Feedback—We hope you find the information in *NASA Tech Briefs* useful. A reader-feedback card has been included because we want your comments and suggestions on how we can further help you apply NASA innovations and technology to your needs. Please use it; or if you need more space, write to the Manager, Technology Transfer Division, P.O. Box 8757, Baltimore, Maryland 21240.

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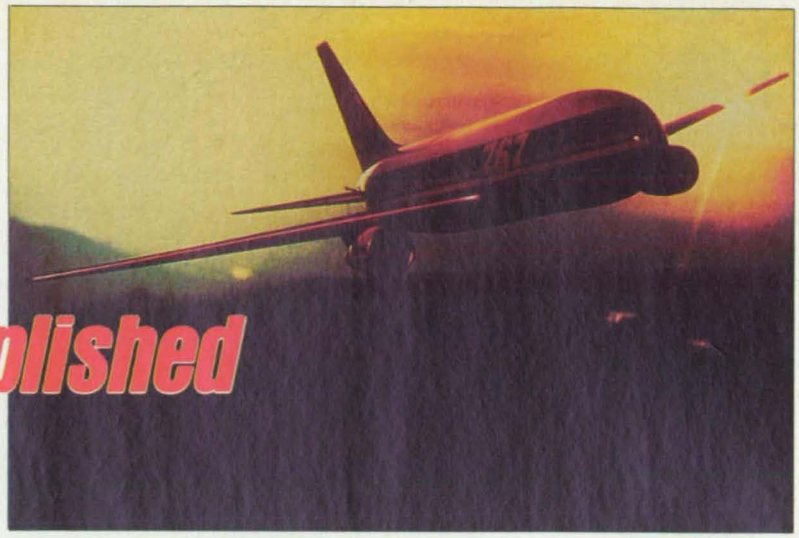
Mission Accomplished

Through the technology transfer process, many of the systems, methods and products pioneered by NASA are reapplied in the private sector, obviating duplicate research and making a broad range of new products and services available to the public.



Boeing's 767 is 1,000 pounds lighter due to a Kevlar-carbon/epoxy structure.

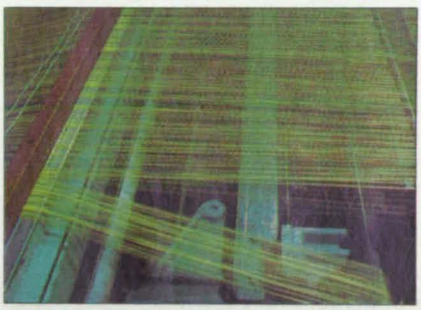
In an effort to reduce fuel consumption and operating costs, design engineers throughout the aircraft industry have focused their attention on the development of lighter planes. The problem has been finding a way to decrease weight while retaining strength and performance. One promising solution is the adoption of advanced composite materials, which offer a higher strength-to-weight ratio than do metal structures.

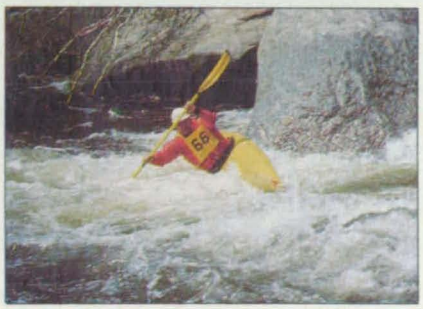
Formed from resins and reinforcing fibers such as aramid, composites can be molded into various aerodynamic shapes, substantially decreasing the overall part count and eliminating most of the rivets and fasteners required in metal construction.

"Ten years ago composites were nothing more than a curiosity", explained Bland Stein, Head of the Applied Materials Branch at NASA's Langley Research Center. "Since then there's been a tremendous increase in their use, to the point where today all new airplanes have some composite parts in them."

At the forefront of this growing technology is Kevlar®, an aramid fiber developed and marketed by the Du Pont Company. Kevlar is five times as strong as steel and ten times as strong as aluminum, with much lower density. More than 45 million pounds of Kevlar fibers are produced annually, with applications ranging from asbestos replacements in automotive parts to linings in bullet-proof jackets. Kevlar has even been used to reinforce the 60,000 square foot retractable roof on Montreal's Olympic Stadium.

Ongoing research at NASA's Langley Research Center has aided Du Pont in the development and advancement of a highly stiff fiber, called Kevlar 49, especially tailored to the demands of the transportation industry. For more than a decade, Langley has conducted extensive tests applying composites to commercial aircraft. Components of Kevlar 49 have been evaluated on the Lockheed L-1011 Tri-Star, Boeing 747 and McDonnell Douglas DC-10. Kevlar-reinforced composites were adapted to the L-1011 in areas such as ceiling panels and wing fairings, reducing the plane's final weight by 800 pounds, a significant figure considering that a single pound of dead weight can consume over 100 gallons of fuel per year.





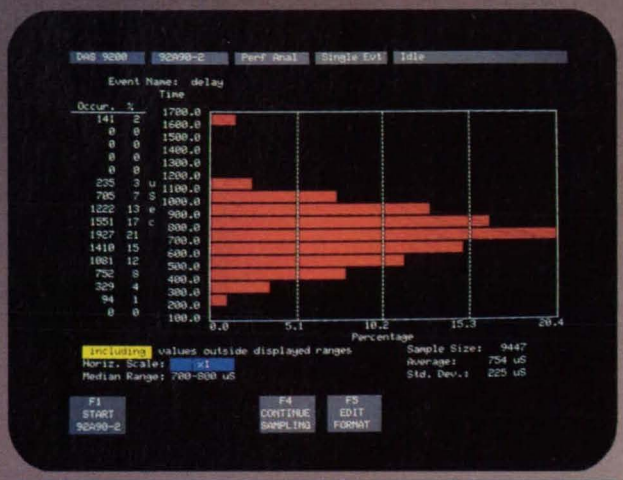
Above: Kevlar aramid fibers
Lower: This kayak molded entirely from advanced composite materials is nearly 50% lighter than a glass fiber model.

Langley's experiments fostered the adoption of fiber reinforced parts on the Boeing 757 and 767. Kevlar components saved Boeing 1,000 pounds per plane, greatly increasing payload capacity. In other commercial applications, the entire interior of De Havilland's DHC-7 was crafted from Kevlar composites, saving more than 200 pounds. And by using Kevlar fibers instead of sheet metal, Sikorsky was able to add another passenger seat to the S-76 helicopter while increasing its range by 20 percent.

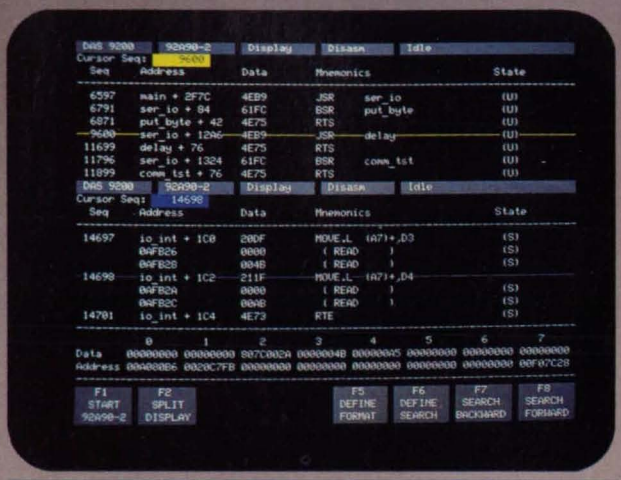
NASA's studies have not only proven Kevlar's lightweight practicality, but have, according to Mr. Stein, "shown that Kevlar components are extremely durable and won't degrade over a long period of service." Stein has found Kevlar to be most useful when applied in a hybrid form. "A hybrid between Kevlar and graphite fibers is probably best," he stated. "They complement each other very well. Kevlar has good tensile strength, while graphite has higher compressive properties."

The most important outcome of Langley's research, says Stein, is one of future promise. "It's shown the commercial airline industry that composites work. We've developed a confidence that they can use composites for a variety of applications, that composites are indeed a tool of the future." □

DAS9200 DIGITAL ANALYSIS: NOW TEK MAKES THE IMPOSSIBLE LOOK EASY.



Software Performance Analysis, like this distribution of a subroutine's execution times, helps you easily understand the activity of your code.



Step backwards through acquired data, including subroutines, stack and register models, using time-correlated split-screen displays to pinpoint problems.

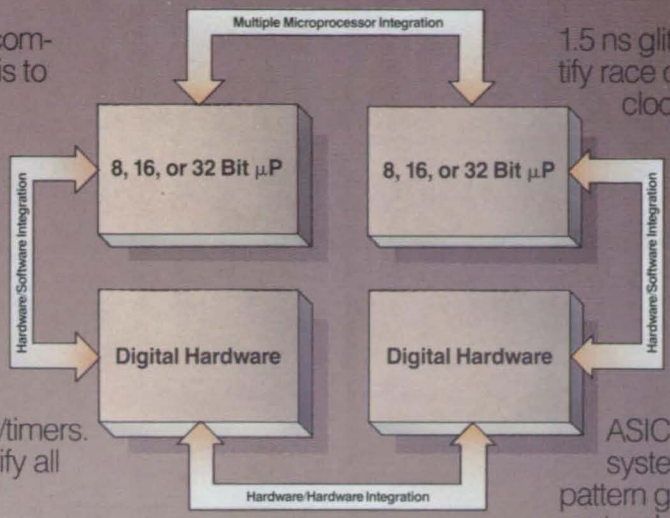
In every dimension—speed, channel width, memory depth, trigger capability, modularity and ease of use—the DAS9200 dwarfs what's been possible before.

The DAS9200 features a tightly coupled, high-speed architecture in which multiple card modules can act as a single unit. Large color-coded displays, pop-up menus, performance analysis graphs,

multi-tasking and more combine to take logic analysis to levels like these:

1 State-driven triggering at 200 MHz. You can use up to 384 channels of sync and async data acquisition. You can assurance-test high-speed logic at full speed, using 4-level state tracking and high-speed counter/timers. You can monitor and verify all timing measurements in a circuit.

2 Symbolic, real-time software debugging. Register deduction and stack simulation let you pinpoint problems like stack overflow or incorrectly restored pointers—without breakpoints or manual notation.



3 Simultaneous integration of up to six microprocessors. Use the dual timebases and real-time handshaking between system modules to set up split-screens displays that scroll in precise time alignment.

4 160 channels of acquisition at 2 GHz. Use up to 500 ps sample interval and 1.5 ns glitch detection to identify race conditions, spurious clocks and setup/hold violations in any logic family. System probes feature input capacitance of <1 pf.

5 Easy ASIC verification at up to 50 MHz. The DAS9200 is available as a low-cost turnkey ASIC device verification system. Featuring 50 MHz pattern generation, 8K bit vector depth, and 1 ns edge placement, it offers the power, precision and simplicity to be an attractive alternative to centralized systems.

6 Stop wishing for the impossible in digital analysis: Compare your wish list against the complete list of DAS9200 capabilities. Contact your Tek sales engineer, or call toll-free for more information. **Call 1-800-245-2036.** In Oregon, 1-213-1220.

Available in desktop and rack-mount versions, the DAS9200 mainframe can be augmented with up to three expansion mainframes for a total of 28 card slots.

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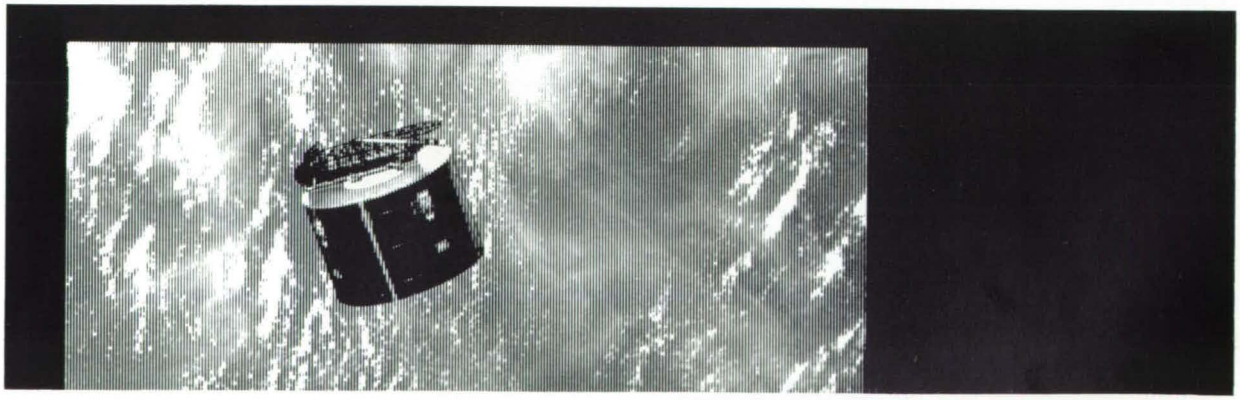

The Space Station's potential for improving life on our planet is boundless. Yet the cost of building and maintaining it comes to roughly two cents a day for every American. Your support for the NASA Space Station will make a difference. So get your two cents' worth in. Say yes to America's manned space station program.

MCDONNELL DOUGLAS