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July 1995 Vol.19 No.7

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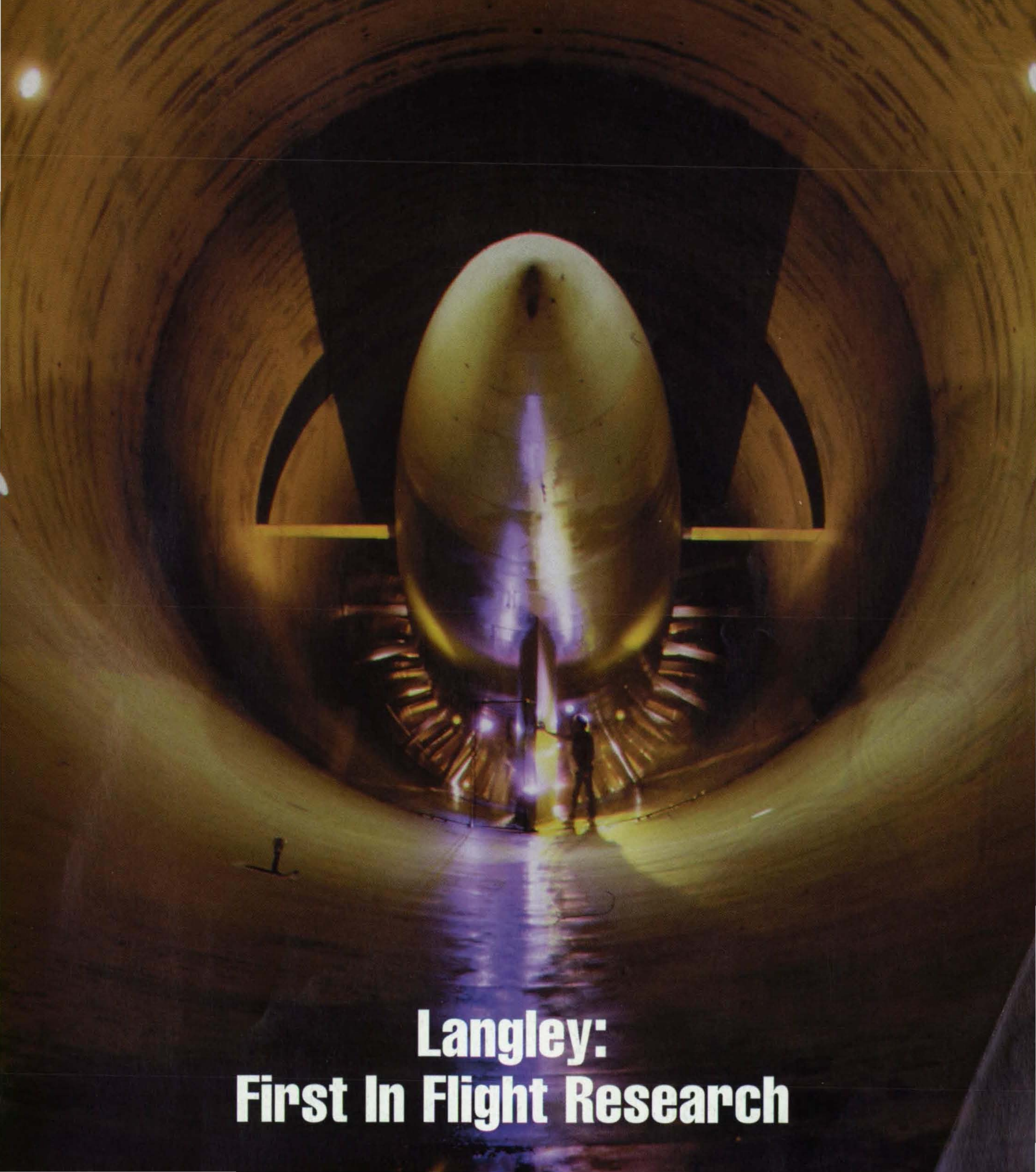

Langley: First In Flight Research

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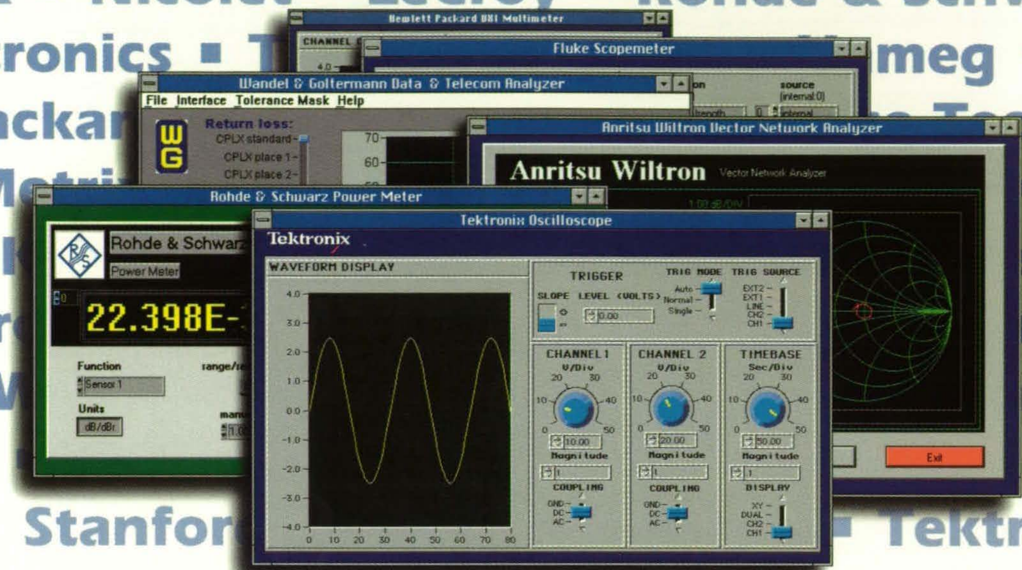

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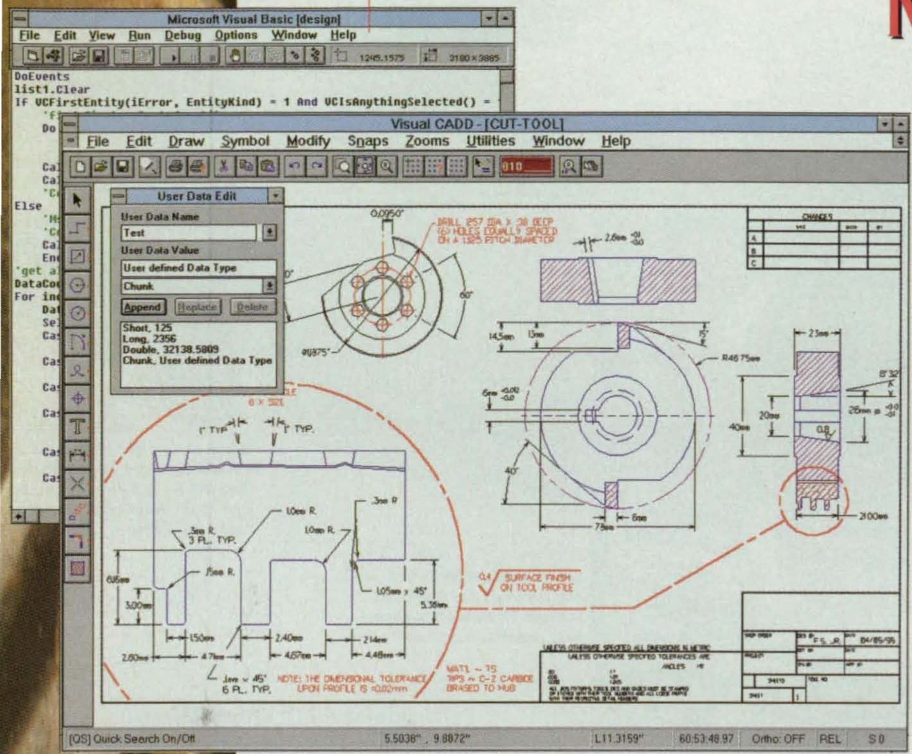

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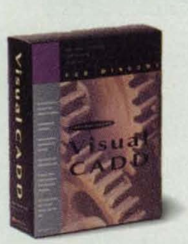

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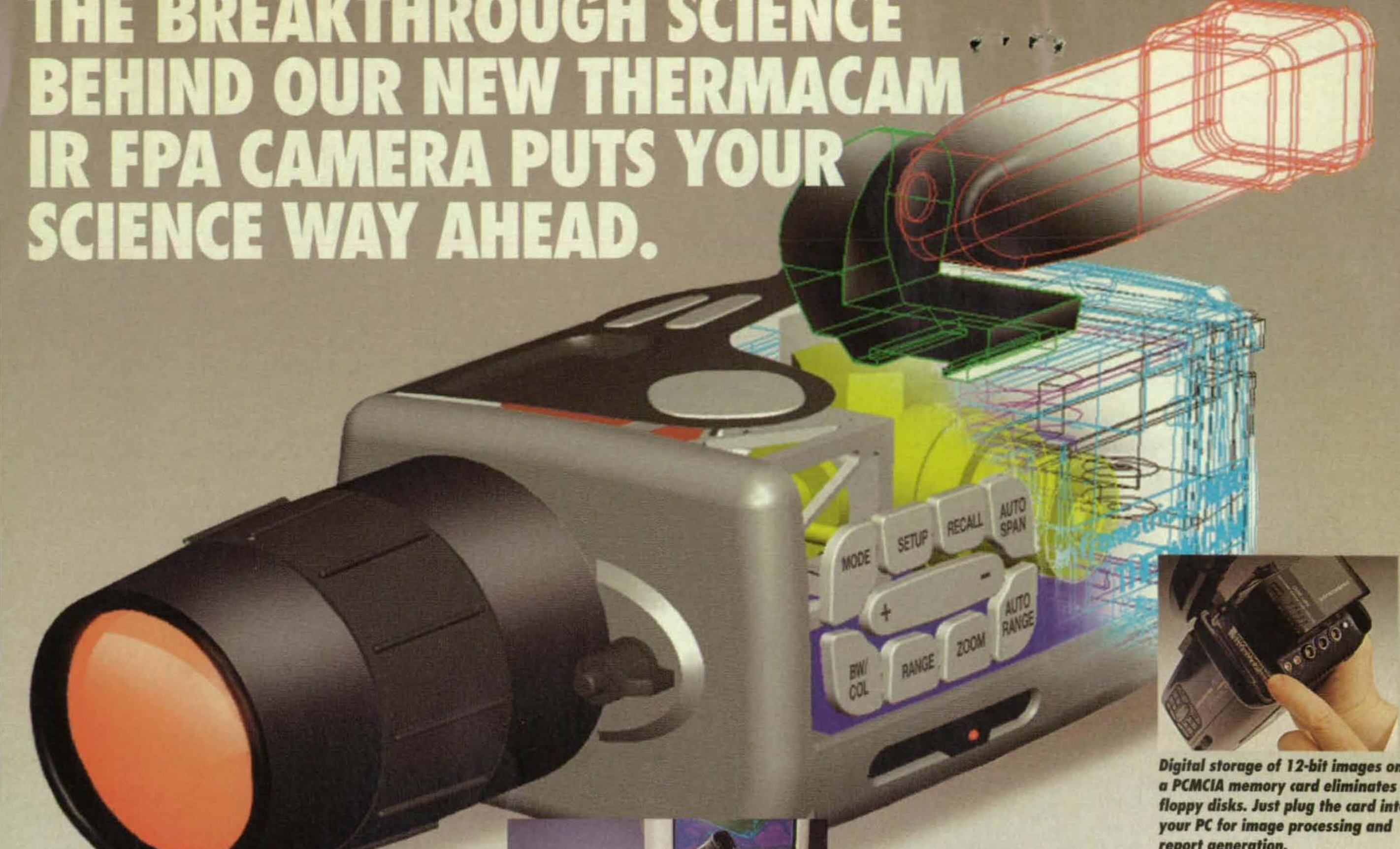

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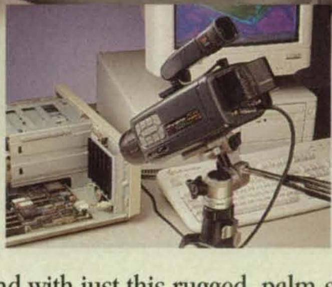

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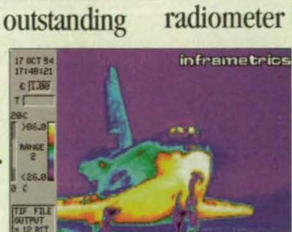

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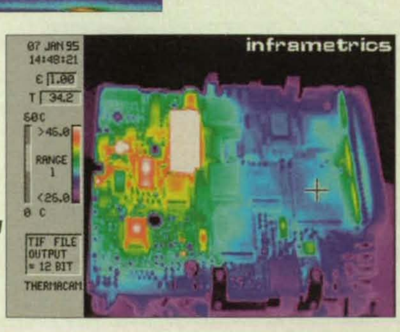

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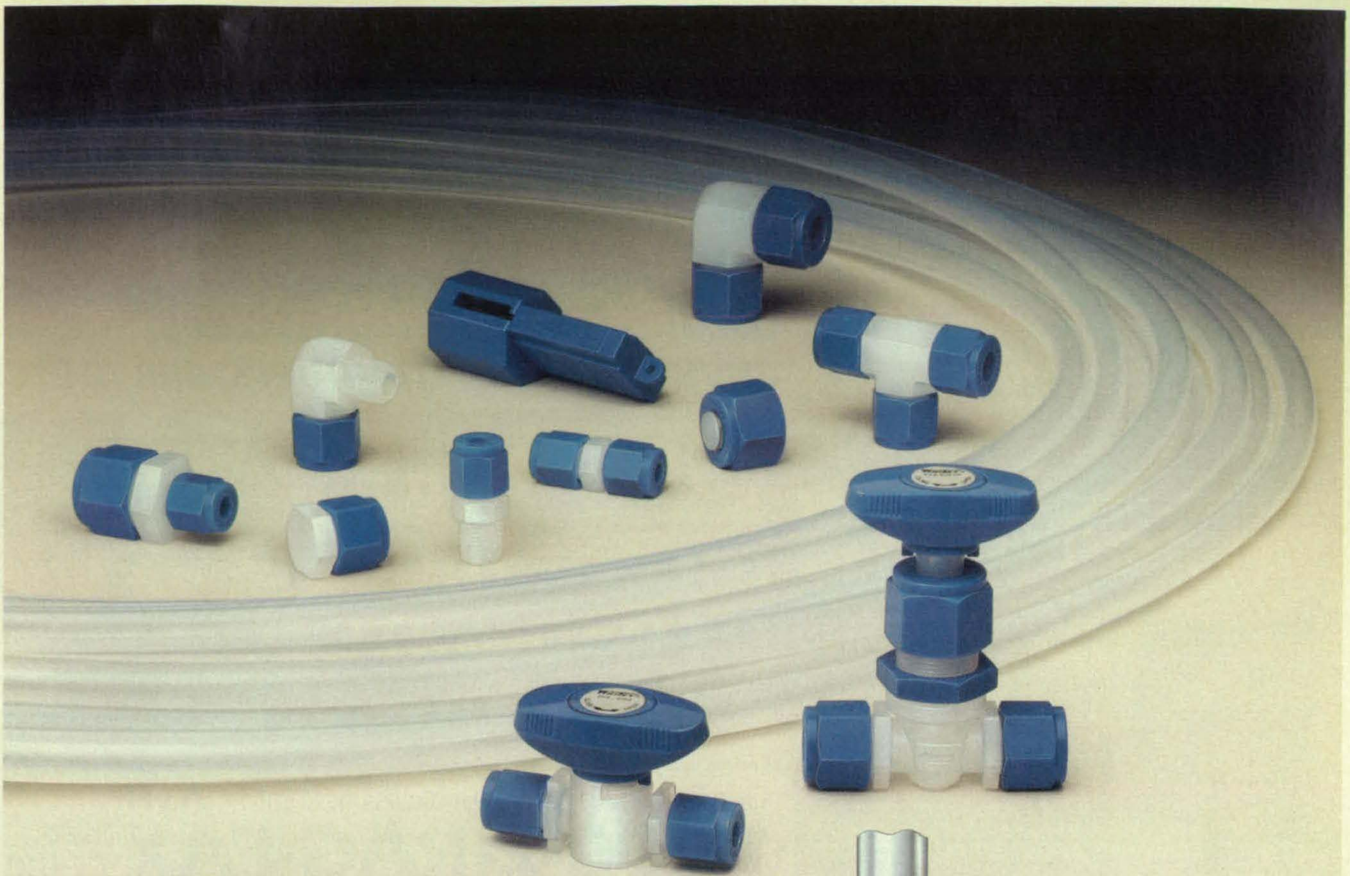

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FEATURES

TECHNICAL SECTION

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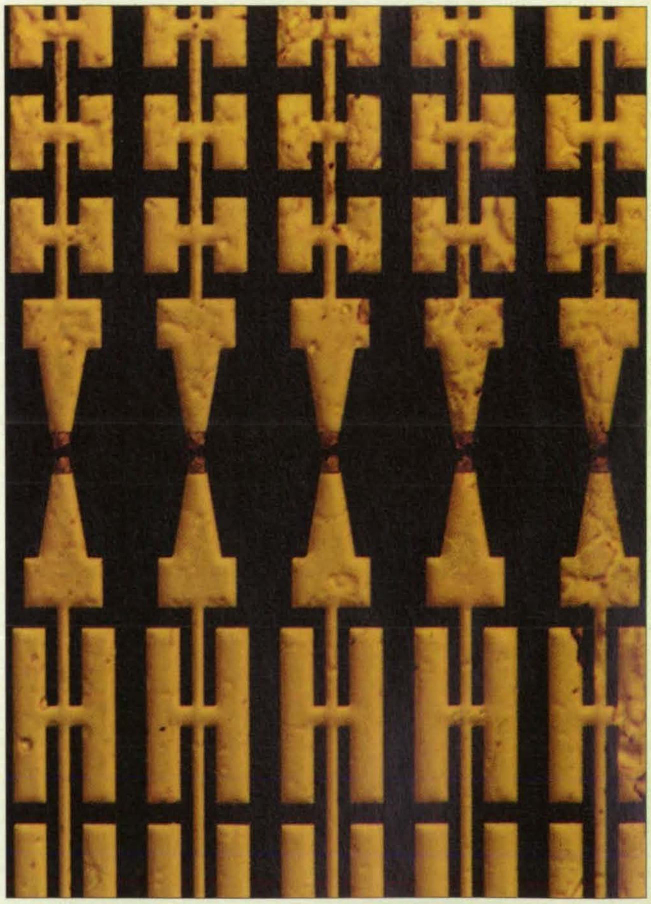

Quartz upside-down integrated device (QUID) process planar GaAs Schottky-barrier diode pairs from Jet Propulsion Laboratory are fabricated as integral units on a quartz substrate. The Schottky contact is formed on lightly doped GaAs, which is on top of a heavily doped GaAs layer for ohmic contacts. Designed to operate as mixers in a waveguide circuit at millimeter and submillimeter wavelengths, these integrated circuits are larger and thus easier to handle and mechanically more robust than the planar Schottky diode, and the quartz substrate is more suitable for waveguide circuits than the GaAs substrate. Turn to the brief on page 32.

Photo courtesy of Jet Propulsion Lab

Contents *(continued)*

__On the Cover:__
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Photo courtesy of Langley Research Center

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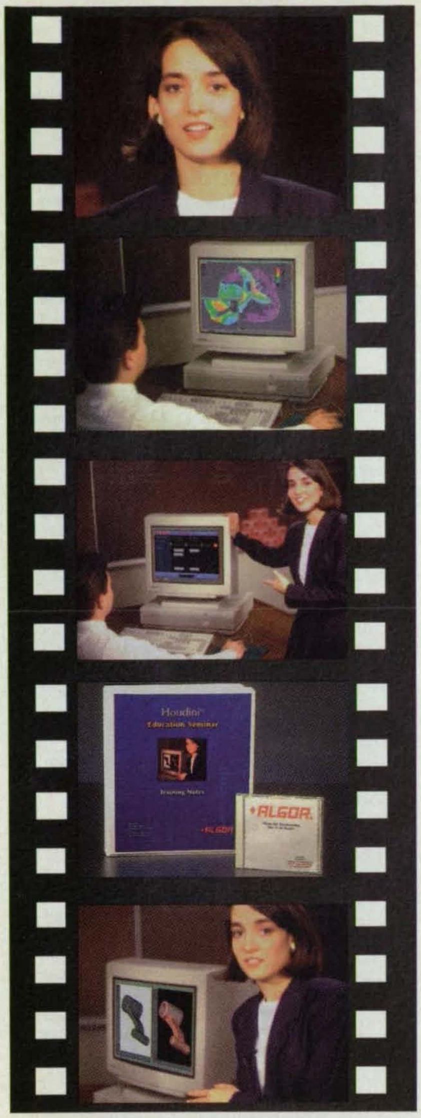

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Mission Accomplished

Thermal imaging–using detection of the infrared radiation we commonly call heat to create visual patterns in the absence of visible light–sprouted on the battlefield from the need to track the enemy's movements at night. But with the maturation of night vision technology has come a parallel development of applications in the commercial and industrial sector. FLIR Systems Inc. is an example of a company that has managed to continue technical strides along both tracks.

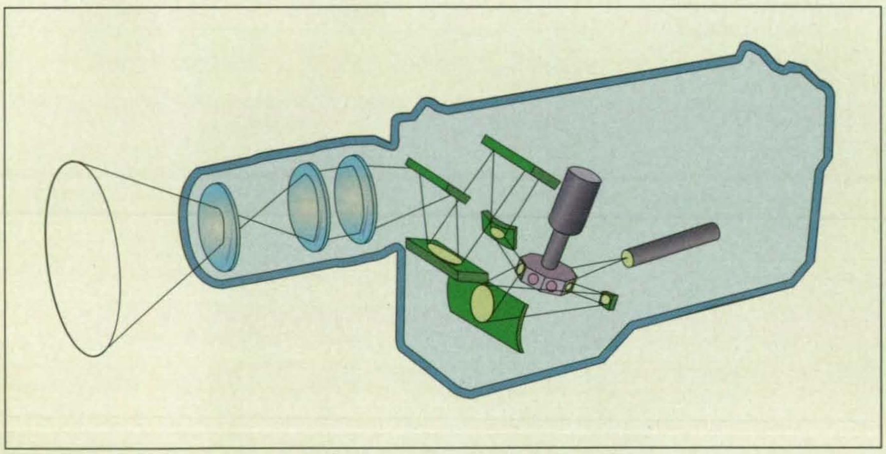
Founded in 1978, the company had its origins in public safety: its early customers were police and fire departments, employing FLIR units for surveillance in darkness, adverse weather, smoke, and haze, as well as for airborne detection. One of its early major investors was the Louisiana Pacific Railway, which used the company's products to search for forest fires along its routes.

As the 1980s progressed, management began to look beyond applications calling for expensive devices with limited resolution. They envisioned a broader range of products that combined price and performance configured for industrial as well as military and public-safety customers. By 1993, when FLIR Systems "went public," it had developed thermal imaging devices for industrial predictive and preventive maintenance, nondestructive testing and evaluation, research and development, and manufacturing process control and monitoring.

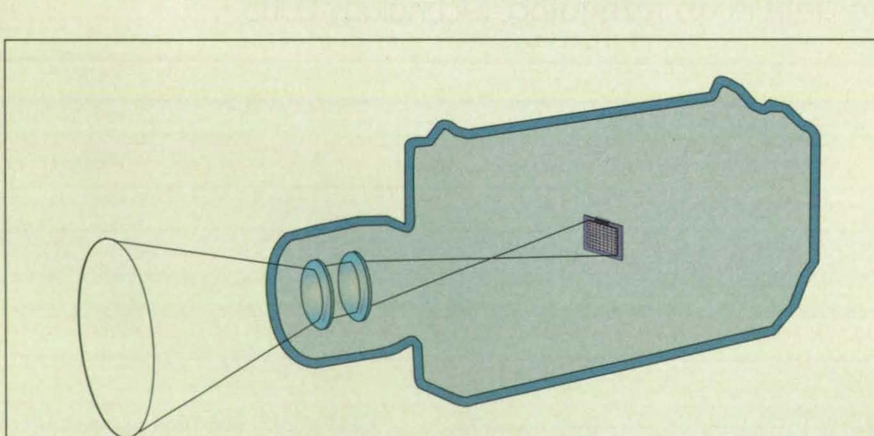
But when FLIR Systems began to expand, it recognized certain limitations. According to Greg Love, vice president of the company's Industrial Division, FLIR's staff needed expertise in instrument portability and detector technology, as well as knowledge of sales channels and the experience necessary to exploit them. As chance would have it, a ready-made opportunity to acquire what was needed was at hand.

Among the contenders in the industrial marketplace was Hughes Aircraft, a subsidiary of which had developed a unit suitable for use in industrial applications as part of a NASA-sponsored research project. Called Probeye, the technology soon found niches in process monitoring, failure analysis, and medical diagnostics.

In what Love calls a "win-win situation," Hughes sold the Probeye assets to FLIR Systems in 1990. With them came the detector-design and sales expertise FLIR needed, in the form of experienced staff. Sufficient research and development funds were at the disposal of the group, and within a few years FLIR Systems had attained a leadership position in handheld thermal imaging technology.



Schematic of a typical mechanically scanned imaging system.



The much simplified optical path of FLIR Systems' Prism series, incorporating staring focal-plane array technology.

Incremental Innovation

Industrial thermal imaging traditionally had been as much art as science, based upon the experienced user's interpretation of crude distinctions between levels of heat. But through a series of steps embodied in its Prism Series of thermal imaging cameras, FLIR Systems brought increased sophistication to shop-floor instrumentation.

The Prism Series incorporates focal-plane array technology developed by the team formerly at Hughes. Among the many benefits it confers on thermal imaging devices are the advantages of solid-state technology: platinum silicide detectors in a charge-coupled device (CCD) configuration. Gains in both performance and portability can be achieved without cost increases of the magnitude that might have been expected previously.

In the Prism DS (digital storage), FLIR Systems' newest-generation camera, 78,000 detectors are arranged in a 244 x 320 pixel staring focal-plane array (FPA). FLIR Systems says this results in an image that retains clarity and resolution even when panning or imaging fast-moving objects.

By replacing the previous mechanical design, the FPA eliminates a number of elements that can inhibit resolution: there are no moving parts, no motors, servos, or galvanometers, and no bending, shaping, or focusing mirrors. Furthermore, detector dwell time can be as much as 16,000 times as long as on a scanning camera's sensors. Elimination of scanning also greatly simplifies the optical path, reducing weight–the Prism DS weighs just 7 lbs.–and size and lowering component costs.

On-camera digital storage capacity is a minimum of 30 images. Images and temperature data are stored on PCMCIA cards, and are transferred easily to a PC, where they can be postprocessed with the optional AnalyzIR™ image analysis software. This capability enables isotherms, image subtraction, time-vs.-temperature trend analysis, and much more. The operational range of the Prism DS extends from -10 °C to 1500 °C, and its modest power consumption enables it to be operated on battery, vehicle, or AC power sources.

Today, FLIR Systems' thermal imaging devices find applications in testing breakers and motors for defects, examining fiber optic cable before it is laid on the ocean floor, and evaluating prototypes of integrated circuits. These and other applications should assure FLIR Systems a major role in thermal imaging's growing reach in the future.

FLIR Systems' products will be on display at Booth 604 at the Technology 2005 Conference and Exposition, October 24-26 at McCormick Place, Chicago, IL.

A pseudocolor thermal image of the exhaust manifolds of one side of an automobile engine, captured with FLIR Systems' equipment, showing heat-affected zones during operation.

Langley Research Center

NASA's history of aeronautical research–and the modern space flight program–began at Langley Research Center in Hampton, VA more than 75 years ago. Originally named Langley Memorial Aeronautical Laboratory for aeronautical pioneer Samuel Pierpont Langley, it was the nation's first government-run civil aeronautics laboratory. Langley was established in 1917, but did not begin conducting research for the National Advisory Committee on Aeronautics (NACA)–NASA's predecessor–until 1920.

NACA's mission was "to supervise and direct the scientific study of the problems of flight, with a view toward their practical solution." The Committee decided that Langley's research priority should be aerodynamics. With the construction of three unique wind tunnels–the Variable Density Tunnel in 1922, the Propeller Research Tunnel in 1927, and the Full Scale Tunnel in 1931–Langley became the world leader in wind tunnel design and research. This fact was affirmed by numerous accolades, including the 1929 Collier Trophy. The Collier, awarded annually "for the greatest achievement in aviation in America," was presented to Langley for its work on engine cowling, which revolutionized aircraft design in the 1930s.

From the start, NACA intended for Langley to form a strong relationship with the fledgling American aircraft industry. In 1926, Langley hosted NACA's first joint conference with aircraft manufacturers' representatives and operators. This event provided a vital forum for the exchange of information and technology between industry and NACA–Langley's first successful attempt at large-scale technology transfer.

In subsequent decades, Langley continued its pattern of developing innovative research facilities and conducting pioneering work in aerodynamics and flight research. Four more Colliers were awarded over the years. Especially notable is Langley's work in high-speed flight (beginning in the transonic region, and eventually expanding into supersonic and hypersonic areas), which led to the development of laminar flow airfoils, the swept wing, and the variable sweep wing. This work proved vital in the evolution of space flight.

In 1958, President Eisenhower signed the National Aeronautics and Space Act which transferred NACA's research, laboratories, and budget into the newly-formed National Aeronautics and Space Administration. That year, Langley began what would be a pivotal role in the space program by serving as the training center for the original seven astronauts in Project Mercury, the first manned spaceflight program. Langley subsequently provided spacecraft design and testing, flight concept development, and mission planning for the Gemini, Apollo, and Skylab manned programs. Unmanned programs such as the Viking Mars project, the Explorer spacecraft, the Echo Communications Satellite, the Lunar Orbiter, the Scout launch vehicle, and the Long Duration Exposure Facility also were supported at Langley.

Today, Langley serves as one of the nation's preeminent research centers, sharing aircraft runways, utilities and other facilities with adjacent Langley Air Force Base. More than half of Langley's current efforts are focused on basic research in aeronautics, such as the improvement of current aircraft, and concept and technology development for future aircraft. Langley resources include more than 45 wind tunnels, research facilities, testing techniques, and computer modeling capabilities to study aerodynamics, structures, materials, acoustics, flight systems, spacecraft analysis, information systems, and atmospheric sciences. Langley researchers continue to improve airborne systems to enable aircraft to operate more efficiently in crowded terminal airways and in all types of weather.

Langley's 20-foot Vertical Spin Tunnel is the only operational spin tunnel in the Western Hemisphere. Used to test spinning and tumbling characteristics of aerospace vehicles, the tunnel features a 12-sided, 20'x25' test section. Langley tests American military fighters, attack planes, primary trainers, bombers, and most experimental aircraft in the facility.

Avionics Research

Langley serves as lead center for NASA's High-Speed Research (HSR) program, which addresses the high-risk technologies needed for an advanced supersonic aircraft. The program is designed to produce the technology for an economically viable, environmentally acceptable High-Speed Civil Transport (HSCT) supersonic airliner. HSCT models are being tested in Langley's National Transonic Facility at temperatures as low as -157° C. The cryogenic testing enables simulation of conditions approaching those of full-scale flight. Langley's 14'x22' Subsonic Tunnel is used to simulate takeoff and landing conditions for a 19' test model of the airliner.

Langley's 20' Vertical Spin Tunnel, the only operational spin tunnel in the Western hemisphere, has been in essentially continuous operation since 1941. All American military fighters, attack airplanes, primary trainers, and bombers, and most experimental airplanes are tested in the facility.

Langley also houses a modified Boeing 737 called the Transport Systems Research Vehicle (TSRV). The TSRV has been used for flight testing of NASA and industry sensors designed to detect wind shear, the sudden shift in wind velocity and direction that has caused nearly 40 percent of U.S. airline fatalities in recent years. The first flight of a sensor that can predict wind shear took place on a Continental 737-300 flight in November 1994.

As a complement to the TSRV, Langley developed the Cockpit Weather Information (CWIN) system that displays live, ground-based weather data not available on current commercial aircraft. It features a color graphical display and touchscreen overlay. A digital system for communications between the aircraft and the ground is established, enabling graphical weather data to be broadcast to all aircraft in flight. Langley is seeking commercial partners to develop products incorporating the CWIN system, which will be tested on a number of domestic commercial flights through the end of 1995.

Langley also conducts research into atmospheric sciences, focusing on developing an understanding of Earth's atmosphere and the impact of human activity. Developing improved techniques for remote monitoring of atmospheric processes and monitoring Earth's radiation are important components of this program.

The center has logged 60,000 wind tunnel test hours evaluating flying characteristics, wing shape, structure, aerodynamics, materials, flight control and guidance, and thermal protection of the space shuttle, and on design studies for space station activities. Further, Langley has contributed to the conceptual design of the Earth Observing System (EOS), the first stage of the international Mission to Planet Earth. EOS incorporates a network of up to five equatorial-orbiting and four polar-orbiting research satellites, designed to advance knowledge of the Earth's systems on a global scale.

A Tradition of Technology Transfer

To maintain its 70-year tradition of technology transfer to industry, Langley formed the Technology Applications Group (TAG) in 1994 to match promising NASA research with U.S. businesses. Since its inception, TAG has initiated more than 30 patent license negotiations between Langley and commercial businesses, and more than 70 partnering agreements.

Among the successful partnerships formed through TAG is Langley's development and subsequent commercialization of an electromagnetic, nondestructive evaluation technology that was licensed to Krautkramer Branson of Lewistown, PA. The company acquired the technology from Langley in September 1994, and released to the market in March 1995 the CrackFinder, a handheld device that detects surface-breaking cracks in aluminum, steel, and most other metals. The technology originally was developed at Langley to detect fatigue cracks in aircraft, and now has new commercial applications in detecting corrosion, gauging coating thickness, and analyzing characteristics of conductive coatings.

Another TAG agreement, with Aura Ceramics of Minnesota, includes the manufacture of Reduced and Internally Biased Oxide Wafer (RAINBOW) piezoelectric ceramics. Aura was granted an exclusive license to manufacture RAINBOW materials, and has marketed the materials since 1993. The wafers can be used commercially to enhance the performance of transducers in loudspeakers and microphones, and in ultrasonic generators, sensors, optics, motors, fans, and other systems.

An important function of TAG is to provide a distribution channel for Langley's software technology. It also serves as a mechanism for users to provide feedback on the value of the technology, which ultimately could affect Langley's future software commercialization efforts. The Langley Software Server (LSS) allows software developers to include a description of their program in the form of a searchable abstract, and to offer the software via the Internet from a central source, provided no distribution restrictions apply. Through the LSS, Langley can distribute software to a greater number of users than ever before–24 hours a day, seven days a week.

The LSS is available on the World Wide Web (WWW), and is accessible from several WWW pages–including the Langley Home Page–or directly, at http://www.larc.nasa.gov/LSS/.

Langley promotes technology transfer through the Technology Opportunities Showcase (TOPS), a three-day exposition held in 1993 and 1995 to develop partnerships primarily with non-aerospace businesses. Among the exhibits featured at TOPS were development activities in various disciplines, exhibits outlining elements of Langley research projects, and Langley-supported Small Business Innovative Research (SBIR) program contracts. TOPS 1995 produced 2,600 requests for follow-up information, including 64 businesses with immediate interest in licensing patents, and 233 that requested near-term follow-up discussions.

Since TOPS 1995 in April, Langley has signed two important agreements designed to transfer technology to local and national businesses. Virginia's Center for Innovative Technology (CIT) in Herndon signed an agreement with Langley that will help CIT identify businesses in the area that could benefit from NASA technology. The agreement, according to TAG Director Charles Blankenship, is an example of how Langley is broadening its mission to transfer NASA technology to the local community, the state, and the nation.

In May, Langley signed a five-year memorandum of understanding with the Minority-Owned Business Technology Transfer Consortium, a not-for-profit organization whose member firms are at least 50% minority-owned. Under the agreement, NASA and the consortium will identify established and start-up minority firms that are candidates for technology commercialization and partnerships. The consortium and Langley each will be responsible for their own work and expenses, with no exchange of funds. Langley will help determine the best partnering vehicle, such as patent licensing and memorandums of agreement, for teaming the center with individual businesses. The center also will help with new product market analysis, foster joint ventures, help identify future capital, and provide follow-up assistance.

For more information, contact Charles Blankenship, Director, Technology Applications Group, Langley Research Center, 11 Langley Blvd., MS 118, Hampton, VA 23681-0001; Tel: 804-864-6005; E-mail: c.p.blankenship@larc.nasa.gov.

Langley's Differential Maneuvering Simulator incorporates helmet-mounted display technology to simulate air-to-air combat. The simulator has two 40-foot diameter projection spheres wtih a cockpit in each. Wide-angle projection systems in each sphere present Earth scenes, sky scenes, and images of additional aircraft to the pilot.

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 Commercial Technology Office of the sponsoring NASA center (see page 20).

Precise Time-Tag Generator for a Local-Area-Network Monitor

A new circuit provides greater precision for monitoring and analyzing the performances of hardware and software in a complex data-processing system. Time information is accurate to 1 μs, as opposed to 1 ms on conventional computer networks. (See page 42.)

Tool for Driving Many Fasteners Simultaneously

A proposed tool would simultaneously tighten or loosen a number of bolts, screws, or nuts that are arranged in a circle on, for example, compressor heads, automobile wheels, pipe flanges, and similar parts. (See page 24.)

Superconducting Field-Effect Transistors

Evaluation of these devices as electronic switches in delay-line-type microwave phase shifters reveals significantly faster switching speeds than from semiconductor counterparts, very large ratios between "open" and "closed" resistances, and readiness for integration with superconducting waveguides. (See page 38.)

Preheating Water in the Covers of Solar Water Heaters

A relatively simple redesign using a double-layer glass cover will allow the incoming water to be preheated and thus increase the efficiency of solar water heaters. (See page 51.)

Active-Pixel Image Sensor With Analog-to-Digital Converters

A proposed single-chip integrated-circuit image sensor would contain a 128 × 128 array of active pixel sensors at a 50-μm pitch. The sensors are designed to operate at a video rate of 30 frames/second, even at low light levels. (See page 37.)

Temperature Measurements Reveal Accretion of Ice on Airfoils

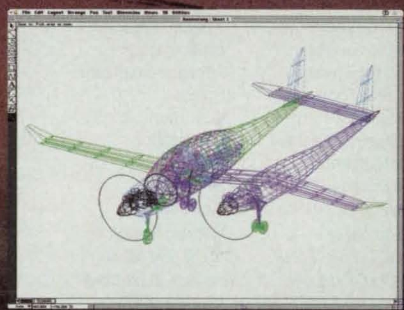
This method detects temperature differences between iced and noniced surfaces of helicopter rotors. Alarms and/or deicing equipment can be triggered. (See page 48.)

Burt Rutan Makes Vellum Fly

Two years after the Voyager completed its record-shattering around-the-world flight, you could still find its designer, Burt Rutan, working at a drafting table with pencil and paper.

Hardware wasn't the problem. He had computers. His company could buy any design system worth owning. What kept Burt grounded was software. CAD so clumsy, it squashed creativity. Or so weak, it simply couldn't do his job.

Maybe that's why the first time he sat down to design with Vellum®, Burt compared the experience to the exhilaration of flying. Vellum is the first CAD program with an autopilot.



Burt's creativity and willingness to explore uncharted territory is exemplified by this sneak peek at one of his latest designs produced (of course) in Vellum.

CAD Software that Works the Way You Think

From GD&T symbols to NURB splines to DXF and IGES file format translators, Vellum has every professional design and drafting tool your job demands. And each tool is endowed with an expert system called the Drafting Assistant™—built-in intelligence that instantly makes every designer more productive. Even on enormously complex jobs.

Rather than force you to fight with the keyboard, or guess about alignment as you draw, Vellum pinpoints and spells out every logical design point for you, on screen. Draw a simple line and the midpoints, endpoints, and construction lines appear automatically. Click the mouse and you get precise alignment to 16 decimal places, instantly.

The Power of Parametrics

Before Vellum, using CAD for conceptual design was like trying to draw in the dirt with a backhoe. Vellum makes precise design as natural as free-hand sketching, with the combined power of Parametrics and Associative Dimensioning.

Simply draw a rough approximation of your design, dimension it, plug in values and click: geometry is automatically redrawn to scale. A part needs to change? Simple. Just change the dimensions and the geometry updates as you watch. Or change the geometry and all the dimensions update perfectly.

From Concept to Finish in Half the Time

According to Burt, "the only way to fully appreciate Vellum is to sit down and use it; tackle a tough job right off. See if the Drafting Assistant doesn't make you two, or even three times more productive than any other CAD package."

If you're like Burt Rutan, you'll find yourself using Vellum from conceptual design right through finished drawings. Best of all, you'll never give the drafting board, or another CAD program, a second thought.

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Sunnyvale, CA 94086

NASA Commercial Technology Team

NASA's R&D efforts produce a robust supply of promising technologies with applications in many industries. A key mechanism in identifying commercial applications for this technology is NASA's national network of commercial technology organizations. The network includes ten NASA field centers, six Regional Technology Transfer Centers (RTTCs), the National Technology Transfer Center (NTTC), business support organizations, and a full tie-in with the Federal Laboratory Consortium (FLC). We encourage all businesses with technical needs to contact the appropriate organizations for more information. For those who have access to the Internet, general information can be accessed with Mosaic software on the NASA Commercial Technology Home Page at URL: http://nctn.oact.hq.nasa.gov. Instructions regarding how to acquire the free Mosaic software can be obtained by sending an e-mail request to: innovation@oact.hq.nasa.gov.

NASA's Technology Sources

If you need further information about new technologies presented in *NASA Tech Briefs*, request the Technical Support Package (TSP) indicated at the end of the brief. If a TSP is not available, the Commercial Technology Office at the NASA field center that sponsored the research can provide you with additional information and, if applicable, refer you to the innovator(s). These centers are the source of all NASA-developed technology.

Ames Research Center
Selected technological strengths: Fluid Dynamics; Life Sciences; Earth and Atmospheric Sciences; Information, Communications, and Intelligent Systems; Human Factors.
Syed Shariq
(415) 604-0753
syed_shariq@qmgate.arc.nasa.gov

Dryden Flight Research Center
Selected technological strengths: Aerodynamics; Aeronautics Flight Testing; Aeropropulsion; Flight Systems; Thermal Testing; Integrated Systems Test and Validation.
Lee Duke
(805) 258-3119
duke@louie.dfrf.nasa.gov

Goddard Space Flight Center
Selected technological strengths: Earth and Planetary Science Missions; LIDAR; Cryogenic Systems; Tracking; Telemetry; Command.
George Alcorn
(301) 286-5810
galcorn@gsfc-mail.nasa.gov

Jet Propulsion Laboratory
Selected technological strengths: Near/Deep-Space Mission Engineering; Microspacecraft; Space Communications; Information Systems; Remote Sensing; Robotics.
William Spuck
(818) 354-2240
william_h_spuck@jpl.nasa.gov

Johnson Space Center
Selected technological strengths: Artificial Intelligence and Human Computer Interface; Life Sciences; Human Space Flight Operations; Avionics; Sensors; Communications.
Hank Davis
(713) 483-0474
hdavis@profs.jsc.-nasa.gov

Kennedy Space Center
Selected technological strengths: Emissions and Contamination Monitoring; Sensors; Corrosion Protection; Bio-Sciences.
Bill Sheehan
(407) 867-2544
billsheehan@ksc.nasa.gov

Langley Research Center
Selected technological strengths: Aerodynamics; Flight Systems; Materials; Structures; Sensors; Measurements; Information Sciences.
Charlie Blankenship
(804) 864-6005
c.p.blankenship@larc.nasa.gov

Lewis Research Center
Selected technological strengths: Aeropropulsion; Communications; Energy Technology; High Temperature Materials Research.
Walter Kim
(216) 433-3742
wskim@lims01.lerc.nasa.gov

Marshall Space Flight Center
Selected technological strengths: Materials; Manufacturing; Nondestructive Evaluation; Biotechnology; Space Propulsion; Controls and Dynamics; Structures; Microgravity Processing.
Harry Craft
(800) USA-NASA
susan.van.ark@msfc.nasa.gov

Stennis Space Center
Selected technological strengths: Propulsion Systems; Test/Monitoring; Remote Sensing; Nonintrusive Instrumentation.
Lon Miller
(601) 688-1632
lmiller@ssc.nasa.gov

NASA-Sponsored Commercial Technology Organizations

These organizations were established to provide rapid access to NASA and other federal R&D and foster collaboration between public and private sector organizations. They also can direct you to the appropriate point of contact within the Federal Laboratory Consortium.

Lee Rivers
National Technology Transfer Center
(800) 678-6882

Robert Stark
Far-West Technology Transfer Center
University of Southern California
(800) 472-6785 or
(213) 743-6132

Dr. William Gasko
Center for Technology Commercialization
(800) 472-6785 or
(508) 870-0042

J. Ronald Thornton
Southern Technology Applications Center
University of Florida
(800) 472-6785 or
(904) 462-3913
Gary Sera

Mid-Continent Technology Transfer Center
Texas A&M University
(800) 472-6785 or
(409) 845-8762

Lani S. Hummel
Mid-Atlantic Technology Applications Center
University of Pittsburgh
(800) 472-6785 or
(412) 648-7000

Chris Coburn
Great Lakes Industrial Technology Center
Battelle Memorial Institute
(800) 472-6785 or
(216) 734-0094

Easy Access To The FLC: Call (206) 683-1005 for the name of the Federal Laboratory Consortium Regional Coordinator in your area. The Regional Coordinator, working with the FLC Locator, can help you locate a specific laboratory to respond to your needs.

NASA Program Offices

At NASA Headquarters there are seven major program offices that develop and oversee technology projects of potential interest to industry. The street address for these strategic business units is: NASA Headquarters, 300 E St. SW, Washington, DC 20546.

Gene Pawlik
Small Business Innovation Research Program (SBIR)
(202) 358-4661
gpawlik@oact.hq.nasa.gov

Robert Norwood
Office of Space Access and Technology (Code X)
(202) 358-2320
rnorwood@oact.hq.nasa.gov

Philip Hodge
Office of Space Flight (Code M)
(202) 358-1417
phodge@osfms1.hq.nasa.gov

Gerald Johnson
Office of Aeronautics (Code R)
(202) 358-4711
g_johnson@aeromail.hq.nasa.gov

Bill Smith
Office of Space Sciences (Code S)
(202) 358-2473
wsmith@sm.ms.ossa.hq.nasa.gov

Bert Hansen
Office of Microgravity Science Applications (Code U)
(202) 358-1958
bhansen@gm.olmsa.hq.nasa.gov

Granville Paules
Office of Mission to Planet Earth (Code Y)
(202) 358-0706
gpaules@mtpe.hq.nasa.gov

NASA's Business Facilitators

NASA has established several organizations whose objectives are to establish joint sponsored research agreements and incubate small start-up companies with significant business promise.

Dr. Stephen Gomes
American Technology Initiative
Menlo Park, CA
(415) 325-5353

Jill Fabricant
Johnson Technology Commercialization Center
Houston, TX
(713) 335-1200

John Gee
Ames Technology Commercialization Center
Sunnyvale, CA
(408) 734-4700

Dan Morrison
Mississippi Enterprise for Technology
Stennis Space Center, MS
(800) 746-4699

If you are interested in information, applications, and services relating to satellite and aerial data for Earth resources, contact: Dr. Stan Morain, **Earth Analysis Center,** (505) 277-3622.
For software developed with NASA funding, contact **NASA's Computer Software Management and Information Center (COSMIC)** at (706) 542-3265, fax (706) 542-4807.
If you have a questions...**NASA's Center for AeroSpace Information** can answer questions about NASA's Commercial Technology Network and its services and documents. Use the Feedback Card in this issue or call (410) 859-5300, ext. 245.

End Effector Coupler/Decoupler

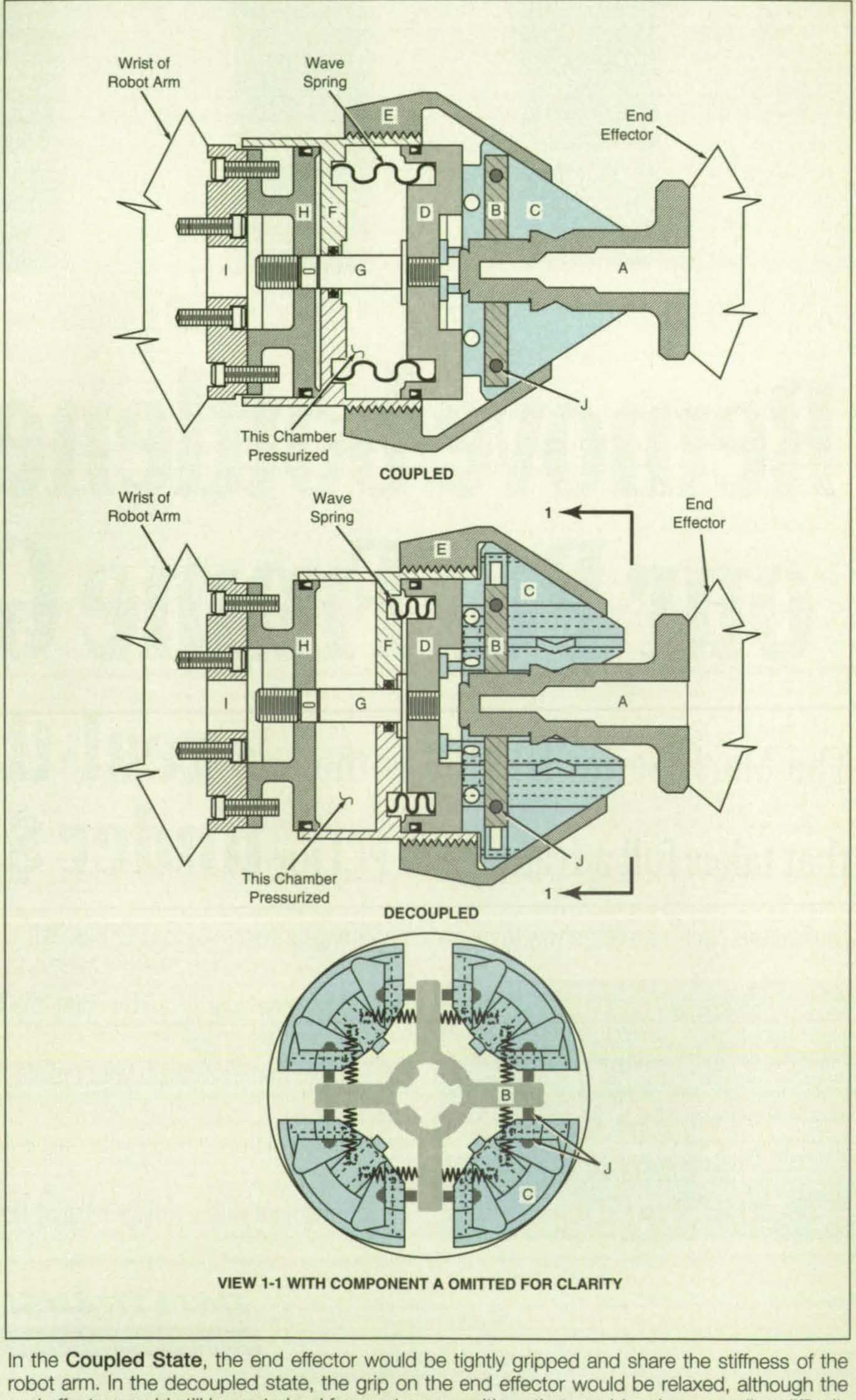
A coupling/decoupling device offers benefits of both stiffness and repositioning.

Langley Research Center, Hampton, Virginia

For accurate positioning of a component that is to be installed by a robotic end effector it may be desirable to latch the end effector to the workpiece before initiating the installation task. If either the workpiece or the robot arm is misaligned, the latching operation may introduce loads into the end effector mechanisms that can cause them to bind and malfunction. Therefore, a coupler/decoupler device has been devised that permits the end effector to be released (decoupled) from the robot arm while attached to the workpiece, and realigned and recoupled to the arm when the end effector task has been completed. This relieves the necessity for accurate positioning of the robot and the workpiece, and compensates for deformations that can be initiated by changes in temperature as well as normal machining variations.

The coupler/decoupler device is mounted between the wrist plate of the robot and the end effector. For normal positioning of the end effector by the robot arm, the device operates in the coupled mode. For this operation, the end effector is pneumatically clamped to a stem to which the end effector is attached. When the end effector has been positioned and is attached to the workpiece, the pneumatic clamping pressure is released, relaxing the attachment forces to the end effector in all three directions of load and moment for small misalignments, yet restraining the end effector from large motion misalignments that could result in total release and damage should the end effector be inadvertently released from the workpiece. When the installation task is complete, pneumatic pressure is applied to the coupler and the end effector is both aligned to the initial location in position and orientation and is securely affixed to the robot arm.

The details of the various operations can be observed in the attached sketch. In the coupled state the pneumatic chamber between components F and D is pressurized, forcing the jaws C to be pressed firmly against a mating surface on the spindle of component A, to which



In the **Coupled State**, the end effector would be tightly gripped and share the stiffness of the robot arm. In the decoupled state, the grip on the end effector would be relaxed, although the end effector would still be restrained from extreme positions that would make recoupling difficult. The end effector could then assume a variety of attitudes with respect to the workpiece and perform its function without exerting large stresses on either the robot arm or the workpiece.

the end effector is attached. In the decoupled state the pressure in the pneumatic chamber between components D and F is released and the chamber between components H and F is pressurized, forcing the load on the jaws C to be relieved. The set of springs between the jaws C shown in view 1-1 force them apart. Alignment of the jaws in the open position is maintained by component B which also has an interior spline that mates with a spline on component A to prevent significant roll deformations. A set of four pins labeled as component J guide the displacements of A in the plane normal to the longitudinal axis of part A.

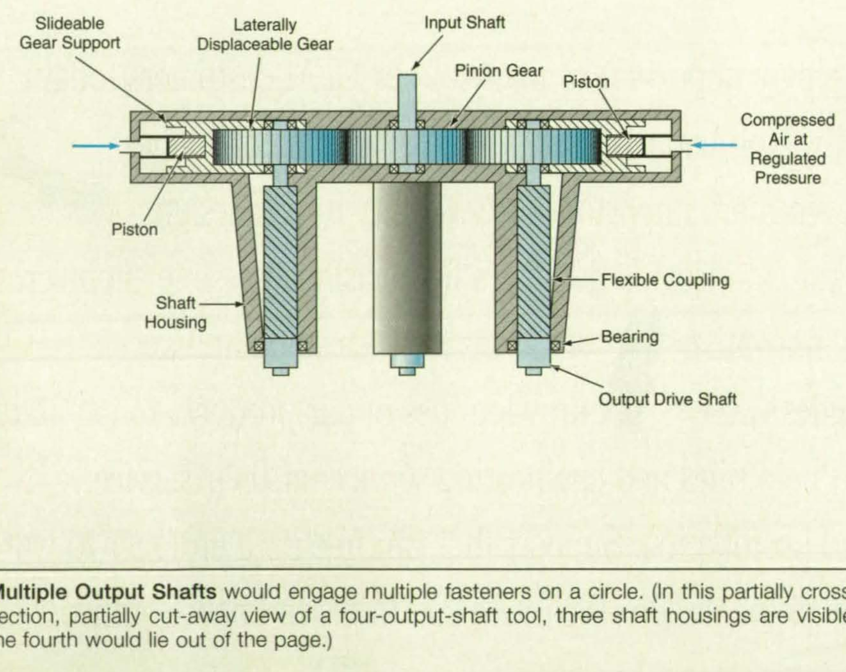
All external loading on the end effector during positioning of the installed part and the load due to pneumatic pressurization are reacted by the stem G. The wave spring between components D and F keeps the jaws C closed in the event of a pressure loss while the device is in the coupled state.

This work was done by Russell W. Smith and Marvin D. Rhodes of **Langley Research Center**. *For further information,* ***write in 72*** *on the TSP Request Card. LAR-14984*

Tool for Driving Many Fasteners Simultaneously

A pneumatically activated mechanism would ensure uniform, synchronized tightening or loosening.

Lyndon B. Johnson Space Center, Houston, Texas



Multiple Output Shafts would engage multiple fasteners on a circle. (In this partially cross-section, partially cut-away view of a four-output-shaft tool, three shaft housings are visible; the fourth would lie out of the page.)

A proposed tool would tighten or loosen several bolts, screws, nuts, or other threaded fasteners arranged in a circle on a compressor head, automotive wheel, pipe-end flange, or a similar object. The tool would enable assembly or disassembly in a fraction of the time needed to tighten fasteners one at a time. It would simultaneously apply the same torque to all fasteners, thereby preventing distortion and enhancing reliability.

The tool would contain a set of shafts — one for each fastener — arranged around a circle at positions corresponding to those of the fasteners, so that they could engage the fasteners. A pneumatic motor powered by compressed air would rotate a central pinion gear, which, in turn, would rotate a number of laterally displaceable gears — one for each fastener. A flexible coupling would connect each laterally displaceable gear with the drive saft for the associated fastener (see figure).

A pneumatic piston associated with each laterally displaceable gear would apply a lateral (radially inward toward the center of the bolt-hole circle) force to the gear through a slideable gear support. As in other, single-fastener, pneumatically driven, torque-limited tools of this type, torque would be limited to a value below which the pneumatically applied lateral force was sufficient to prevent slippage of the gear teeth.

The pistons would also be driven by compressed air. The same pressure would be supplied to all the piston cylinders via a pneumatic system that would include a control valve, a self-venting pressure regulator, and a pressure gauge. Therefore, the same lateral force would be applied to each displaceable gear, causing the torques applied to all the fasteners to be limited to the same value when all the fasteners are tightened simultaneously.

This tool concept is not limited to circular fastener patterns. It could be adapted to rectangular configurations like those on engine intake manifolds, for example, by adding gears to the drive train to provide the proper spacing. It could be designed to deliver a fixed or adjustable maximum torque. To ensure even seal loading, piston pressure could be simultaneously ramped from initial to final values to maintain relatively constant torque loading on all fasteners until the final specification limit is achieved.

This work was done by Joseph S. Cook, Jr., of **Johnson Space Center**. *For further information,* ***write in 274*** *on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center; (713) 483-4871. Refer to MSC-22386.

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Adjustable Tool for Driving Multiple Fasteners

Output shafts could be set on bolt circles of various diameters.

Lyndon B. Johnson Space Center, Houston, Texas

The figure illustrates a proposed tool that would tighten or loosen several bolts, screws, nuts, or other threaded fasteners arranged in a circle on a compressor head, automotive wheel, pipe-end flange, or a similar object. The tool would combine some of the features of the related mechanism described in the preceding brief, "Tool for Driving Many Fasteners Simultaneously" (MSC-22386).

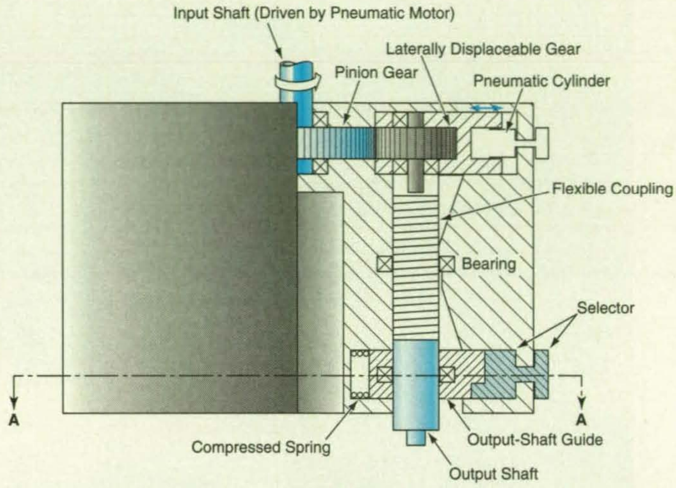
Like the tool described in the prior article, this one would contain a set of shafts — one for each fastener — arranged around a circle at positions corresponding to those of the fasteners, so that they could engage the fasteners. A pneumatic motor powered by compressed air would drive a central pinion gear, which, in turn, would drive a number of laterally displaceable gears — one for each fastener. A flexible coupling would connect each laterally displaceable gear with an output shaft that would transmit the torque to the associated fastener.

The laterally displaceable gears would be preloaded against the pinion with a preset force, and the torque transmitted to the output shafts would be limited to the torque that would overcome the preload and thus cause the gears to slip. In the figure, the preload is shown as being applied pneumatically according to the scheme described in the immediately preceding article. Alternatively, the preload could be applied by use of springs.

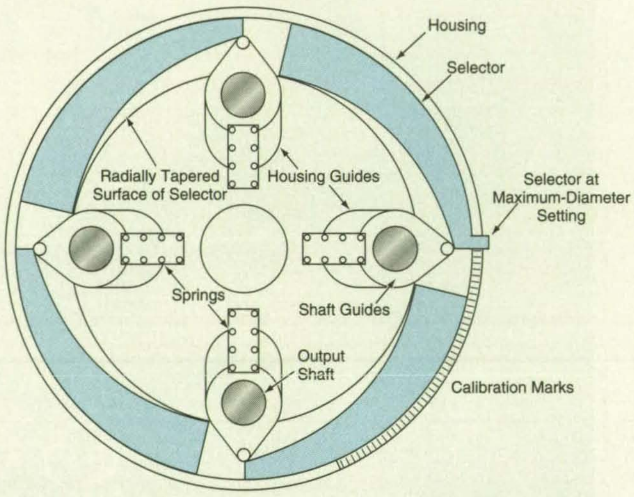
A unique feature of this proposed mechanism is that the lateral positions of the output shafts could be adjusted, by use of a mechanism called the "selector," to fit fastener patterns with larger or smaller bolt circles. The range of radial (relative to the axis of symmetry) adjustment would depend on the flexibility of the lower halves of the flexible couplings and on the design of the selector and of the housing. To isolate the torque-setting mechanism at the top of each flexible coupling from radial force caused by the radial adjustment and thus prevent interference with the torque setting, the flexible coupling would be braced by a bearing at its midlength.

Each output shaft would turn in a bearing in an output-shaft guide, which could slide radially within a housing and would be spring-loaded radially outward. The selector would include surfaces that would press radially inward on the output-shaft guides, against the spring loads. The radius of each of these surfaces would vary from an inner extreme at an extreme circumferential position to an outer extreme at another extreme circumferential position. The flexible couplings would allow the output shafts to move radially along with the output-shaft guides. Thus, as the selector was turned, the output-shaft guides would move radially inward or outward and could be set at any radius between the two extreme bolt-circle radii defined by the extreme radii of the selector. The selector would include an indicator and bolt-circle-diameter calibration marks so that a technician could easily set the tool to the desired bolt-hole diameter.

This concept can be extended from the circular pattern to a rectangular pattern for application to automobile headers and intake manifolds.



PARTIAL CROSS SECTION OF TOOL, SHOWING ONE OF SEVERAL OUTPUT SHAFTS



SECTION A-A, PARTIALLY SCHEMATIC, SOME PARTS OMITTED FOR CLARITY

This **Tool Would Drive Multiple Fasteners** like bolts arranged on a bolt circle on a flange. The tool could be adjusted to fit bolt circles of various sizes.

This work was done by Joseph S. Cook, Jr., of **Johnson Space Center**. *For further information,* ***write in 51*** *on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center; (713) 483-4871. MSC-22423.

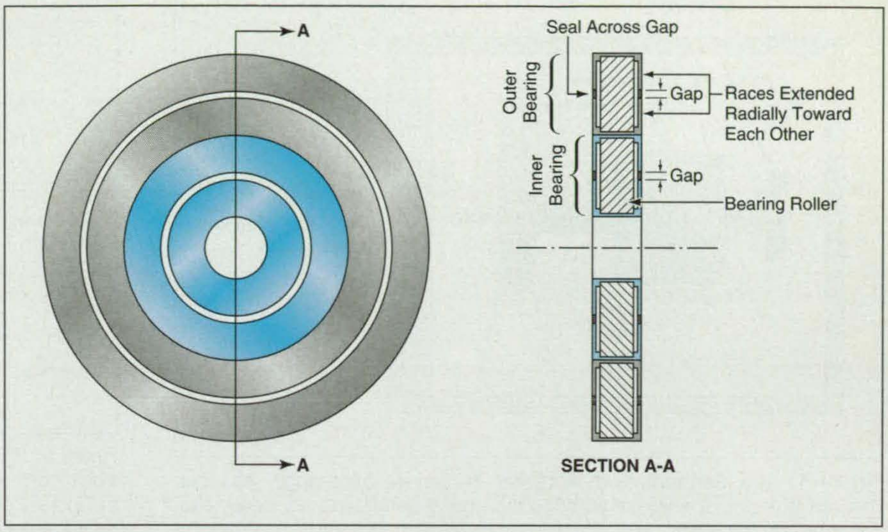
Redundant Bearing Assembly

One bearing would be held by another.

Lyndon B. Johnson Space Center, Houston, Texas

A proposed redundant bearing assembly would consist of two modified ball or roller bearings, one held by the other. In the version illustrated in the figure, the outer race of the inner bearing would be press-fit into the inner race of the outer bearing. Within each bearing, the side walls of the inner and outer races would be extended radially toward each other so as to leave only a small gap.

If one of the bearings failed by seizing, the bearing assembly would continue to function as long as the other bearing remained intact. In the event that the rollers or balls in one bearing suffered excessive wear, the small gap between the races of that bearing would close at some point along the circumference, in effect causing the worn bearing to seize. Again, the bearing assembly would continue to function as long as the other bearing remained intact.



In the **Redundant Bearing Assembly**, one bearing would continue to allow free rotation when the other failed.

Bearing wear could be monitored by examination of the gaps between the races. In an alternative design, the inner race of the outer bearing and the outer race of the inner bearing could be manufactured as a single piece.

This work was done by Jay M. Wright of **Johnson Space Center**. *No further documentation is available.*
MSC-22425

Gravity-Referenced Elevation Encoder

This encoder can be mounted directly on an object that is to be tilted precisely.

NASA's Jet Propulsion Laboratory, Pasadena, California

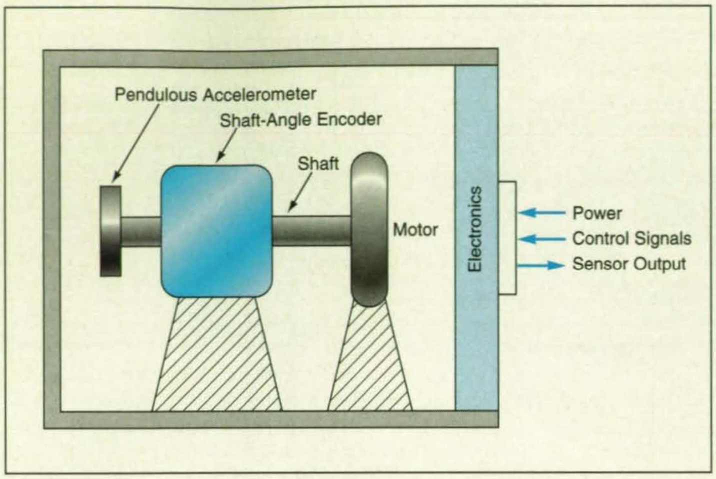


Figure 1. The **Sensors and Actuator** in the elevation-angle encoder include a motor, a shaft-angle encoder, and a pendulous accelerometer mounted on the shaft.

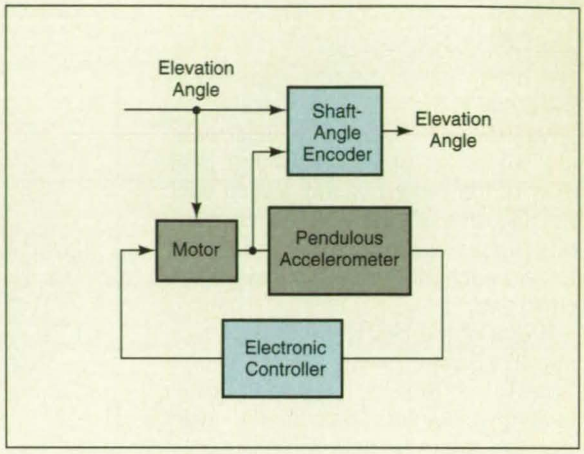


Figure 2. This **Elevation-Encoder System** includes an electronic controller along with the sensors and actuator illustrated in Figure 1. The controller implements a control law that compensates for bearing friction and the dynamics of the apparatus.

A tilt-measuring apparatus that is undergoing development gives a precise indication of the elevation angle of a scientific instrument or other object that must be aimed precisely. In the original intended application, the apparatus would be mounted directly on the primary reflector of a large radio antenna. The apparatus (see Figure 1) includes a torque-balanced pendulous accelerometer mounted on a motor shaft equipped with an optical shaft-angle encoder. The motor, accelerometer, shaft-angle encoder, and a controller are combined into an electronic control-and-sensing system as shown in Figure 2.

The pendulous accelerometer is designed so that it gives zero output when its designated reference axis is perpendicular to gravity. Accordingly, the controller causes the motor to turn the shaft until the output of the pendulous accelerometer is nulled. The output of the shaft-angle encoder at the null-output position is thus a measure of the angle of gravitation relative to the reference frame of the motor and encoder and thus of the elevation angle to be measured.

A prototype system was tested in a laboratory and found to exhibit acceptably small values of noise and long-term drift. The controller apparatus kept the simulated elevation error to less than 1 mdeg when the apparatus was subjected to vibrations equivalent to those on a 70-m-diameter paraboloidal antenna reflector.

This work was done by Ralph E. Goddard of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 66*** *on the TSP Request Card.*

NPO-19224

High-Performance Ball Bearing

A durable cage with self-lubricating inserts ensures long life.

Marshall Space Flight Center, Alabama

The ball bearing shown in the figures is designed to operate at high speed (tens of thousands of revolutions per minute) in a cryogenic environment like that of a liquid-oxygen or liquid-hydrogen turbopump. Like other ball bearings, this one includes an inner race, an outer race, and a cage that keeps the bearing balls equally spaced: what sets this bearing apart from the others is a unique design that provides solid lubrication of the balls and races and ensures low wear of the cage, thereby promoting endurance.

The balls roll in circumferential grooves in the inner and outer races. Cylindrical lands adjacent to the grooves act as pilot surfaces, which maintain the alignment of the cage (the cage rotates between the lands with a sliding fit). The inner race is fabricated as two rings to facilitate the assembly of the bearing: the cage and balls are inserted in the outer race, then the two rings of the inner race are inserted in the central hole and clamped together in alignment so that their abutting tapered sections constitute the circumferential groove in which the balls roll. The races can be made of any suitable alloy or other material as dictated by such operating parameters as expected loads, speeds, temperatures, and flows of lubricants.

The cage (see Figure 1) is made of a strong, lightweight composite of glass fibers in a solid lubricant matrix of polytetrafluoroethylene. The cage contains apertures for the balls; each ball aperture is lined with an insert made of a composite of bronze and polytetrafluoroethylene. A polygonal (square in the case of Figure 1) flange with rounded corners on each insert fits in a mating counterbore in the cage and applies the centrifugal load of the insert to the cage and prevents rotation of the insert with respect to the cage. During operation, the balls pick

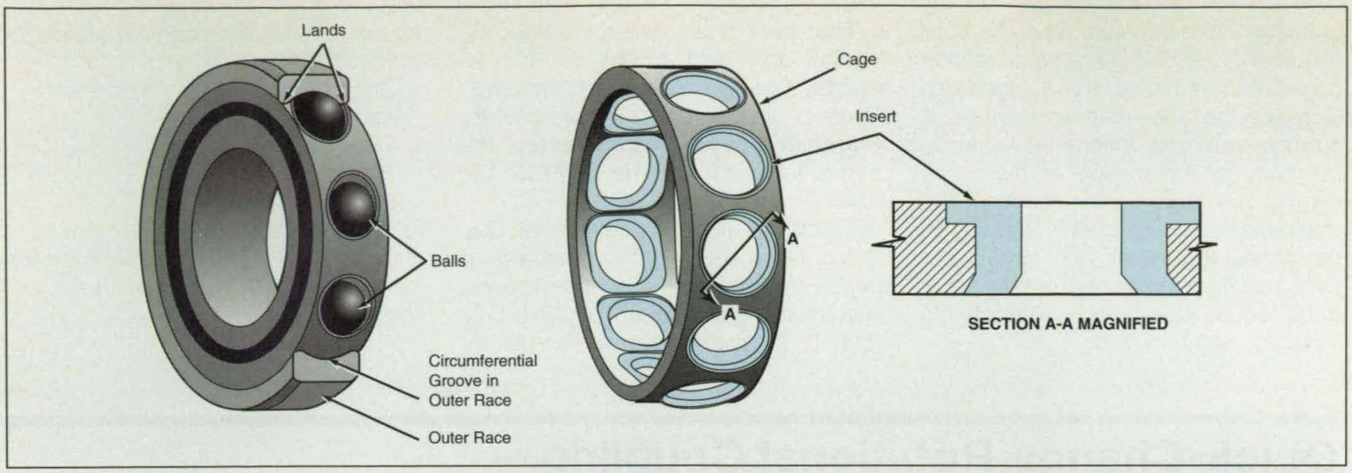


Figure 1. The **High-Performance Bearing** features a strong, lightweight, self-lubricating cage with self-lubricating liners in the ball apertures.

up the polytetrafluoroethylene solid lubricant from the inserts and deposit it on the races; the lubricant then prevents direct contact between the balls and races.

Because of the light weight, high strength, and lubricity of the cage material, the rubbing of the cage against the lands of the outer race produces very little wear. Indeed, it is this lack of wear that makes it possible to pilot the cage

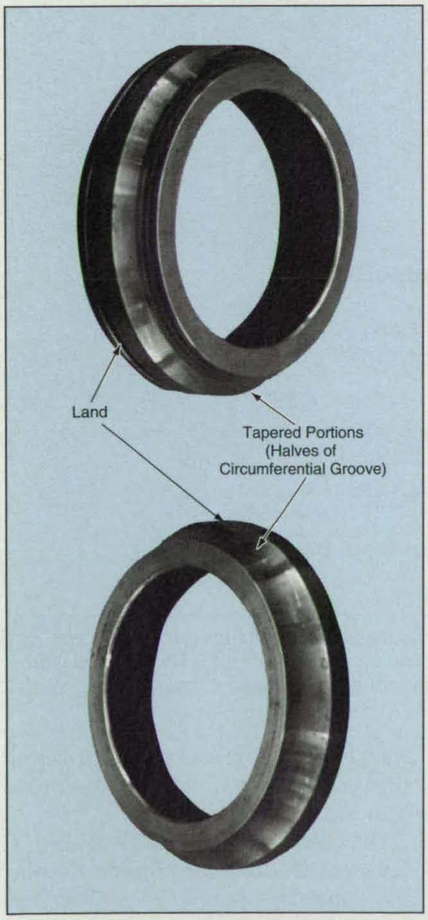


Figure 2. The **Inner Race Is Made in Two Halves** to facilitate assembly of the bearing.

on the lands of the outer race: the poor rub-wear performances of older bearing cages made it necessary to pilot those cages on the lands of inner races — an arrangement that inherently leads to instability in the motion of the cage. Piloting the cage on the lands of the outer race ensures greater stability in the sense that what little cage wear (with resulting imbalance of the cage) does occur does not contribute to instability of the motion.

This work was done by Roger W. Bursey, Jr., David A. Haluck, John B. Olinger, Samuel S. Owen, and William E. Poole of United Technologies Corp. for **Marshall Space Flight Center.** *For further information,* ***write in 77*** *on the TSP Request Card.*

Title to this invention, covered by U.S. Patent No. 5,230,570, has been waived under the provisions of the National Aeronautics and Space Act [42 U.S.C. 2457(f)]. Inquiries concerning license for its commercial development should be addressed to

United Technologies Corporation
Attn: John Swiatocha
One Riverview Square
7th Floor
East River Drive
Hartford, CT 06108

Refer to MFS-28810, volume and number of this NASA Tech Briefs *issue, and the page number.*

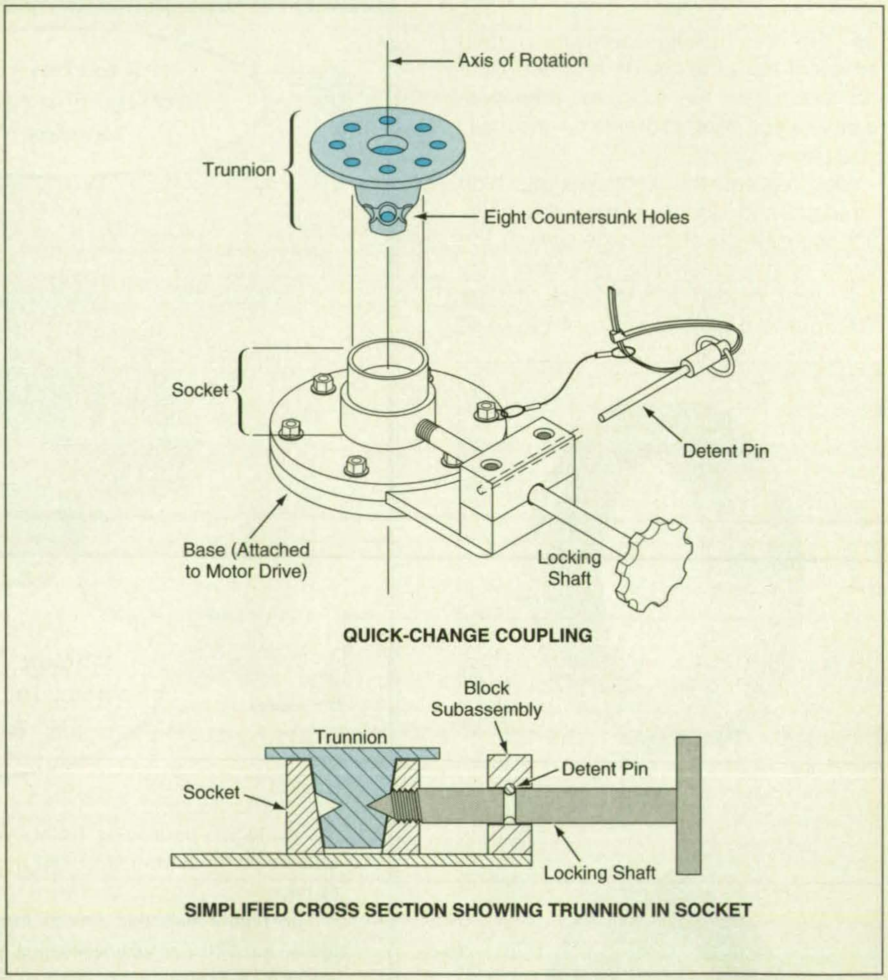
Quick-Change Rotational Coupling

A locking shaft prevents slippage between driving and driven components.

Lyndon B. Johnson Space Center, Houston, Texas

A rotational coupling is designed to enable quick connection and disconnection of driving and driven components and to transmit torque without slippage. The coupling was originally designed to provide for quick adjustment of the relative positions of a chair and a rotary motor drive for vestibular tests of human subjects in outer space. With the coupling, a technician can reorient the chair in about 30 seconds. The coupling is also suitable for use in other situations in which turntables, rotating scientific instruments, or other equipment must be connected and disconnected frequently for adjustment or replacement. (However, it is not suitable for replacement of permanent rotary couplings.)

The part of the coupling on the motor-drive side is an assembly that includes a stainless-steel socket, a stainless-steel locking shaft, and a locking-block subassembly (see figure). The socket is cylindrical and contains a central hole with a 10° conical taper. The socket is welded to a base, which is rotated by the motor drive. The chair (omitted from the figure for clarity) or other item to be rotated is bolted to an aluminum bronze trunnion machined to an outer conical taper matching that of the hole in the socket. Eight holes are countersunk at equal intervals around the conical part of the trunnion that engages the socket.



The **Quick-Change Coupling** connects a motor drive to a flanged trunnion connected to the object to be rotated. The locking shaft prevents slippage but can be quickly removed so that the trunnion can be changed or rotated to another of eight angular positions.

The technician pushes the trunnion into the socket, then turns the locking shaft, screwing it into the threaded hole in the side of the socket. As the locking shaft advances into the socket, the conical tip of the shaft engages one of the countersunk holes: this engagement prevents rotation of the trunnion relative to the socket. Slots that are milled into the countersunk holes provide for firm seating of the locking shaft with, nominally, two-point contact. The technician then inserts a detent pin into the locking-block subassembly; this pin engages grooves in the locking shaft and locking block, preventing the locking shaft from backing out in case the threaded connection becomes loose. To release the trunnion, the technician simply removes the detent pin and unscrews the locking shaft. The trunnion can then be pulled from the socket.

This work was done by Millard F. Reschke of **Johnson Space Center** *and Joe Bufkin of KRUG Life Sciences. For further information,* ***write in 47*** *on the TSP Request Card. MSC-22350*

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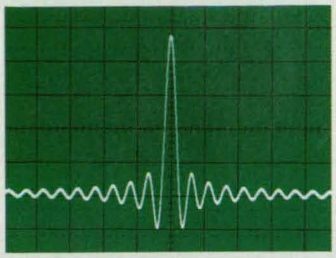

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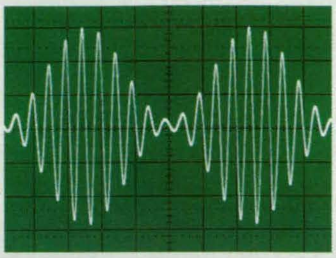

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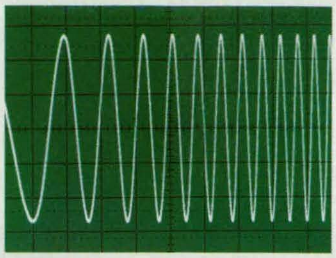

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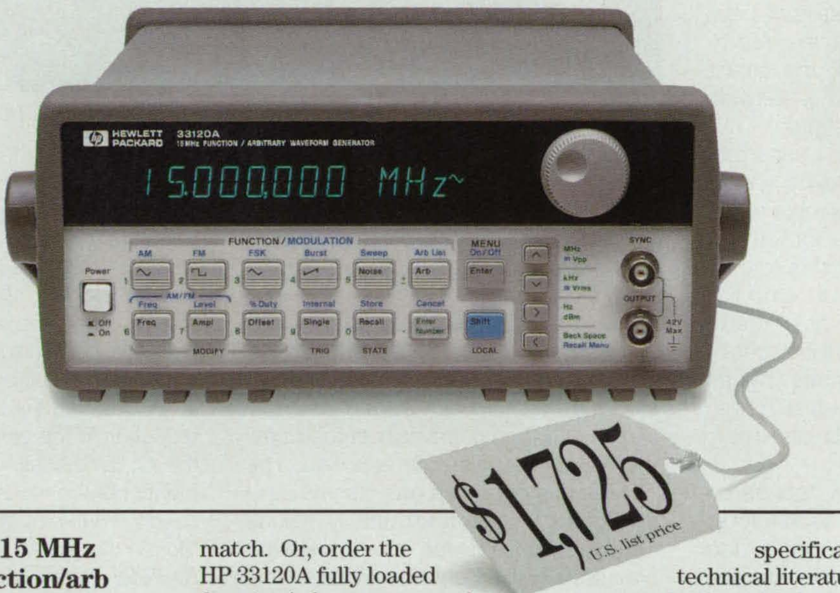

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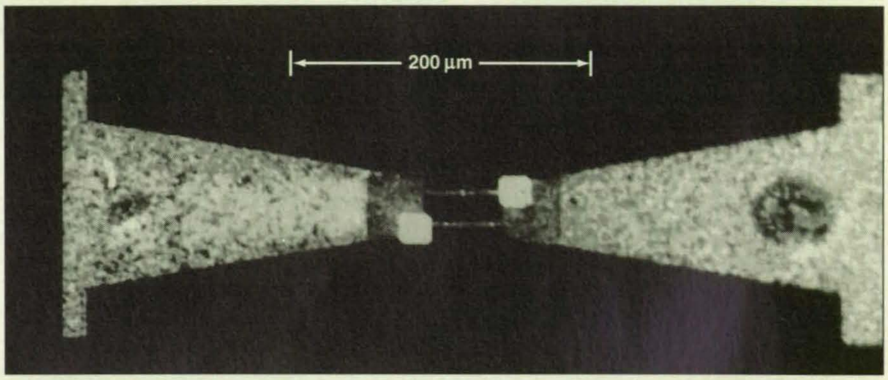
Millimeter and Submillimeter-Wave Integrated Circuits on Quartz

GaAs Schottky diodes and circuit elements are fabricated as integral units on a quartz substrate.

NASA's Jet Propulsion Laboratory, Pasadena, California

Integrated circuits that include planar GaAs Schottky diodes and passive circuit elements (such as bandpass filters) have been fabricated on quartz substrates. These circuits are designed to operate as mixers in a waveguide circuit at millimeter and submillimeter wavelengths. These integrated circuits are mechanically more robust, larger, and therefore easier to handle than are the planar Schottky diode chips that have been used heretofore to make waveguide mixers. Furthermore, the quartz substrate is more suitable for waveguide circuits than the GaAs substrate.



Part of a QUID Circuit is shown here with a Schottky diode pair. This structure is ready to be mounted in a waveguide block for testing.

The proposed Quartz substrate Upside-down Integrated Device (QUID) technology relies on a UV-curable adhesive to bond the semiconductor with the quartz. The Schottky contact is formed on lightly doped GaAs, which is on top of a heavily doped GaAs layer for ohmic contacts. The diode material is separated from the GaAs substrate by an AlGaAs layer which acts as an etch-stop layer when the substrate is chemically etched from the back.

The planar diodes are fabricated using photolithographic technology. The diodes require both an ohmic and Schottky contact. The GaAs surface is passivated with a dielectric, and Ti/Pt/Au is used as the Schottky contact. The waveguide circuit element, a hammerhead filter structure, is defined in the same step as the fingers that join the Schottky anode with the ohmic contact. The individual devices are isolated by etching a channel around each circuit.

The wafer is then bonded, upside-down, onto a quartz substrate using a UV-cured adhesive. The GaAs substrate is mechanically lapped down to 50 µm and then chemically etched until the AlGaAs layer is fully exposed. The AlGaAs is etched in a gas plasma, and all of the GaAs from the wafer is removed, except for the immediate area around the Schottky anodes. This circuit has the minimum amount of GaAs required for proper device operation. The resulting chip is diced into individual integrated circuits, which are placed in a waveguide block for testing (see figure).

Subharmonically pumped integrated mixers of this type have been fabricated and tested at 220 GHz. The performance of these mixers is slightly worse than the best discretely mounted chip mixers. However, by improving the quality of the Schottky contacts along with a reduction in the parasitic capacitance of the QUID diodes, substantial improvements can be realized.

This work was done by Imran Mehdi, Mohammad Mazed, Peter Siegel, and R. Peter Smith of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 25*** *on the TSP Request Card.*
NPO-19304

Cosmic-Ray Detectors With Interdigitated Electrodes

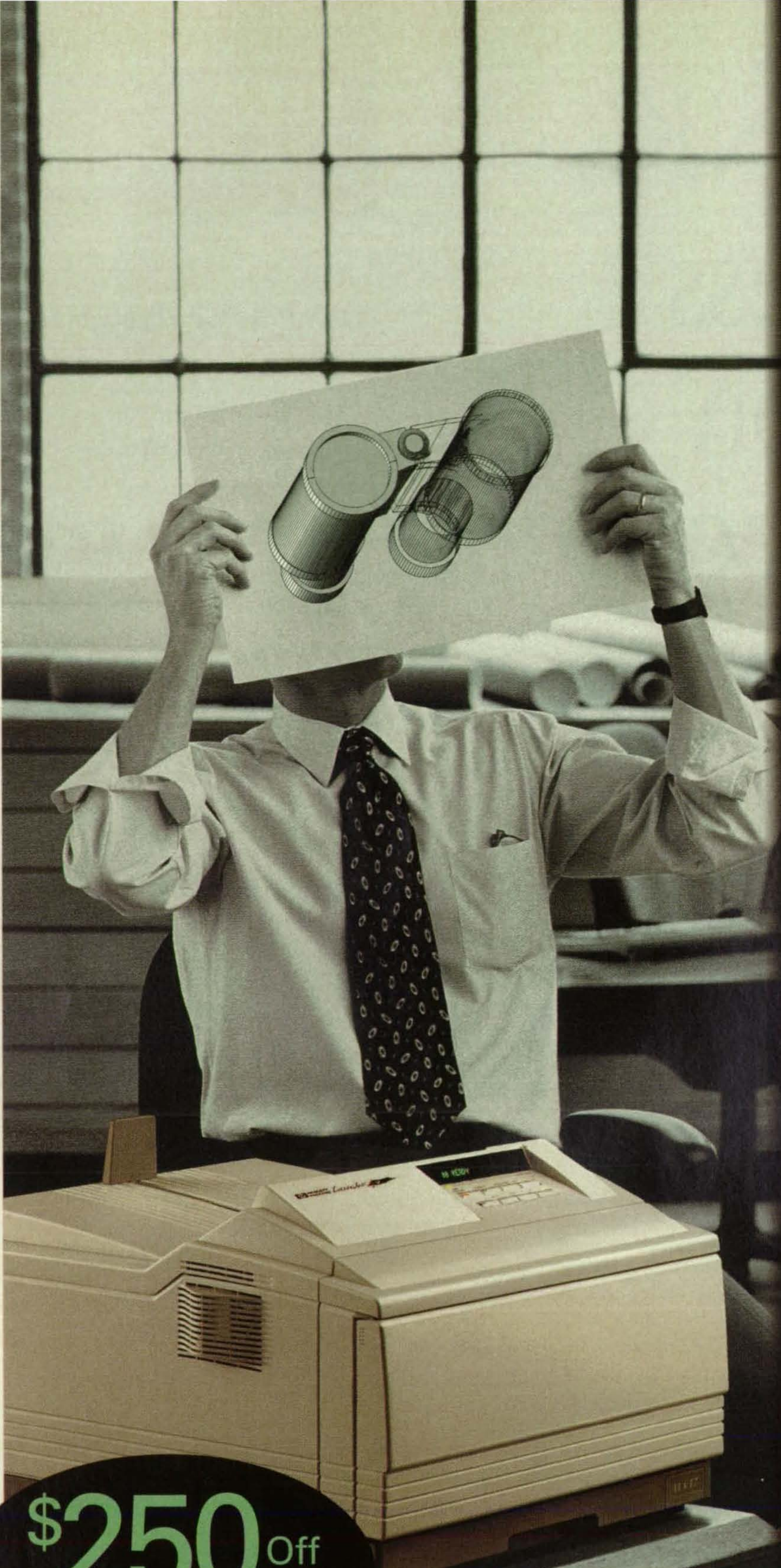
These detectors measure both positions of incidence and energies of incident charged particles.

NASA's Jet Propulsion Laboratory, Pasadena, California

Figure 1 illustrates a stack of cosmic-ray detectors of a type that is still undergoing development. These detectors are operated in coordination with each other for measurement of both the trajectories and the energies of the incident energetic charged particles that constitute cosmic rays. Each detector in the stack is fabricated as a wafer that contains layers of p-doped, undoped, and n-doped silicon; that is, the detector is of the positive/intrinsic/negative (PIN) silicon type. A reverse-bias voltage is applied to the p and n layers to create an electric field inside each wafer.

When a cosmic ray passes through a wafer, its kinetic energy is dissipated in the generation of electron/hole pairs; about 1 pair per 3 eV of energy. The electric field sweeps the electrons and holes to the p and n layers, where they are collected; the amount of charge col-

(continued on page 37)



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(continued from page 32)

lected is thus proportional to the energy dissipated by the incident particle. The stack is arranged so that the lower wafers are thick enough to absorb the energy remaining after passage of the cosmic ray through the upper wafers. Thus, the total energy of an incident particle can be computed as a sum of energies dissipated in all the layers. The pulse of current used to measure the energy dissipated in each wafer is collected via the lower doped (p or n) layer of the wafer and buffered through a precise amplifier to external circuitry.

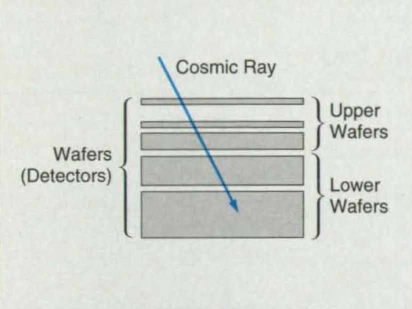


Figure 1. **A Stack of Detector Wafers** intercepts a cosmic ray. The detectors measure the positions of incidence to determine the cosmic-ray trajectory and the charge generated within them (proportional to the cosmic-ray energy dissipated within them).

The upper (n or p) doped layer of each wafer is divided into a pattern of interdigitated electrodes (see Figure 2) that define pixels (typically 1 mm square) for determining the locations of incidence of the cosmic ray at the upper surface of the wafer. These electrodes are not used to measure the charge generated by dissipation of energy, but to obtain signals indicative of incidence of a cosmic ray within a pixel; a "hit" is recorded whenever a measurable amount of charge diffuses from a cosmic-ray track to the nearest row-and-column pair of interdigitated electrodes. The trajectory of the cosmic ray can then be computed as a line that passes through the "hit" pixels in successive wafers in the stack.

In tests thus far, the detectors have proved partially functional but for unknown reasons they have exhibited very high dark currents and soft breakdown at applied potentials of 10 to 80 V. Further development efforts are expected to identify the causes of these deficiencies and overcome them.

This work was done by Thomas J. Cunningham, Mohammed Mazed, Melinda J. Holtzman, and Eric R. Fossum of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 67*** *on the TSP Request Card.*
NPO-19231

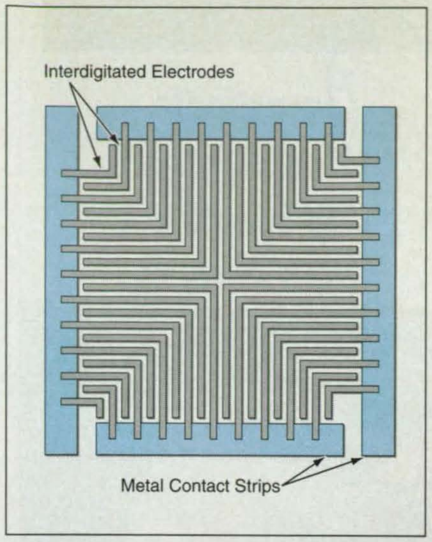


Figure 2. This **Interdigital Electrode Pattern** is repeated over many rows and columns on the tops of the detector wafers in the stack. The electrode pattern defines pixels within which the points of incidence of incident cosmic rays can be located.

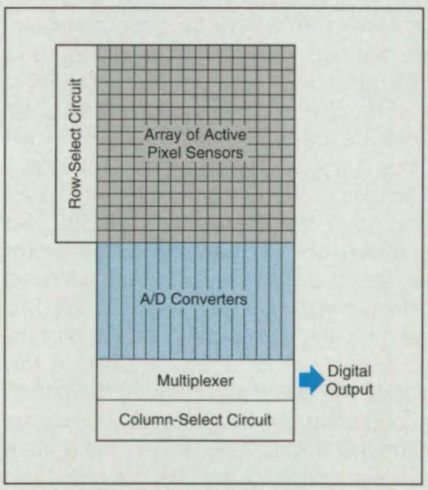
Active-Pixel Image Sensor With Analog-to-Digital Converters

Each column would include an analog-to-digital converter based on Σ-Δ modulation.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed single-chip integrated-circuit image sensor would contain a 128 x 128 array of active pixel sensors at a 50-µm pitch. The output terminals of all of the pixels in each given column would be connected to an analog-to-digital (A/D) converter located at the bottom of the column (see figure). The pixels would be scanned in semiparallel fashion, one row at a time; during the time allocated to scanning a row, the outputs of all the active pixel sensors in the row would be fed to their respective A/D converters. The design of the chip is based on complementary metal oxide semiconductor (CMOS) technology, and individual circuit elements (but not the whole integrated circuit) have been fabricated according to 2-µm CMOS design rules. The active pixel sensors are designed to operate at a video rate of 30 frames/second, even at low light levels.

The A/D scheme is based on first-order Σ-Δ modulation, in which the input signal is oversampled (that is, sampled at a sampling frequency greater than the Nyquist rate), the samples are integrated, the integral is compared with a reference voltage to achieve two-level (0,1) quantization, and each time the output of the quantizer is 1, the reference voltage is subtracted to reset the integral to near zero for the next sampling interval. Basing the design on Σ-Δ modulation enables the use of relatively low-power, low-accuracy analog components.



In the **Semiparallel Architecture** of the proposed image sensor, all the active pixel sensors in a column would be connected to the same A/D converter. Rows would be read out periodically; during a given row-readout period, the outputs of all the active pixels in a row would be sampled simultaneously.

The output of the Σ-Δ modulator in each A/D converter is averaged by summing the outputs of the quantizer in a 10-bit counter circuit. At the end of each row-readout period, the count is latched. While A/D conversion is performed on the outputs from the active pixel sensors in a given row, the latched counter outputs for the preceding row are transferred out through a multiplexer.

According to a computer simulation, the integrated circuit would consume about 53 mW of power, and its root-mean square noise (referred to the input) would be only 11.2 electrons. The predicted performance of the circuit system, in terms of speed of operation and noise, was found to be limited by the design of operational amplifiers in the A/D converters.

This work was done by Eric R. Fossum, Sunetra K. Mendis, Bedabrata

Pain, and Robert H. Nixon of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 56*** *on the TSP Request Card.*

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

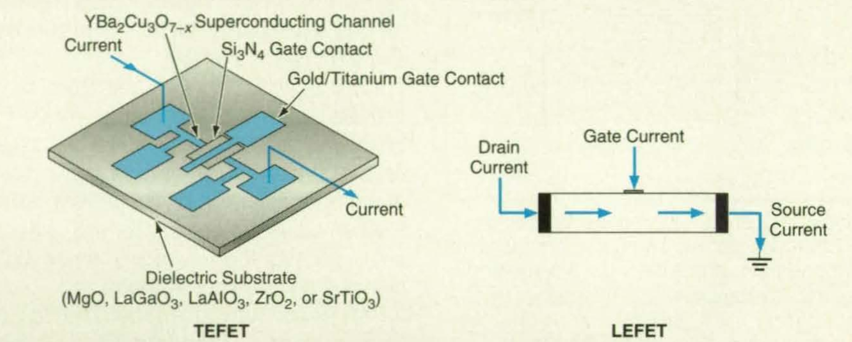
William T. Callaghan, Manager
Technology Commercialization
JPL-301-350
4800 Oak Grove Drive
Pasadena, CA 91109

Refer to NPO-19117, volume and number of this NASA Tech Briefs *issue, and the page number.*

Superconducting Field-Effect Transistors

These devices offer switching speeds greater than those of their semiconducting counterparts.

Lewis Research Center, Cleveland, Ohio



Superconducting Field-Effect Transistors resemble semiconductor field-effect transistors in some respects, but their operation is based on a different principle; namely, electric-field control of the transition between superconductivity and normal conductivity.

High-T_C superconducting field-effect transistors (SUPEFETs) have been investigated for use as electronic switches in delay-line-type microwave phase shifters. (T_C denotes the temperature of the transition between superconductivity and normal conductivity.) A SUPEFET is useful for this purpose because it can be switched electrically between a state of superconductivity (switch closed) and normal conductivity (switch open).

The SUPEFETs investigated thus far can be classified into two main types (see figure); transverse-electric-field-effect transistors (TEFETs) and longitudinal-electric-field-effect transistors (LEFETs). The principle of operation of a TEFET is similar to that of a semiconductor FET in that an electric field in a gate region is used to control the conductance of a channel between a source and a drain. In this case, the electric field across the superconducting channel between the source and the drain is varied to vary the surface charge density of the channel, giving rise to a variation in the T_C of the channel. Thus by suitable choice of voltage applied to the gate, the T_C of the channel can be brought above or below the actual temperature, rendering the device superconductive or normally conductive as desired.

A LEFET is a pseudo-three-terminal device that includes a drain, a source, a superconducting drain-to-source channel, and a titanium-film Schottky gate contact located between the source and the drain. The drain-to-source channel is switched from superconductive to normally conductive by introducing a gate-to-source current that exceeds the superconducting critical current.

The results of investigations thus far indicate that the construction of SUPEFETs is feasible and that SUPEFETs offer several advantages:

- SUPEFETs are capable of switching at speeds greater than those of their semiconductor counterparts.
- In principle, the ratios between the "open" and "closed" resistances of SUPEFETs are infinite; in practice these ratios can be $> 10^7$ — much greater than those of comparable semiconductor FETs.
- SUPEFETs can be integrated readily with superconducting waveguides.

This work was done by Kul Bhasin and Robert R. Romanofsky of **Lewis Research Center** *and Massood Tabib-Azar of Case Western Reserve University. For further information,* ***write in 80*** *on the TSP Request Card.*
LEW-15596

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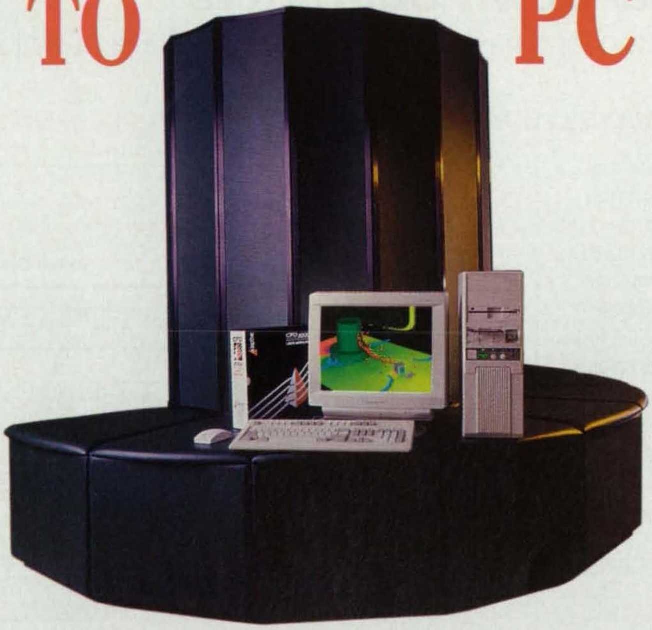

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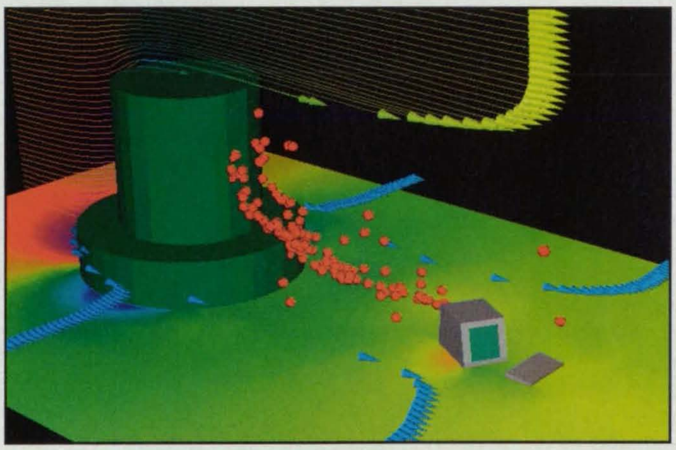

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For More Information Write In No. 505

Simplified Digital Down-Converters

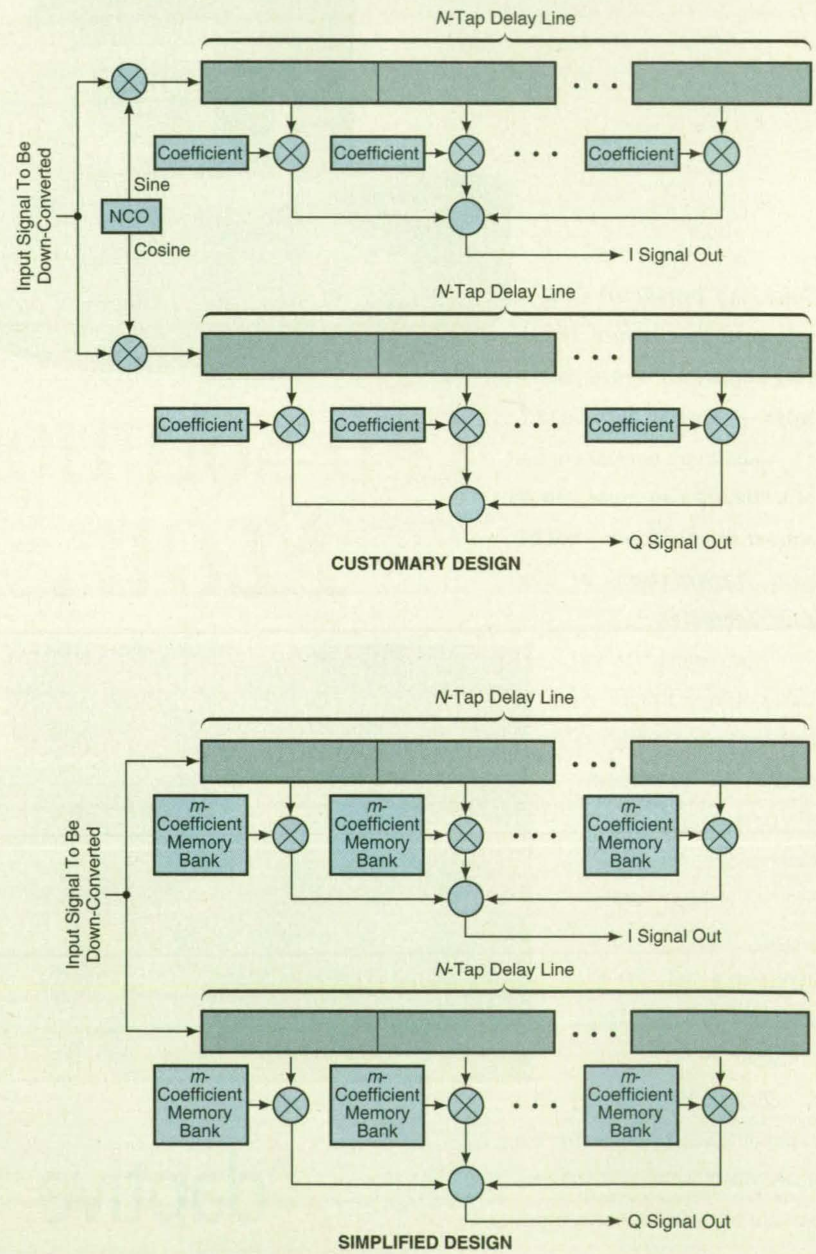
Number-controlled oscillators and mixers are eliminated and their functions implemented in filter coefficients.

NASA's Jet Propulsion Laboratory, Pasadena, California

The design of digital frequency down-converters can be simplified by eliminating the need for both high-speed number-controlled oscillators (NCOs) and mixer-multipliers, and implementing their functions via the multiplication coefficients of finite-impulse-response (FIR) filters. This simplification depends on particular choices of operating frequencies, as explained below. The simplified designs can be implemented with commercial FIR integrated circuits.

The upper part of the figure shows the basic functional blocks of a digital down-converter according to the customary, more complex design concept. The input signal to be down-converted is sampled at a rate of f_i. The digital samples are fed to two quadrature mixer-multipliers, which multiply the signal by the sine and cosine local-oscillator signals generated by an NCO at a frequency of f_L. The output of each mixer is low-pass filtered by a FIR filter in the form of an N-tap delay line with a cutoff frequency of f_c. In the FIR filters, the outputs of the delay elements are multiplied by constant coefficients and summed to obtain the FIR output. The outputs of the FIR filters are sampled at an output clock rate f_o, where $f_o < f_i$ and $f_o \geq 2f_c$. The quadrature (Q) output of the down-converter can be phase-shifted by 90° and added to (or subtracted from) the in-phase output to generate an output in the frequency range 0 to f_c, which is a down-converted version of the upper (or lower, respectively) sideband with respect to the local-oscillator frequency.

Inasmuch as the combined functions of the NCO and mixers are equivalent to multiplication of the input-signal samples by time-varying coefficients, the NCO and mixers could both be eliminated if it were possible to incorporate these coefficients into the multiplication coefficients of the FIR filters. Unfortunately, in the general case, the FIR coefficients would have to be updated every output clock cycle. However, if the local-oscillator frequency is restricted to integer multiples of the output clock frequency, then the local-oscillator coefficients that must be



The **NCO and Mixers are Eliminated** and their functions are implemented in FIR multiplier coefficients in the simplified design.

incorporated into the FIR coefficients are constants because each one always represents the same phase of the local-oscillator signal. With this choice of frequencies ($f_L = nf_o$, where n is an integer) the NCO and mixers can be eliminated without difficulty.

The restriction on the allowable local-oscillator frequencies can be relaxed somewhat if each FIR multiplier is equipped with a coefficient memory so that its coefficient can take on any of m stored values representing one of m phases of the local-oscillator signal, and provided further that each FIR multiplier can cycle through its m stored coefficient values at a rate of f_o. In that case, the local-oscillator frequency can be nf_o/m, where n is any suitable integer. This results in the simplified design shown in the lower part of the figure.

This work was done by Elliott H. Sigman of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 34*** *on the TSP Request Card.*
NPO-19438

Precise Time-Tag Generator for a Local-Area-Network Monitor

Time information is accurate to one microsecond.

Lyndon B. Johnson Space Center, Houston, Texas

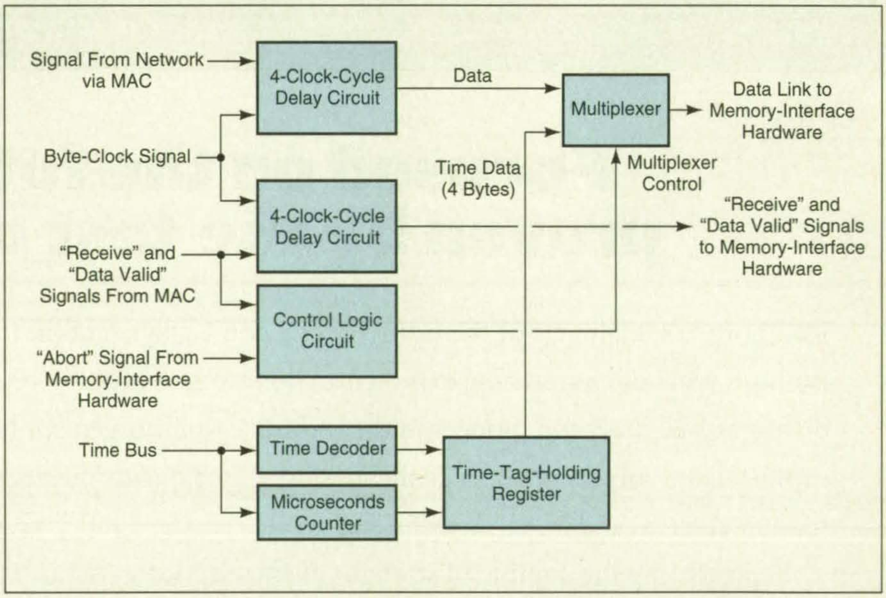
A time-tag-generating circuit has been designed for use in a LAN monitor — a circuit that monitors frames of data transmitted among computers on a local-area network (LAN). Heretofore, LAN monitors have not contained time-tag generators. Instead, time stamps have typically been generated by the communicating computers and have been no more precise than about 1 millisecond. Greater precision is needed for monitoring and analyzing the performances of hardware and software in a complex data-processing system in which a LAN is only one of several interfaces through which computers communicate.

The present time-tag generator offers the needed precision. To each frame of data that the LAN monitor receives from the LAN, the time-tag generator appends ancillary data on the time of arrival of the frame, precise to within 1 microsecond of a centrally generated time signal. This signal is distributed, on a time bus, to the LAN monitor and to other test equipment throughout the facility served by the LAN.

The LAN monitor is connected to the LAN through an interface circuit that includes a media-access-control (MAC) layer, which delimits the LAN signals into frames. The MAC layer also provides a "receive" control signal (which indicates frame reception is in progress) and a "data valid" control signal, which indicates the presence of valid frame data on the MAC output. Other parts of the interface circuit convert the frames into a byte-serial stream and clock the stream, via memory-interface hardware, into a buffer memory in the monitor. As shown in the figure, the time-tag generator includes parts that are inserted in the path between the MAC layer and the memory-interface hardware. The time-tag-generator performs additional processing of the data stream before it reaches local memory interface.

The time-tag generator delays each data-frame stream by four clock cycles. However, because it also delays the "receive" and "data valid" signals from the MAC layer by four clock cycles, the delay is transparent from the perspective of the memory-interface hardware. During these four cycles, four bytes of time information derived from the time signal (these bytes constitute the time tag) are inserted into the stream in place of the four Frame Check Sequence (FCS) bytes; it is possible to do this without losing any data or functionality because the FCS is needed only by the MAC to check for errors, and therefore the FCS is superfluous in subsequent processing.

The insertion of the time tag does not change the overall size of the data frame and thus does not change the minimum interval between frames. This is important for two reasons: (1) Memory-interface hardware typically performs buffer-management functions during this interval, and data would be lost if the interval were allowed to become shorter than the minimum recovery time of the memory-interface hardware; and (2) Because the particular LAN interface circuitry in the original application for which this time-tag generator was devised uses all of the available memory bandwidth during operation at full load, it is not possible to insert a time tag by direct memory access.



The **Time-Tag Generator** inserts ancillary time data in place of already used (and therefore superfluous) frame-check data before the frames of data are stored in the memory of the LAN monitor.

This work was done by David R. Stauffer and Khoa Duy Tran of International Business Machines Corp. for **Johnson Space Center**. *For further information,* ***write in 13*** *on the TSP Request Card.*
MSC-22487

Radar for Measuring Vertical Cloud Structure

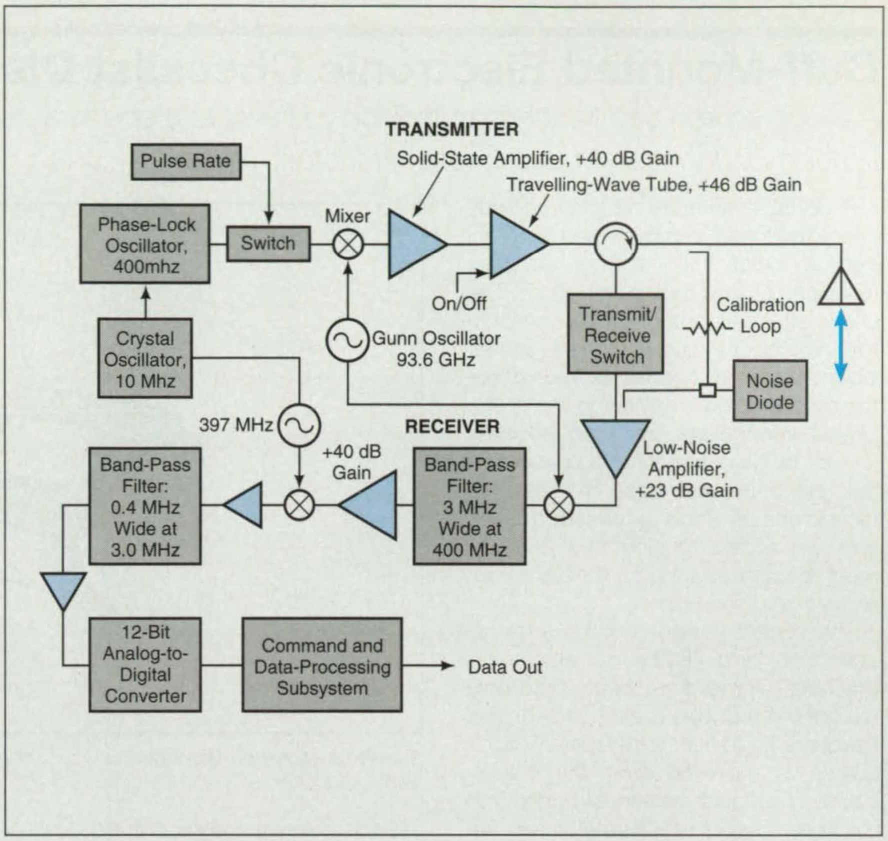
Vertical resolution would be 500 m.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed radar system would view clouds from above and measure their vertical structures with a resolution of 500 m. Operation of the system at frequencies of 35 and 94 GHz was investigated theoretically, and 94 GHz was determined to offer the potential for superior overall performance. At present, the developers envision two versions of the system; an initial developmental version to be flown aboard an aircraft and a final version to be flown aboard a spacecraft in circular orbit around the Earth at an altitude of 400 km.

One important design consideration is to minimize undesired radar returns from the surface of the Earth. Antenna side-lobe levels to minimize these returns were calculated. The preliminary design concept calls for short, uncoded radar pulses, rather than the phase-coded long pulses that are used in some radar systems, to further reduce undesired returns from the surface of the Earth. The use of a scanning antenna was rejected on the same basis because its side lobes could give rise to excessive returns from the ground.

The figure shows the major functional blocks of the system. In the transmitter, a carrier signal at a frequency of 400 MHz would be turned on in pulses 3.33 μs long at a repetition rate of 4.25 KHz. The resulting pulsed signal would be up-converted to 94 GHz. The signal would be amplified, then sent to an antenna through a ferrite circulator. The circulator would serve as a transmit/receive switch, protecting the receiver while pulses from the transmitter were sent to the antenna.



This **Pulse Radar System** would measure the heights of cloud structures below the flying radar platform. According to a preliminary design, the system would have a mass of 108 kg and would consume an average power of 225 W.

During the reception periods between transmitted pulses, the return signal received by the antenna would be routed through the circulator to a 94-GHz low-

For More Information Write In No. 413

noise amplifier in the receiver. The received signal would then be filtered and down-converted through two intermediate-frequency stages. At the second intermediate frequency, the received signal would be sampled by an analog-to-digital converter and sent to a data-processing system for calculation of results.

This work was done by Eastwood Im, Fuk K. Li, Stephen L. Durden, and William J. Wilson of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 27*** *on the TSP Request Card.*
NPO-19495

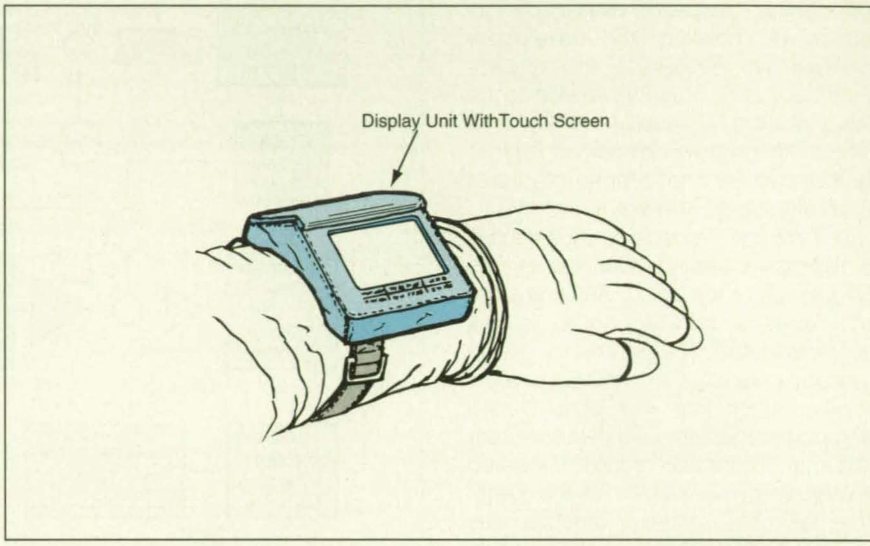
Cuff-Mounted Electronic Checklist Display Unit

A touch screen and liquid-crystal display shows text and pictures.

Lyndon B. Johnson Space Center, Houston, Texas

A portable electronic display unit has been developed to provide text and pictures to guide users through complex technical procedures in the field. The unit is strapped onto the user's wrist in the manner of a wristwatch (see figure), leaving the user's hands free to carry out the procedures while referring to the displayed information. Intended originally for use by an astronaut in a space suit, the unit could also ease the tasks of technicians on Earth by providing quick and easy access to information, without need to carry and thumb through massive service manuals.

The current design contains a microcontroller and 2MB of electrically erasable, programmable, read-only memory. The display is a 320 x 240-pixel liquid-crystal device. A transparent touch screen is mounted over the display device. The touch screen is divided into six areas; touching each area causes the display of a specific menu or page, or could activate an electronic stopwatch.



The **Wrist-Mounted Display** Unit would make available about 800 pages of text and illustrations. A touch screen would facilitate access to desired pages, even with a heavily gloved hand.

The unit is powered by 10 commercial alkaline AA battery cells, which provide somewhat more than 20 hours of operation. The total weight of the entire assembly is about 2.5 lb. (1.14 kg). The unit contains a heater to keep the display device warm enough for operation in cold environments.

Information and operating code for the display unit is compiled and organized by use of a personal computer, to which the unit would be connected for this purpose. The information to be displayed can be updated and otherwise changed as needed via the computer, as demonstrated during a recent flight experiment.

This work was done by Jose A. Marmolejo and Richard Fullerton of **Johnson Space Center,** *and Paul Cottingham, Chen-Hsiang Chen, and Charles Shepherd of Lockheed Engineering & Sciences Co. For further information,* ***write in 5*** *on the TSP Request Card. MSC-22403*

Computing Thickness of Sea Ice From Polarimetric SAR Data

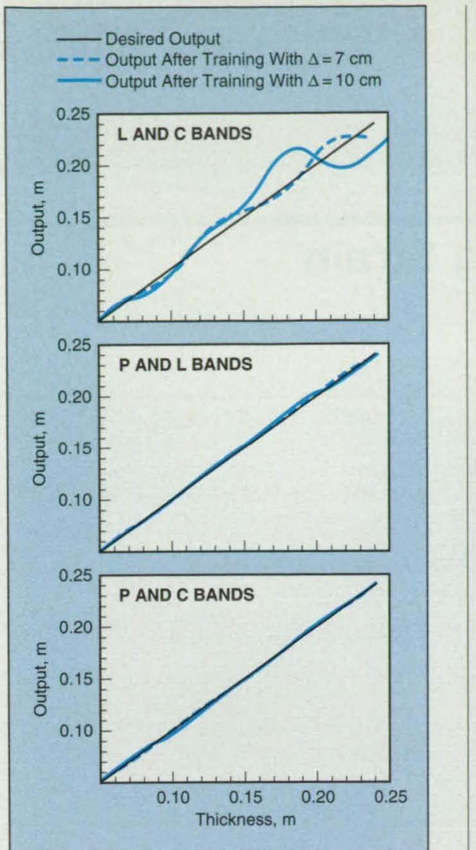
A neural network computes fairly accurate thicknesses from simulated SAR scattering coefficients.

NASA's Jet Propulsion Laboratory, Pasadena, California

An artificial neural network has been developed for computing the thickness of sea ice from polarimetric synthetic-aperture-radar (SAR) data. Once the neural network is trained, no further intervention is needed: when stimulated with SAR scattering data, it quickly responds with an estimate of the thickness of sea ice. This is an important development because there has long been a need for a method of remote measurement of the thickness of sea ice for studies of the ice itself and of the fluxes of heat from polar regions.

The neural network is of the multilayer perceptron type, with one output node (output neuron), a second hidden layer containing 30 nodes, a first hidden layer containing 10 nodes, and an adjustable number of input nodes. Each input node receives one of the polarimetric SAR scattering coefficients, which express the amplitude and phase relationships among the incident and scattered horizontally and vertically polarized components of the radar signal. There are five independent SAR scattering coefficients for each operating frequency. Thus, for example, five input nodes are used to process single-frequency polarimetric SAR scattering data, or 10 input nodes for two-frequency data.

Because of a lack of experimental data, the neural network was initially trained and tested with SAR scattering data computed from a mathematical



The **Outputs of the Neural Network** (estimates of the thickness of sea ice) are plotted here along with the desired outputs, which are the thicknesses used in the mathematical model to compute the input test data.

model of sea ice. The model incorporates the known dielectric properties of ice and sea water and the known geometry of brine inclusions within the ice. To make the training and testing more nearly realistic by incorporating effects of variations in ice thickness, the input data of the training set for each nominal thickness d were computed by averaging the model-generated data over a range of thicknesses from $d-\Delta/2$ to $d+\Delta/2$.

The figure shows the actual and desired responses of the neural network for one- and two-frequency sets of input data after training with model data averaged with Δ values of 7 and 10 cm. The average error for $\Delta = 7$ cm was < 5 percent, while that for the 10 cm case was ≈ 10 percent. Even better results were obtained when the neural network was trained with three-frequency sets of data (P, L, and C bands): for both values of Δ, the average errors were about 2 percent or less.

This work was done by Dave D. Huynh, Simon H. Yueh, Son V. Nghiem, and Ronald Kwok of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 40*** *on the TSP Request Card.*
NPO-19343

X-Ray Moiré Techniques for Measuring Strain

Distributions of strains in hidden locations can be measured.

Langley Research Center, Hampton, Virginia

An x-ray moiré method provides for measurement of strains throughout relatively large regions and in locations that are invisible or that are inaccessible to measurement by other techniques. For example, the x-ray moiré technique can be used to measure strains between layers of material in rubber tires. The method exploits the body of knowledge already developed for optical moiré measurement of strains.

The x-ray moiré method offers advantages over optical methods of measuring strains within the depths of objects, in that x-ray imaging is not restricted to optically transparent materials. The x-ray moiré method also offers advantages over the strain-gauge method in that gauge wires are not needed and measurements are not limited to discrete gauge points.

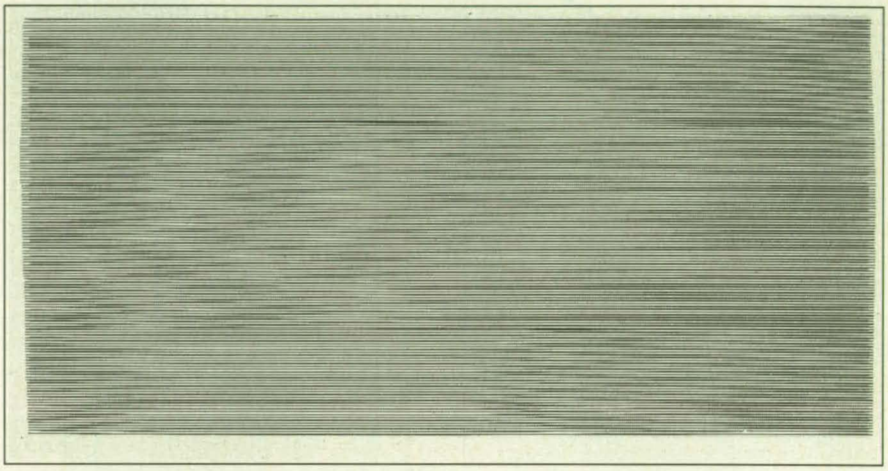


Figure 1. **Parallel Wires** 0.005 in. (≈0.13 mm) in diameter and spaced 0.020 in. (≈0.51 mm) apart were embedded in a matrix of room-temperature-vulcanizing silicone rubber.

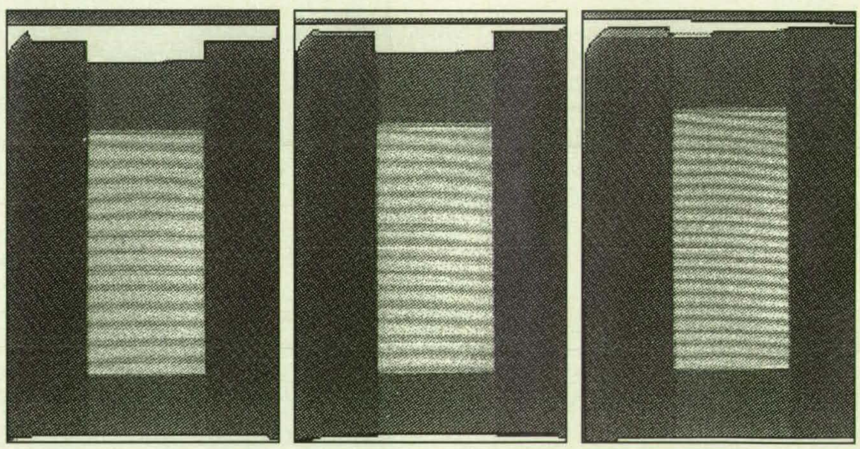


Figure 2. The **Differences Between Successive Moiré Patterns** show differences between strains at three levels of tensile loading of a strip of rubber to which a grid of wires was attached.

In preparation for a typical application of the x-ray moiré method, a radiopaque material arranged in a grid or line pattern is attached to the surface of the strain specimen. Alternatively, if the specimen is made by casting a monomer and then polymerizing it, the radiopaque material can be embedded in the specimen at or before the time of casting (see Figure 1). In the case of a tire, the internal belts could constitute the test grid.

When the specimen is strained, an x-ray photograph or electronic image is made in the usual way. Being radiopaque, the wires show up in the x-ray image, and any distortion in the line or grid pattern of the wires can serve as a measure of strain in the material in the immediate vicinity of the wires.

To enable extraction of information on the distortion of the wire pattern, it is necessary to provide a grid pattern or a second pattern of lines or dots to superimpose upon, or through which to view, the wire pattern in the x-ray image. In this aspect, the method adapts nicely to computer analysis: The pixel pattern or scan lines of a video camera used in digitizing the x-ray image or, alternatively, a pattern of lines or dots generated by digital processing could serve as the second pattern.

In any event, the combination of the two patterns yields a moiré pattern, which varies with the distortion of the wires (see Figure 2). To obtain quantitative data on the distribution of distortion and thus of strain, the moiré pattern is analyzed by established moiré-analysis techniques, with a few simple modifications and straightforward corrections for differences between the geometries of optical and x-ray imaging.

This work was done by Eric Irvine Madaras of **Langley Research Center.** *No further documentation is available.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center; (804) 864-3521. Refer to LAR-15104.

Temperature Measurements Reveal Accretion of Ice on Airfoils

Release of latent heat of fusion gives rise to a characteristic gradient of temperature.

Lewis Research Center, Cleveland, Ohio

A method of detecting the accretion of ice on an airfoil is based on measurement of a difference between the temperatures at icing and nonicing locations on the airfoil. The temperature at a nonicing location is usually close to ambient temperature, while the temperature at an icing location is slightly higher because the freezing process releases latent heat of fusion. The temperatures and the difference between them can be measured by use of contact sensors (e.g., thermocouples) or a remote sensor (infrared detector). The measurements can be used to trigger alarms and/or deicing equipment.

The method is intended especially for detecting accretion of ice on a helicopter rotor. Because of the difficulty of instrumenting a helicopter rotor, remote sensing would be preferable in this application. As shown in Figure 1, an infrared detector could be mounted on a helicopter fuselage facing up toward the rotor, with its lens adjusted to focus on the plane of the rotor.

The infrared detector could be a mercury cadmium telluride device maintained at a temperature of about 200 K by a thermoelectric cooler. The peak spectral response of a mercury cadmium telluride infrared detector lies in the wavelength range of 2 to 5 μm, which represents an engineering compromise between available detector performance (which is better at shorter infrared wavelengths) and the wavelength of the peak of the black-body-radiation spectrum at temperatures of interest (about 10 μm at 0 °C).

The output signal of the detector would be amplified, high-pass filtered to remove any dc bias and retain only the short-term-change signal components, and digitized. To provide a time reference for correlation of the detector output with position along the chord of the rotor blade, the digitizing circuitry would be triggered by an optoelectronic subsystem that would detect the passage of the blade through the focal point of the infrared detector.

Typically, icing occurs at or near the stagnation point on the leading edge of an airfoil, and not at the trailing edge. Thus, icing can be detected in terms of an increase in temperature as the leading edge crosses the focal point of the detector, followed by a decrease toward the trailing edge (see Figure 2). In practice, a resolution of about 0.2 °C in measurement of the differential temperature between leading and trailing edges is achievable and is sufficient for detecting accretion of ice if the design of the specific rotor airfoil is such that only leading-and trailing-edge measurements are needed.

This work was done by Robert J. Hansman, Jr., and Adam Lee Dershowitz of Massachusetts Institute of Technology for **Lewis Research Center.** *For further information,* ***write in 53*** *on the TSP Request Card.*
LEW-15639

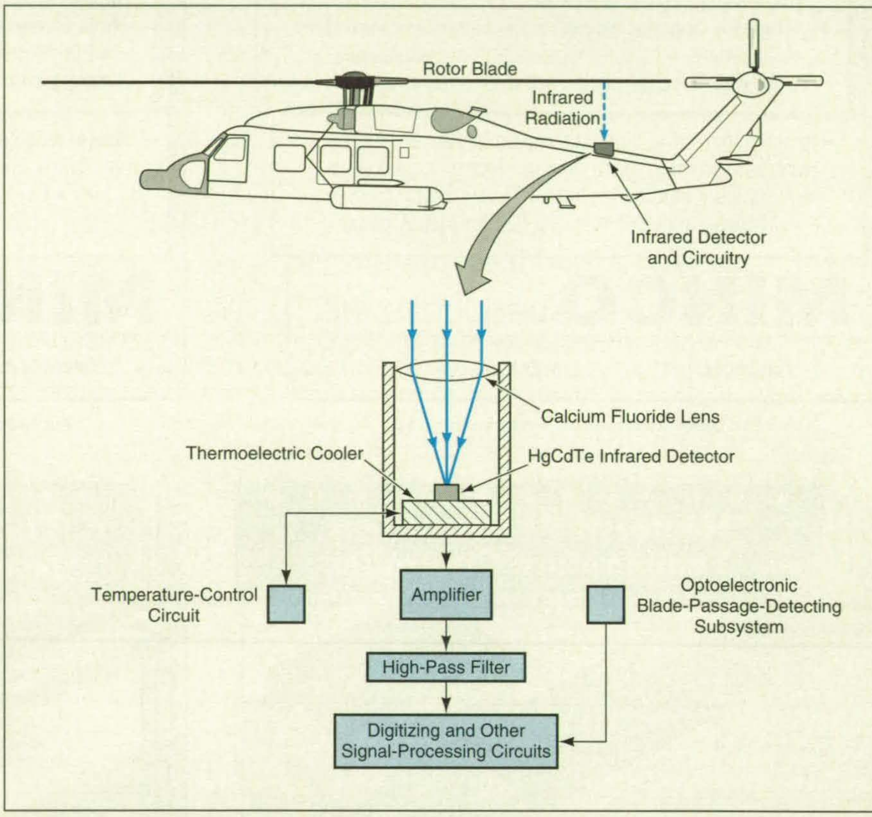


Figure 1. An **Infrared Detector Would Be Focused** at a point on the plane of the rotor to measure the instantaneous temperatures at passing surface points on the rotor blade.

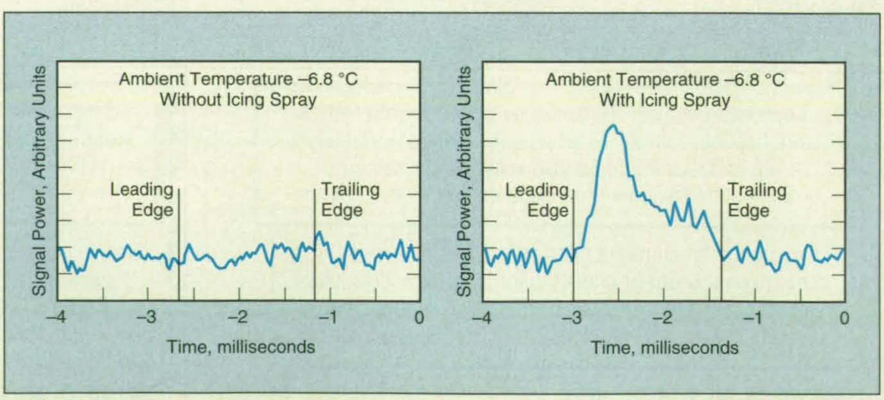


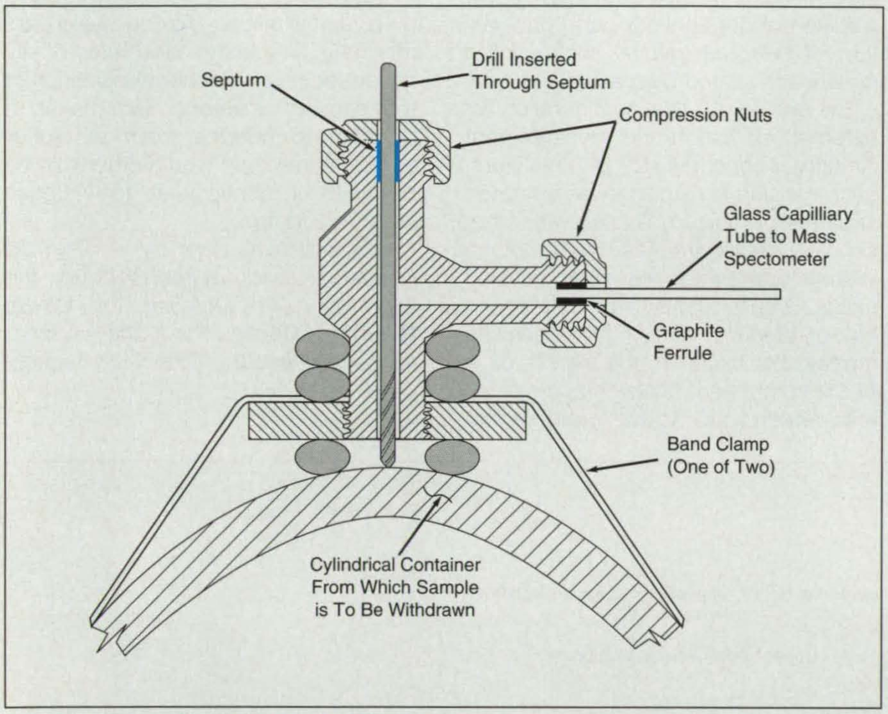
Figure 2. These **Digital-Oscilloscope Traces** represent the processed outputs of the detector in a prototype of the system of Figure 1 under some icing and nonicing conditions in a test on a model rotor in a laboratory freezer. Note the increases in temperature near the leading edge under icing conditions.

Fixture for Sampling Volatile Materials in Containers

A sealing T-connector provides for analysis without exposure to the atmosphere.

Marshall Space Flight Center, Alabama

A fixture based on a T-connector enables mass-spectrometric analysis of the volatile contents of cylindrical containers without exposing the contents (gas or liquid) to ambient conditions. The fixture can be used to sample the volatile contents of pressurized containers, the contents of such enclosed processing systems as gas-phase reactors, gases in automotive emission systems, and gas in hostile environments.



The **Fixture for Sampling Volatile Materials** is clamped onto a cylindrical container. It is used to drill a hole in the container to draw off gases for analysis.

As shown in the figure, the ends of all three arms of the T-connector are threaded. The threaded end of the bottom arm of the T-connector is screwed into a tapped hole in an aluminum plate 1/8 in. (3.2 mm) thick. The end of the top arm of the T-connector contains a formed septum held in place by a compression nut. The horizontal is fitted with a graphite ferrule that holds one end of a glass capillary tube.

The fixture is attached via band clamps (hose clamps) to the cylindrical container, the contents of which are to be analyzed. The clamps press the aluminum plate and the bottom arm of the T-connector against the container. O-rings are used to seal the plate to the body of the T-connector and to the container. The strength of the O-ring seal determines the limits of pressure that can be tolerated.

In preparation for taking a sample for analysis, the capillary tube in the horizontal arm of the T-connector is connected to the intake port of a mass spectrometer, and a vacuum is formed in the T-connector. A background mass spectrum from the fixture is obtained. Then a drill is inserted through the septum in the top arm of the T-connector and is used to make a hole in the cylindrical container. Material from inside the container then passes into the tee and out the capillary tube to the mass spectrometer for analysis.

This work was done by Donald Melton and Earl Howard Pratz of Martin Marietta Corp. for **Marshall Space Flight Center.** *For further information,* ***write in 96*** *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; (205) 544-0021. Refer to MFS-28843.

Improved Solid-State Microanemometer

Structural rigidity is combined with optimum sensing capability and versatility.

Lewis Research Center, Cleveland, Ohio

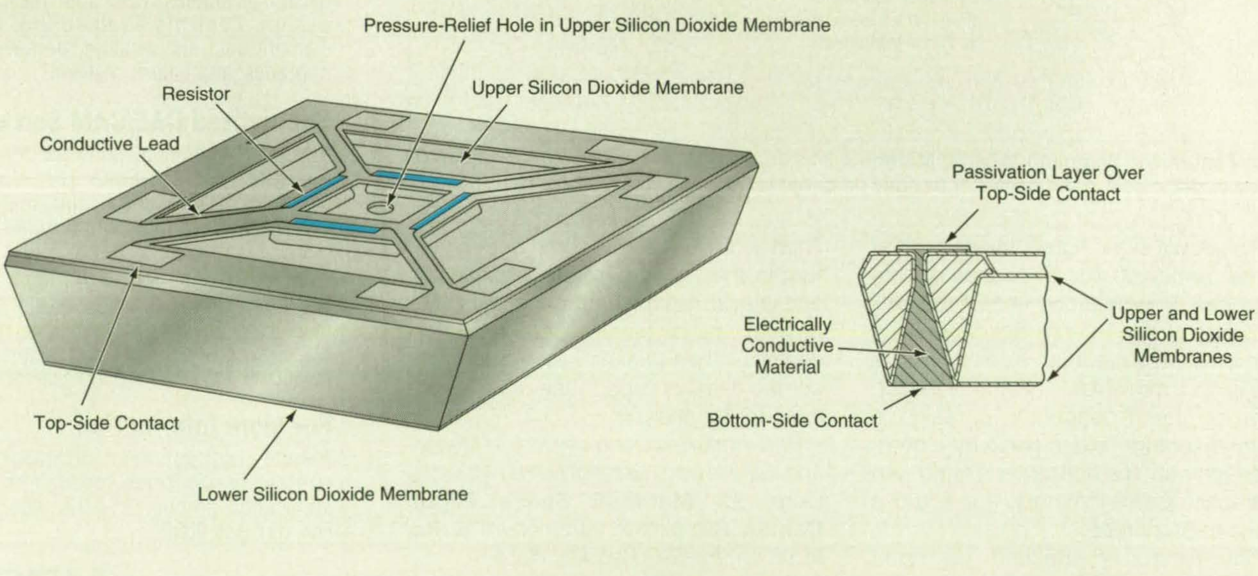
The figure illustrates an improved solid-state (that is, semiconductor) microanemometer that is suitable for measuring flows in a variety of biomedical, industrial, and other applications. This device includes four integral sensing resistors that are exposed to the flow to be measured and that serve as hot-film anemometer subunits: the electrical resistance of a subunit varies with the degree of cooling induced by the flow and is thus indicative of the flow velocity. The sensing resistors can be connected to external excitation-and-measurement circuits that operate in any of the standard hot-film-anemometer modes; constant input voltage, constant input current, or constant resistance with feedback.

The small size, unique design, and one-piece construction of this microanemometer provide a combination of short response time, structural rigidity, optimal dissipation of heat, and versatility in application. The microanemometer is made from a single crystal of silicon that has been initially doped with deep-level impurity (gold) atoms to a density of about 10^{15} cm^{-3} to provide increased sensitivity via an exponential relationship between the concentration of free charge carriers and temperature. The crystal is also preferably counter-doped with phosphorus atoms to a density of about 5×10^{14} cm^{-3}. After doping, the crystal is thermally oxidized to create silicon dioxide layers on the surfaces. Thereafter, the crystal is micromachined to the required geometric, electrical, and material configuration in a sequence of processing steps that include etching, oxidizing, deposition, diffusion of dopants into, and passivation of selected various parts of the crystal designated by masks.

By choice of the configuration of external excitation-and-measurement circuitry connected to the resistors, each sensing resistor can be operated separately or in combination with other sensing resistors as part of a Wheatstone bridge or other sensing circuit. Consequently, the device can be operated in a variety of flow-sensing modes. For example, the sign (+ or –) of the component of flow along a given axis perpendicular to two resistors that are parallel to each other can be determined by use of a differential measurement mode to compare the current, voltage, or resistance readings of the two resistors. This measurement yields the sign because the flow cools the upstream resistor slightly more than it cools the downstream resistor.

This versatility is made possible by the unique micromachined structure, in which the sensing resistors are thermally and electrically isolated from each other and substantially thermally and electrically isolated from the rest of the structure. The isolation is provided by layers of silicon dioxide, which are thermally insulating and electrically nonconductive. The thermal isolation of the sensing resistors also makes it possible to operate them at higher temperatures than would otherwise be possible or convenient, to increase sensitivity to flow.

This work was done by H. Thurman Henderson and Walter Shieh of the University of Cincinnati for **Lewis Research Center.** *For further information, **write in 22** on the TSP Request Card. LEW-15172*



This **Microanemometer** is fabricated by micromachining a single crystal of silicon. Its characteristics include improved response time, structural rigidity, optimal dissipation of heat, and versatility in application. The use of bottom-side contacts increases structural rigidity and eliminates the need for wire contact leads that could excessively perturb the measured flow.

Preheating Water in the Covers of Solar Water Heaters

Efficiencies would be increased.

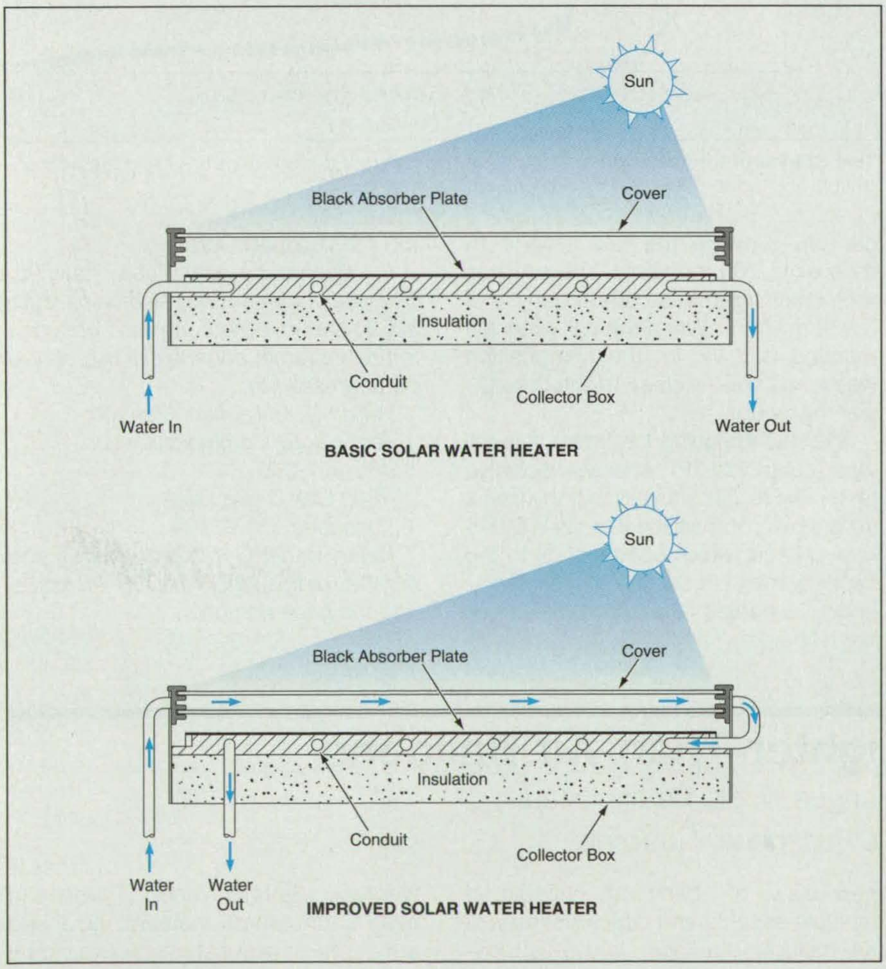
NASA's Jet Propulsion Laboratory, Pasadena, California

Solar water heaters that include glass covers over absorber plates can be redesigned to increase their efficiencies, according to a proposal. A typical redesign would include modification of a single-layer glass cover into a double-layer glass cover and the addition of plumbing so that the cool water to be heated could be made to flow between the layers of the cover before entering the absorber plate (see figure).

Reradiation and convection from the absorber plate, plus some direct absorption from incident sunlight, result in parasitic heating of the cover. For the basic solar water heater nothing is done about this parasitic heating, and most of the heat absorbed by the cover is lost to the environment by convection and radiation. In the improved design, the parasitic heating effect is used to preheat the water. Some of the heat that would otherwise be lost is recovered and the net result is an increase in the overall solar-heat-absorption efficiency.

The solar water heater would operate most efficiently when the temperature of the water entering the cover was close to or below the ambient temperature. Seals at the edges of the cover should be designed to accommodate thermal expansion of the cover layers. The flow of water in the cover layers should be kept laminar because turbulence could contribute to undesired scattering of incoming solar radiation.

This work was done by Pradeep Bhandari of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 86*** *on the TSP Request Card. NPO-19142*



In the **Improved Solar Water Heater**, cool water would be preheated during flow between inner and outer glass layers of a cover. The preheated water would then flow, as in a basic solar water heater, through a serpentine conduit in a black absorber plate.

Increasing the Lithium Capacity of a Carbon Electrode

Lithium can be intercalated into carbon up to the theoretical maximum concentration.

NASA's Jet Propulsion Laboratory, Pasadena, California

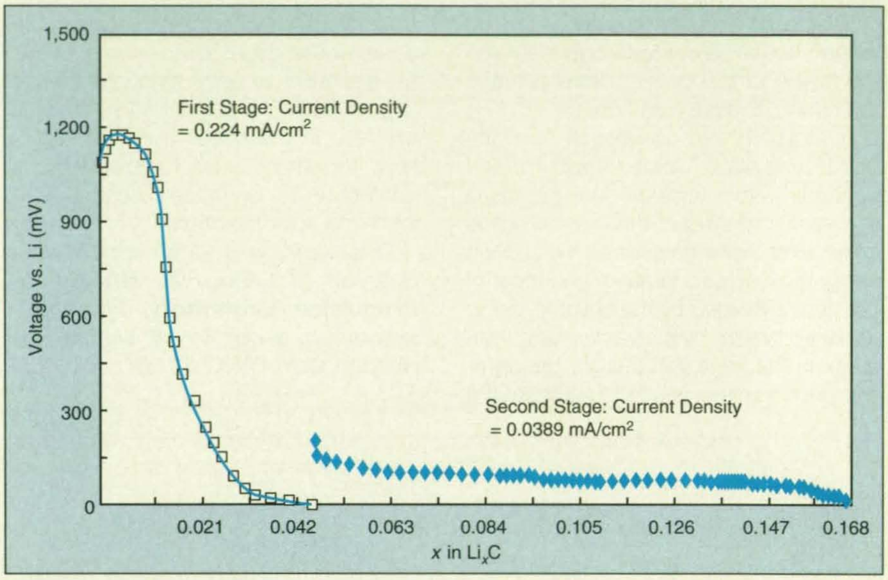
Two techniques of electrochemical intercalation have been found to increase the lithium capacity of an electrode made of commercial graphitic carbon. Carbons of various kinds have been investigated for use in lithium-bearing anodes (instead of pure lithium anodes) in rechargeable lithium cells. Although carbon has the desired properties (low weight, low voltage vs. lithium, and chemical stability in the presence of electrolytes), intercalation of lithium into carbon is not a trivial problem. Some prior research had focused on the use of special carbon materials that exhibit maximum reversible lithium capacity; but until now, it was not known how to intercalate lithium into commercially available carbon to achieve maximum theoretical capacity. The useful range of lithium concentrations in commercial carbon was also not known.

The two techniques for increasing the lithium capacity of a carbon electrode were discovered in charge/discharge measurements on an electrochemical cell of the configuration

(–) Li/[(1.5M $LiAsF_6$ in 10 percent ethylene carbonate) + (90 percent 2-methyl tetrahydrofuran)]/Li_xC (+)

In the first technique, the cell was initially discharged (that is, lithium was allowed to intercalate into the carbon electrode) at a constant current density of 0.28 mA/cm^2. When the cell voltage reached zero vs. Li, the current was cut off, allowing the cell voltage to rise to its open-circuit value of 1.6 V vs. Li. The cell was again discharged at constant current; this procedure was repeated for a total of four discharges. After the fourth discharge, it was found that lithium could be intercalated into the carbon electrode at nearly the maximum theoretical composition of $x = 1/6$.

The second technique was similar to the first except that it involved two discharges at different currents. The cell was first discharged at a constant current of 0.224 mA/cm^2 until it reached 0 V vs. Li, at which point the composition was $Li_{0.045}C$. The current was then cut off, allowing the cell voltage to recover to 200 mV vs. Li. The cell was then discharged at a current density of 0.389 mA/cm^2. When the cell potential reached 0 V vs. Li, the composition was $x = 0.166$ — close to the theoretical maximum.



Two Stages of Intercalation of Li into C at two different current densities bring the concentration of Li up to nearly the theoretical maximum of $x = 1/6$.

After the foregoing treatment, the cell was subjected to charge/discharge tests. The results showed that the useful (reversible) compositional range is $0.045 < x < 0.166$, which corresponds to the capacity range of second-stage intercalation, whereas the unusable (irreversible) compositional range is $0 < x < 0.045$, which corresponds to the first stage of intercalation.

This work was done by Chen-Kuo Huang, Subbarao Surampudi, Alan I. Attia, and Gerald Halpert of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 113*** *on the TSP Request Card.*

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

William T. Callaghan, Manager
Technology Commercialization
JPL-301-350
4800 Oak Grove Drive
Pasadena, CA 91109

Refer to NPO-18822, volume and number of this NASA Tech Briefs issue, and the page number.

Substances To Fill Lighter-Than-Air Balloons

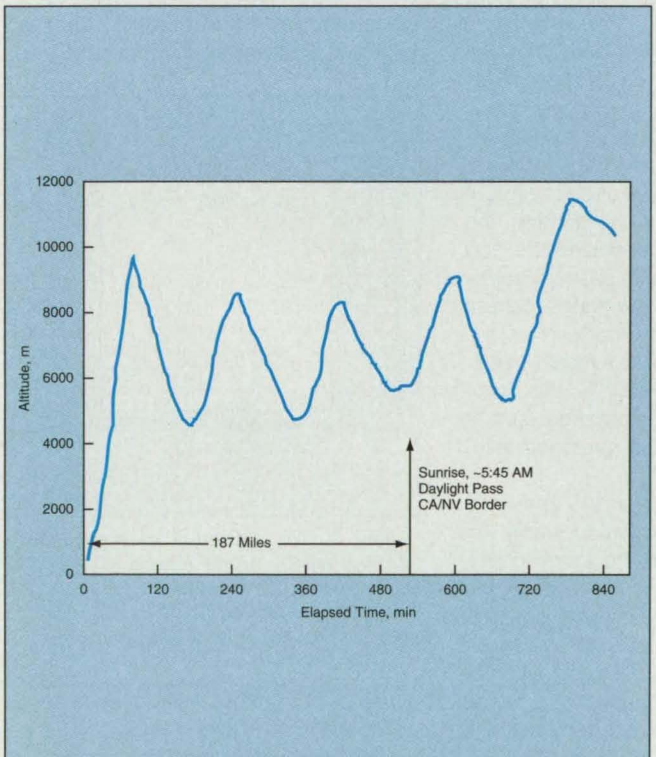
Chemical reactions and phase changes would be exploited.

NASA's Jet Propulsion Laboratory, Pasadena, California

Various combinations of solid and liquid chemicals have been proposed as sources of hydrogen and other gases for inflating lighter-than-air balloons. In the original intended application, the balloons would represent a new class of spacecraft capable of multiple ascents and descents, as well as multiple landings, in the atmosphere of Venus. The same technology could be used to explore the atmospheres of Jupiter, Saturn, Uranus, Neptune, Saturn's moon (Titan), and even Earth, where meteorological and atmospheric pollution studies could be performed at multiple altitudes with a single balloon. In all cases the energy used to propel the balloon upward or downward comes from temperature differences in the planet's atmosphere itself. Phase changes and/or reversible chemical reactions could be used to vary quantities of gases in balloons as functions of pressure and temperature and, thus, as functions of altitude: this capability would provide means to control the altitude of a balloon. For example, an unfilled balloon launched from an aircraft or spacecraft could be allowed to descend until the increase in temperature with decreasing altitude initiated a chemical reaction that released hydrogen gas, preventing further descent. For another example, to make a balloon oscillate between higher and lower altitudes, a lightweight metal hydride could be alternately heated at lower altitudes, then cooled at higher altitudes to desorb, then absorb hydrogen.

Yet another example involves the use of a fluid that condenses or vaporizes at a specific altitude to form a liquid or a heavier-than-air gas, respectively. In this example, a primary lifting balloon would be filled with hydrogen or helium. A secondary, height-controlling balloon would contain a substance such as methylamine or R114 ($CClF_2$ $CClF_2$), which are gases at the surface of the Earth but condense at an altitude of about 6 – 7 km. Although the density of these vapors exceeds that of air, its increased volume (over that of the liquid) would displace additional air and cause the vehicle to be more buoyant. If the condensed fluid was trapped in a pressure vessel by a valve, the balloon could then descend to the surface, and later lift off when the valve is opened.

This work was done by Jack A. Jones of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 283*** *on the TSP Request Card.* *NPO-19223*



Actual Flight Data of a helium balloon with a secondary balloon of R114 fluid shows bobbing occurring at an altitude of about 7 km. The R114 condenses above 7 km, creating less lift, and it evaporates below 7 km, creating more lift.

$Ni/NiCl_2$ Reference Electrodes for $Na/NiCl_2$ Cells

Advantages of $Ni/NiCl_2$ include simplicity of construction, stable potential, and durability.

NASA's Jet Propulsion Laboratory, Pasadena, California

Reference electrodes made of nickel cores with surface layers of nickel chloride have been proposed for use in molten sodium tetracholoroaluminate electrolytes in experimental sodium/nickel chloride electrochemical cells. These and other sodium/metal chloride cells have been investigated for use in several applications, including powering electric vehicles and leveling loads in power-distribution systems. In comparison with the aluminum electrodes used heretofore, the proposed nickel/nickel chloride electrodes offer potential advantages of greater durability, greater stability and reproducibility of electrochemical potentials, less sensitivity of electrochemical potentials to variations in compositions of electrolytes, and greater compatibility with the cathodes, which are made of nickel chloride.

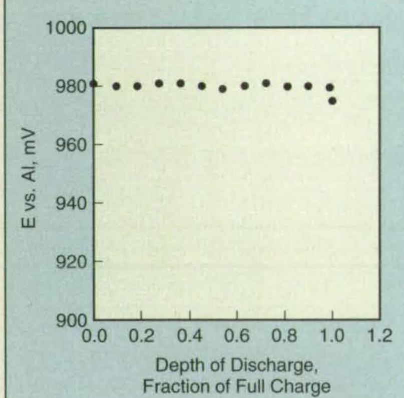


Figure 1. The **Variation of Potential** of a $Ni/NiCl_2$ reference electrode with its state of charge (or, equivalently, with the thickness of the $NiCl_2$ layer) is very small until discharge is nearly complete (until the layer nearly reaches zero thickness).

A sodium/metal chloride cell comprises a molten sodium anode, a separator made of sodium β″ alumina (a solid electrolyte), the molten electrolyte, and a cathode made of a transition-metal chloride. One of the characteristics that a metal chloride must have to perform successfully as a cathode material is its insolubility in the molten sodium tetracholoroaluminate electrolyte. Of the various metal chlorides examined, nickel chloride appears to be the least soluble in the basic chloroaluminate melt. Previous research has shown that a nickel electrode that has been slightly anodized exhibits stable and reproducible potentials in sodium chloroaluminate melts that contain various concentrations of chloride ions (incorporated via NaCl and $AlCl_3$ impurities). It has been conjectured that anodizing forms a thin layer of $NiCl_2$ on the surface of the Ni. The insolubility of the nickel chloride would thus enable the use of an anodized nickel electrode to obtain stable potential independent of the amount of $NiCl_2$ on the surface.

Nickel/nickel chloride electrodes also have large exchange-current densities, which enable them to function as depolarizable electrodes. Large exchange-current density is one of the requirements for a reference electrode; without a large exchange-current density, the electrode can become polarizable and may even fail to attain its proper equilibrium potential. The exchange-current density for a $NiCl_2$ electrode is of the order of 10^{-3} A/cm^2 at a typical operating temperature of ≥ 250 °C; this compares well with the exchange-current densities of a hydrogen reference electrode on platinum.

A nickel/nickel chloride reference electrode can be fabricated easily by electrochemically oxidizing a high-purity, polished nickel wire immersed in the electrolyte to form a few layers of nickel chloride on its surface. The wire electrode can typically be charged to a chloride layer with a thickness of 5.5 μm (which corresponds to the area specific capacity of 2.88 C/cm^2 at 220 °C) before a voltage inflection begins. The potential of the electrode is 950 mV vs. Na^+/Na at 250 °C. Also, the potential is stable (within 1 mV) and invariant (within 1 mV) with the state of charge (or, equivalently, the thickness of the $NiCl_2$ layer) (see Figure 1). Its potential measured against an aluminum reference electrode increases with temperature at a rate of 0.26 mV/°C. Against a Na^+/Na electrode — that is, an $Na/NiCl_2$ cell — its potential has a negative temperature coefficient of –0.233 mV/°C (see Figure 2).

The durability of a nickel/nickel chloride reference-electrode material has been demonstrated in basic electrochemical studies on metal chloride cathodes, some lasting months. For example, ac-impedance data on a 2-Ah $Na/NiCl_2$ cell subjected to 100 charge/discharge cycles for four months were found to be highly reproducible and free of scatter when the $Ni/NiCl_2$ electrode was used. A nickel/nickel chloride reference electrode can be reconditioned by electrochemical oxidation, if necessary, to ensure the presence of $NiCl_2$ on its surface.

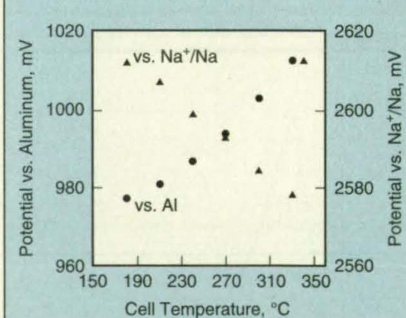


Figure 2. **The Potential of the $Ni/NiCl_2$ Reference Electrode** against an Al reference electrode increases with temperature, while its potential vs. an Na+ electrode decreases with temperature.

This work was done by Ratnakumar Bugga, Alan Attia, and Gerald Halpert of Caltech for **NASA's Jet Propulsion Laboratory***. For further information,* ***write in 279*** *on the TSP Request Card.* *NPO-19179*

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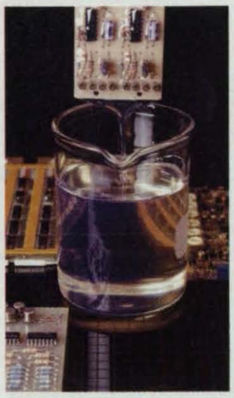

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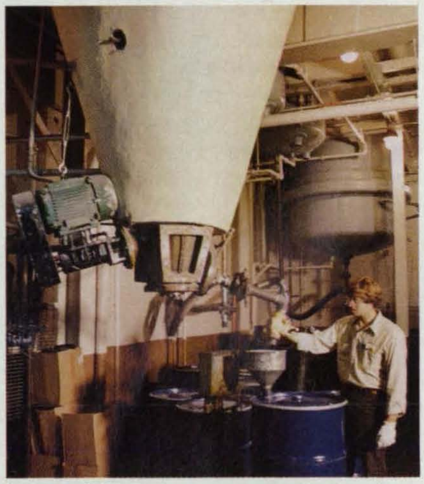

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Transition-Metal Additives for Long-Life $Na/NiCl_2$ Cells

These additives alleviate fading of capacity.

NASA's Jet Propulsion Laboratory, Pasadena, California

Transition-metal additives in the cathodes of $Na/NiCl_2$ high-temperature, rechargeable electrochemical cells have been found to slow a premature fading of charge/discharge capacity. The decline in capacity of such a cell has been attributed to the agglomeration of Ni particles at the cathode: this agglomeration reduces the electrochemical area of the cathode. The addition of sulfur alleviates the premature fading of capacity almost completely, but also gives rise to corrosion and other adverse effects.

The investigation of transition metals as alternatives to sulfur was inspired, in part, by the observation that there is no agglomeration of Fe particles or premature loss of capacity in $Na/FeCl_2$ cells. On the other hand, $FeCl_2$ cathodes, especially those that contain Ni as an additive for overcharge protection, exhibit increased porosity after cycling. It follows that addition of Fe should alleviate the agglomeration of Ni and the concomitant loss of capacity in $NiCl_2$ cathodes. Other transition metals should also exert this beneficial effect. These transition-metal additives would also oxidize during charging, forming mixed chlorides. Depending on the choice of transition-metal additive for a particular cell, the additive might even participate in the desired electrochemical reactions in the cell, thus contributing to the specific energy of the cell.

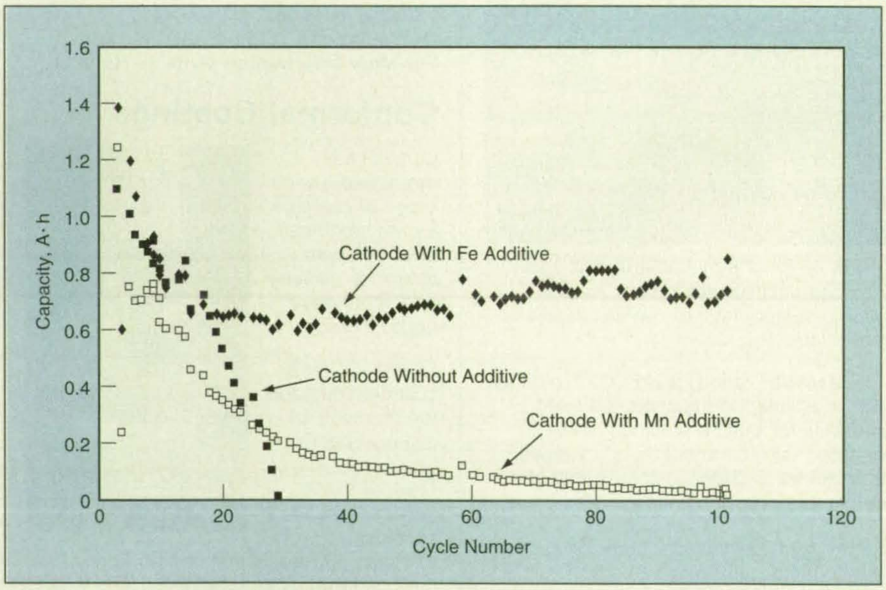
In preparation for experiments to test this concept, cathode electrode bodies that contained 90 weight percent nickel plus, variously, 10 weight percent of cobalt, manganese, or iron, were fabricated by sintering under conditions similar to those for making nickel (only) cathode bodies for $NiCl_2$ cathodes. Because the potentials of the chlorides of Co, Mn, and Fe are lower than that of $NiCl_2$, these metals could be chlorinated during charge, to form mixed-chloride cathodes. It was theorized that uniform dispersions of the additives in the cathode matrices might prevent agglomeration of nickel particles and maintain the microstructures, thereby maintaining the capacities of the cathodes.

Data from charge/discharge measurements were performed on 2-A•h cells constructed with these cathodes and one with a $NiCl_2$ (no additive) cathode. The cells that contained the additives retained their capacities somewhat better than the no-additive cell did (see figure). In addition, the additives underwent reversible electrochemical reactions in the potential range of 2.0 to 3.0 V, thus contributing to the charge/discharge capacities and energy densities, which otherwise would have decreased. The cell that contained cobalt failed prematurely, possibly because of a failure of its solid electrolyte.

The beneficial effect of the metal additives is not as prominent as is that of sulfur. Nevertheless, it may be possible to combine the addition of transition metals to cathodes with the addition of sulfur to electrolytes to obtain a synergistic beneficial effect on the microstructure and, thus, the retention of capacity of $NiCl_2$ cathodes during charge/discharge cycling.

This work was done by Ratnakumar V. Bugga, Subbarao Surampudi, and Gerald Halpert of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 18*** *on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office–JPL; (818) 354-5179. Refer to NPO-19200.



The **Charge/Discharge Capacities** of all the cells faded, but that of the cell containing the cathode without additive declined most rapidly.

Supertough Stainless Bearing Steel

Fracture toughness exceeds that of any other bearing steel.

Marshall Space Flight Center, Alabama

The composition and processing of a supertough stainless bearing steel were designed with the help of computer-aided thermodynamic modeling. The fracture toughness [typically, 47 $MPa(m)^{1/2}$] and hardness (60.4 Rockwell C) of this steel exceed those of other bearing steels like 440C stainless bearing steel (see figure). The steel was developed for service in fuel and oxidizer turbopumps on the Space Shuttle main engine. Because of its strength and toughness, it may also prove useful in other applications like gears and surgical knives.

This steel is significant not only because of its unique mechanical properties but also because it is a prototype product of an emerging interdisciplinary, systems approach to the design of materials from specifications and first principles: In this approach, the steel or other material is regarded as a system of interdependent processing, structure, and property subsystems. The composition selected by this approach for this particular steel is 56.15 Fe/22.5 Co/12 Cr/8.5 Ni/0.3 Mo/0.25 V/0.30 C (numbers indicate weight percentages). The carbon content was chosen to obtain the required hardness, while the chromium content was selected for resistance to corrosion. The molybdenum and vanadium contents were chosen to maximize nucleation of desired metal carbides (M_2C) while limiting undesired metal carbides (M_6C). The nickel and cobalt contents were determined by requiring a specific amount of austenite to be stable at tempering temperatures. The thermodynamic stability of the precipitated austenite at room temperature was optimized to enhance transformation toughening.

This work was done by Gregory B. Olson of Northwestern University for **Marshall Space Flight Center**. *For further information,* ***write in 110*** *on the TSP Request Card.*

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

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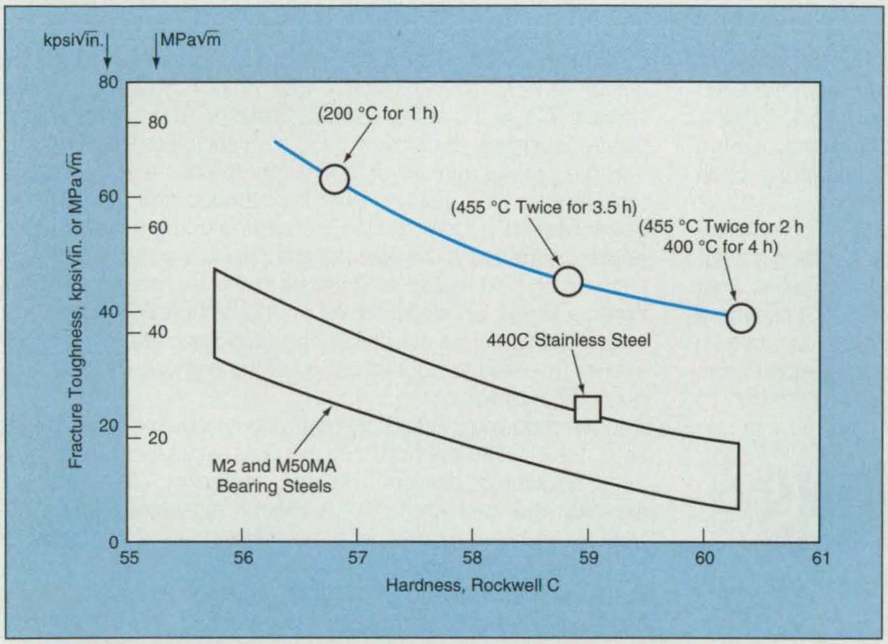
Refer to MFS-26233, volume and number of this NASA Tech Briefs issue, and the page number.



The **Toughness of the Designed Stainless Bearing Steel** exceeds that of several other bearing alloys at similar hardness values. The temperatures and times indicated in parentheses are those of tempering heat treatments.

Improved Growth of Diamond Films From Oxyacetylene Torch

Addition of CO increases the number of nucleation sites for growth of diamond.

Marshall Space Flight Center, Alabama

Two modifications have been proposed to improve the nucleation and growth of diamond films on surfaces by use of an oxyacetylene torch. In one modification, carbon monoxide would be added to the fuel gas; in the other modification, carbon monoxide, methane, and oxygen would be added in synchronized pulses. The second modification is intended not only to improve the nucleation and growth of diamond films but also to make those films more nearly homogeneous over areas larger than the spots of such film grown by the oxygen/acetylene-growth technique that has been used until now. The modified technique is expected to enable deposition of diamond films on alternative materials — in particular, copper.

Heretofore, oxygen/acetylene growth of a diamond film has been effected by orienting an oxyacetylene torch above a substrate of silicon or molybdenum, controlling the temperature of the surface of the substrate, and maintaining the ratio of acetylene to oxygen in the general range of 0.85 to 1.02. In the best case, this produces a spot deposit that consists primarily of diamond in the center, but the proportion of carbon in nondiamond forms increases with distance outward from the central region. This radial distribution prevents the use of oxygen/acetylene growth to produce continuous diamond coats because the nondiamond carbon is deposited on the surface prior to the deposition of diamond.

Both modifications are expected to increase the rate of nucleation and the rate of growth of diamond. Preliminary experiments indicate that the first modification (the simple addition of CO) increases the number of nucleation sites of diamond deposits and improves the quality of the deposits. The second modification (pulsed, synchronized additions of CO, CH_4, and O_2) is expected to remove nondiamond carbon and increase the nucleation of diamond, thereby promoting the growth of larger, more nearly homogeneous (and, perhaps continuous) diamond films.

This work was done by Floyd E. Roberts III 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; (205) 544-0021. Refer to MFS-28838

Improved Fabrication of Cathodes for Solid-State Li Cells

Utilization of the cathode material is increased.

NASA's Jet Propulsion Laboratory, Pasadena, California

Improved composite-cathode/polymer-electrolyte units for solid-state lithium secondary electrochemical cells have been fabricated in a modified version of the original method of fabrication. Further development of the improved units may lead to increases in the energy and power densities and in the cycle lives of rechargeable lithium cells.

In both the original and modified methods, a composite-cathode/polymer-electrolyte unit is made by (1) casting a solution of the composite cathode material, (2) allowing the solvent to evaporate to form a composite cathode film, (3) casting a solution of the polymer electrolyte on the cathode film, and (4) allowing the solvent from this second solution to evaporate also to form the solid electrolyte. The cathode material is a composite of polyethylene oxide (PEO), $LiN(CF_3SO_2)_2$, and TiS_2, wherein TiS_2 is the active cathode material. The polymer electrolyte consists of a matrix of PEO containing $LiN(CF_3SO_2)_2$.

In the original method of fabrication, the same solvent (acetonitrile) is used in casting both the cathode and the polymer electrolyte. As a result, during the casting of the polymer electrolyte on the cathode, some of the TiS_2 is leached out of the cathode and deposited as particles in the polymer electrolyte. When a lithium anode is placed on the cathode/polymer-electrolyte unit to form a cell, these TiS_2 particles make small short circuits that lead to poor utilization of the cathode material and quick degradation of the cell.

In the modified method, the cathode is cast from acetonitrile as in the original method, but the polymer electrolyte is cast from a different solvent; namely, methanol. This method exploits the fact that (1) methanol dissolves PEO and $LiN(CF_3SO_2)_2$ salt at temperatures around 50 °C but not at room temperature and (2) once dissolved at the higher temperature, the PEO and $LiN(CF_3SO_2)_2$ do not precipitate when the solution is cooled to room temperature. This means that when the polymer-electrolyte solution is applied to the cathode, the cathode remains intact and TiS_2 is not leached out.

In an experiment, a composite-cathode/polymer-electrolyte unit made by the modified method was assembled with a lithium anode to form a cell of 30 mA•h nominal capacity. A similar cell was assembled with a cathode/electrolyte unit made by the original method. In charge/discharge cycles at a temperature of 56 °C, the cathode made by the modified method exhibited superior performance (see table).

This work was done by Ganesan Nagasubramanian of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 108*** *on the TSP Request Card. NPO-19285*

Method of Fabrication of Composite-Cathode/Polymer-Electrolyte	Capacity, mA · h (1st Cycle)		Capacity, mA · h (7th Cycle)	
	Discharge	Charge	Discharge	Charge
Modified (Two Solvents)	13.3	13.1	15.5	15.5
Original (One Solvent)	9.1	8.4	5.6	5.2

Both Initial Capacity and Capacity Retained after several charge/discharge cycles were greater in the case of the cathode made by the modified (two-solvent) method.

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Mechanics

Updated Panel-Method Computer Program

PMARC_12 computes potential flows, and includes capabilities for modeling wakes.

Panel-method computer programs are software tools of moderate cost used for solving a wide range of engineering problems. The panel code PMARC_12 (Panel Method Ames Research Center, version 12) can compute potential-flow fields around complex three-dimensional bodies such as complete aircraft models.

PMARC_12 is a well-documented, highly structured computer code with an open architecture that facilitates modifications and the addition of new features. Adjustable arrays are used throughout the code, with dimensioning controlled by a set of parameter statements contained in an "include" file; thus, the size of the code (i.e., the number of panels that it can handle) can be changed very quickly. This enables the user to tailor PMARC_12 to specific problems and to the constraints imposed by computer hardware. In addition, PMARC_12 can be configured (through one of the parameter statements in the "include" file) so that an iterative matrix-equation-solving algorithm in the code is run entirely in random-access memory (RAM) rather than by reading a large matrix from disk at each iteration. This significantly increases the speed of execution of the code, but it requires a large RAM.

PMARC_12 contains several advanced features, including internal mathematical modeling of flow, a time-stepping wake model for simulating either steady or unsteady (including oscillatory) motions, a capability for a Trefftz computation of drag induced by a plane, and capability for computation of off-body and on-body streamlines, and capability of computation of boundary-layer parameters by use of a two-dimensional integral boundary-layer method along surface streamlines.

In a panel method, the surface of the body around which the flow field is to be computed is represented by a set of panels. Singularities are distributed on the panels to perturb the flow field around the surfaces of the body. PMARC_12 provides constant-strength source and doublet distributions over each panel; this characteristic makes it a low-order panel method. Panel methods of higher order provide for the strengths of singularities to vary linearly or quadratically across each panel. Experience has shown that panel methods of higher order can cover a wide range of cases, with significantly reduced computation times; hence, the low-order formulation was adopted in PMARC_12.

The flow problem is solved by modeling the body as a closed surface that divides space into two regions: (1) the region outside the surface, in which region an unknown velocity potential represents the flow field of interest, and (2) the region inside the surface, in which region a known velocity potential that represents a fictitious flow is prescribed as a boundary condition. Both velocity potentials are required to satisfy Laplace's equation. A surface integral equation for the unknown potential outside the surface can be written by applying Green's Theorem to the external region. Using the internal potential and zero flow through the surface as boundary conditions, one can solve for the unknown potential external to the surface.

The internal-flow option enables the analysis of flows in closed ducts, wind tunnels, and similar internal-flow apparatus. When this option is selected, the geometry is modeled in such a way that the flow field of interest is inside the geometrical object that defines the boundary and the fictitious flow is outside the object. Such items as wings, struts, and aircraft models can be included in an internal-flow problem.

The time-stepping wake model gives PMARC_12 the ability to model both steady and unsteady flows. The wake is convected downstream from the wake-separation line by the local velocity field. With each time step, a new row of wake panels is added to the wake at the wake-separation line. Time stepping can start from time $t=0$ (no initial wake) or from time $t=t_0$ (an initial wake is specified). A wide range of motions can be prescribed, including constant rates of translation, a constant rate of rotation about an arbitrary axis, oscillatory translation, and oscillatory rotation about any of the three coordinate axes.

Investigators interested in visual representations of the phenomena they are studying with PMARC_12 may want to consider obtaining the program GVS (ARC-13361), the General Visualization System. GVS is a Silicon Graphics IRIS program that was created to support the scientific-visualization needs of PMARC_12. GVS is available separately from COSMIC.

PMARC_12 is written in standard FORTRAN 77, with the exception of the NAMELIST extension used for input. This makes the code fairly machine-independent. A compiler that supports the NAMELIST extension is required. The amount of free disk space and RAM required for PMARC_12 varies, depending on how the code is dimensioned by use of the parameter statements in the "include" file. The recommended minimum memory capacities are 20 Mb of free disk space and 4 Mb of RAM. PMARC_12 has been successfully executed on a Macintosh II computer running System 6.0.7 or 7.0 (using MPW/Language Systems FORTRAN 3.0), a Sun SLC computer running SunOS 4.1.1, an HP 720 computer running HP-US 8.07, an SGI IRIS computer running IRIX 4.0 (it cannot be executed

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under IRIX 3.x.x without modifications), and IBM RS/6000 computer running AIX, a DECstation 3100 computer running ULTRIX, and a CRAY-YMP computer running UNICOS 6.0 or later. Because of its memory requirements, this program does not readily lend itself to implementation on MS-DOS-based computers. The standard distribution medium for PMARC_12 is a set of three 3.5-in. (8.89-cm), 800K Macintosh-format diskettes and one 3.5-in. (8.89-cm), 1.44 Mb Macintosh-format diskette that contains an electronic copy of the documentation in MS Word 5.0 format for the Macintosh. Alternate distribution media and formats are available upon request, but these do not include the electronic version of the document. No executable codes are included on the distribution media. This program is an update to PMARC version 11, which was released in 1989. PMARC_12 was released in 1993. It is available for use by United States citizens only.

This program was written by Dale L. Ashby of **Ames Research Center**. *For further information,* ***write in 81*** *on the TSP Request Card. ARC-13362.*

Mathematics and Information Sciences

Estimating Maintenance Demands of a Space Station

RENEW estimates failure and repair times by use of Monte Carlo simulations.

The RENEW computer program simulates maintenance events and estimates data pertinent to maintenance demands. RENEW was developed in support of the Space Station Freedom Program (SSFP) Work Package 4 at NASA Ls Research Center. RENEW uses data on reliability and maintainability (R&M) as well as logistical data to estimate both average and time-dependent maintenance demands. RENEW uses Monte Carlo techniques to compute failure and repair times as functions of the R&M and logistical parameters. The estimates are generated for a single type of orbital replacement unit (ORU) (basically, an equipment module).

The RENEW simulation gives closer estimates of performance than steady-state average calculations do because it uses a time-dependent approach and depicts more factors that affect the failure and repair of an ORU. RENEW gives both average and time-dependent values of maintenance demands and generates graphs of both failures over the duration of a mission and yearly occurrences of failures. The demand rate for the ORU averaged over the duration of the mission is also calculated. While RENEW displays the results in graphs, the results are also available in tables of data.

The process of using RENEW starts with keyboard entry of the R&M and operational data. Once entered, the data can be saved in a data file for later retrieval, and the parameters can be viewed and changed. The simulation program runs the number of Monte Carlo simulations requested by the operator. Plots and tables of the results can be viewed on the computer video monitor or sent to a printer. The results of the simulation are saved along with the input data. Help screens on the video display are provided with each menu and data-entry screen.

RENEW is written in BASIC and Assembly language for IBM PC-series and compatible computers running MS-DOS. Microsoft QuickBasic Professional Development System and Crescent Software's QuickPak Professional are required to compile the source code. A CGA or VGA monitor is required. A sample executable code is provided on the distribution medium. The standard distribution medium for this program is one 5.25-in. (13.34-cm) 360K MS-DOS-format diskette. This program was developed in 1992.

This program was written by B.L. Bream of **Lewis Research Center.** *For further information,* ***write in 76*** *on the TSP Request Card. LEW-15666*

Machinery

NASA-GRA — Geared-Rotor Analyzer

Effects of elasticities, unbalances, and errors are modeled.

NASA-GRA is a computer program designed to solve for the steady-state dynamic responses of multigeared rotor systems. It is based on the transfer-matrix method combined with the harmonic-balance method. NASA-GRA includes an accurate gear-mesh model for spur and helical gears, containing time-varying mesh stiffnesses, gear-mounting errors, and gear-profile errors. The program also includes an accurate disk model containing inertia-based dynamic coupling terms due to the mass and skew unbalances. In addition, it includes a massless-elastic-shaft model and a linearly coupled fluid-film bearing model. The analysis frequencies are chosen by the user.

NASA-GRA is written in FORTRAN 77 to be machine-independent. It has been successfully implemented on computers, from 486 PCs to Crays. Because of the large sizes of certain array structures, implementation on the IBM PC-series computers is not recommended. NASA-GRA requires 4MB of random-access memory for execution. The standard distribution medium for NASA-GRA is a 0.25-in. (6.35-mm) streaming-magnetic-tape cartridge (Sun QIC-24) in UNIX tar format. Alternate distribution media and formats [3.5-in. (8.89-cm) floppy disk in DOS format] are available upon request. NASA-GRA was developed in 1989 and released to COSMIC in 1993.

This program was written by N. Park of Pusan National University, D. Kim of the University of Ulsan, and J. W. David of North Carolina State University for **Lewis Research Center.** *For further information,* ***write in 156*** *on the TSP Request Card. LEW-15148*

Mechanics

Omnidirectional Actuator Handle

The actuating force could be applied from any direction.

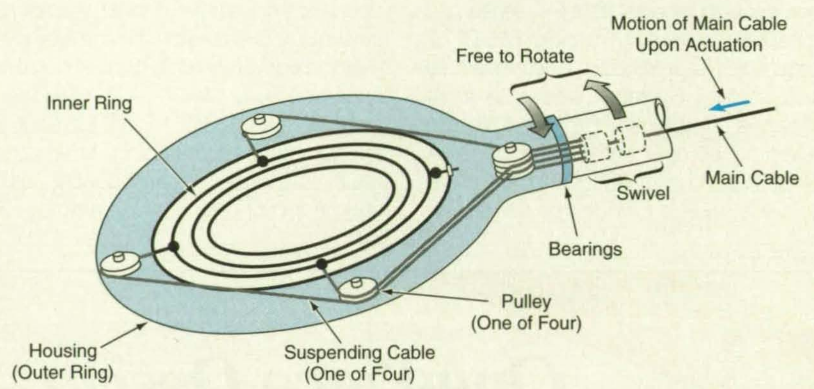
Lyndon B. Johnson Space Center, Houston, Texas

A proposed actuator handle would comprise two normally concentric rings, cables, and pulleys arranged such that relative displacement of the rings from concentricity would result in pulling of a cable and consequent actuation of an associated mechanism. Unlike conventional actuator handles like levers on farm implements, which can be actuated from one or two directions only, the proposed handle could be reached from almost any direction and actuated by pulling or pushing the inner ring in any direction with respect to the outer ring.

The outer ring would be a housing, in which the inner ring would be suspended by a set of cables (see figure). These suspending cables would be wrapped around pulleys in the housing, then extended to a common point, where they would be attached to a main cable in a shaft connected to the housing. Bearings between the shaft and housing and a swivel on the main cable would allow free rotation of the handle around the shaft axis to whatever angle is most advantageous for the user.

Grasping the two rings from any direction and squeezing would pull the outer ring toward the housing, thereby pulling at least one of the suspending cables. The pulled suspending cable(s) would, in turn, pull on the main cable, thereby actuating an external mechanism connected to it. Upon being grasped, the housing would rotate on bearings in the shaft, turning itself to the most advantageous position for the user. An alternative embodiment (not shown) provides a means for creating mechanical advantage in the cable.

This work was done by John B. Moetteli of Lockheed Engineering & Sciences Co. for **Johnson Space Center**. *For further information,* ***write in 74*** *on the TSP Request Card. MSC-22023*



Relative Movement of the Rings in any direction would cause pulling on the main cable. Flanges (not shown) could be installed on the inner ring to cover the gap between the inner ring and the housing to prevent clothing from being caught.

Energy-Absorbing Footpad Assembly

This assembly limits the impact load on the supported structure.

Lyndon B. Johnson Space Center, Houston, Texas

A proposed footpad assembly that would support a structure would also absorb impact energy in both horizontal and vertical directions. The footpad assembly would resist impact deformation with approximately constant force, unlike older impact devices, in which the forces are erratic and difficult to predict and control. The footpad assembly could therefore be designed to absorb more energy in a given stroke and to protect the structure from high peak shock loads. The footpad assembly would be lightweight, compact, and easy to manufacture.

The footpad assembly would rely on friction to absorb kinetic energy in the vertical direction and on a crushable material to absorb kinetic energy in the horizontal direction. The assembly could be designed for a specific maximum load, nearly independent of the speed and angle of impact. It could be used in a variety of single-impact applications; for example, on pallets dropped by parachute from airplanes.

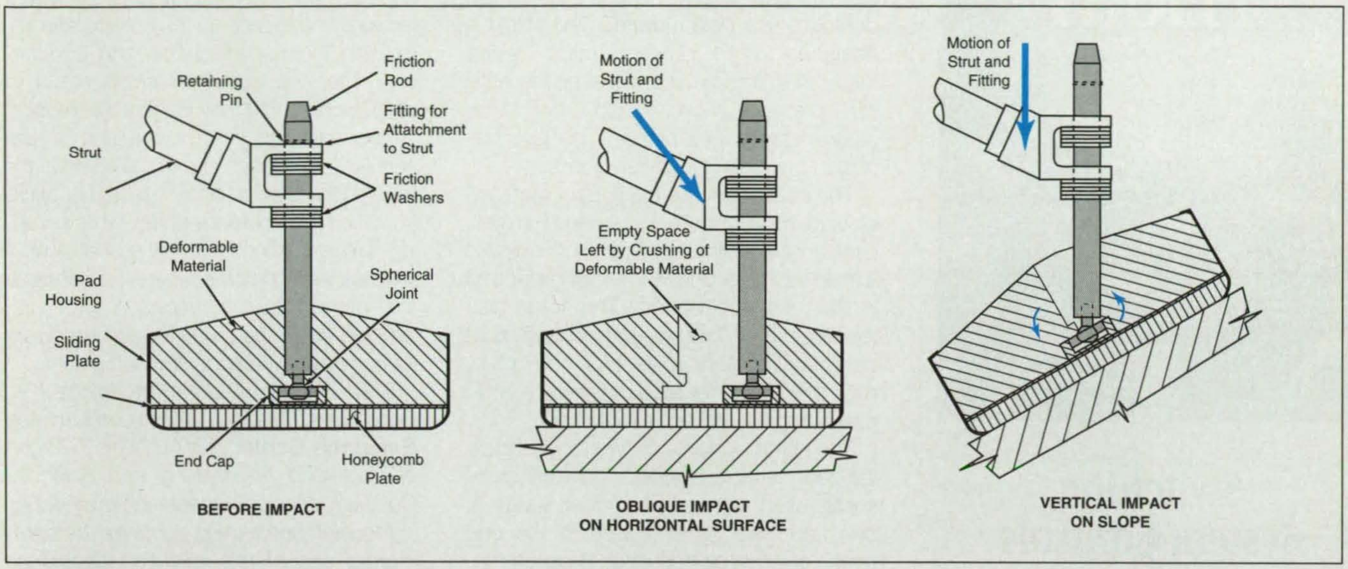
When the footpad struck a surface, the vertical load would drive a friction rod upward (see figure). Vertically directed impact energy would be dissipated by the sliding of the rod through two stacks of press-fit friction washers. Because the inner surfaces of the washers would yield plastically in the press fit, they would impose a nearly constant, limited friction force on the rod throughout the stroke, regardless of the impact velocity. Also because of the plastic yielding, narrow dimensional tolerances between the rod and washers would be unnecessary, and the rod and washers could be manufactured easily.

If the impact velocity included a horizontal component, the footpad would absorb energy partly by the friction of sliding on the impact surface and partly by crushing of a deformable honeycomb material inside the pad housing. The maximum lateral force on the friction rod would be determined mostly by the characteristics of the deformable material, which could be designed to fit the expected energy-absorption needs: Like the friction washers, the deformable material would resist deformation with a force nearly independent of the impact velocity.

The footpad assembly could also accommodate a sloping impact surface. The footpad would rotate about a spherical joint on the friction rod. As the pad rotated, the deformable material would be crushed, absorbing more energy.

This work was done by Christopher P. Hansen of **Johnson Space Center.** *For further information,* ***write in 105*** *on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center; (713) 483-4871. Refer to MSC-22277.



Friction Washers and Deformable Material would help to absorb impact energy. The yielding force would be determined partly by the sizes and number of washers and partly by the honeycomb, foam, or other configuration of the deformable material. The spherical joint would accommodate a sloped impact surface.

Shield for Flexible Pipe

Easily installable shells restrain fragments and redirect the flow of escaping pressurized fluid.

Langley Research Center, Hampton, Virginia

A cylindrical shield is designed to fit around a flexible pipe to protect nearby workers from injury and equipment from damage if the pipe ruptures. The shield is designed as a pressure-relief device rather than as a pressure vessel: the walls of a pressure vessel would have to be heavier and would perhaps be less reliable in preventing injury and damage.

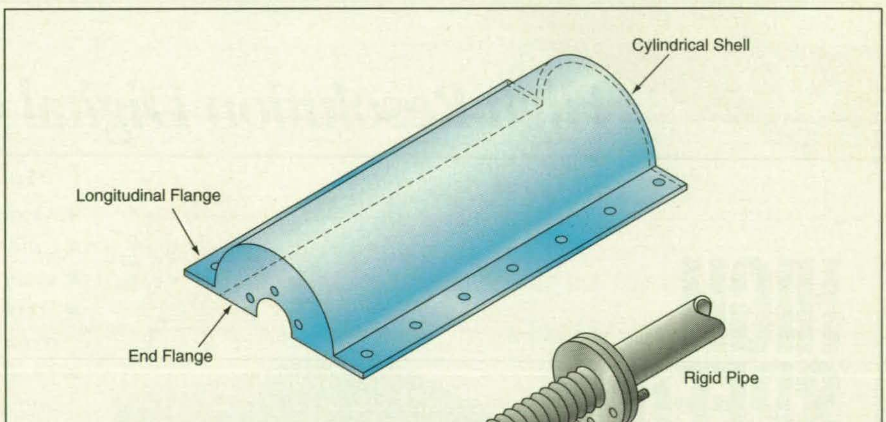
The shield absorbs the impact of debris ejected radially from the broken flexible pipe. (In the original application, the pipe is a stainless-steel bellows helically wrapped in stainless-steel bands.) The shield also redirects the flow of pressurized fluid escaping from the broken pipe onto a flow path that allows for relief of pressure while minimizing the potential for harm.

The shield consists of two longitudinally flanged stainless-steel half-cylindrical shells, each with a half annular flange at one end (see figure). Holes in the end flange of each cylindrical shell accommodate bolts that extend from a flange at one end of the flexible pipe. The end flange of one cylindrical shell is fastened to the pipe-flange bolts by use of nuts at one end. The end flange of the other cylindrical shell is slid onto the pipe-flange bolts at the other end, but not fastened by nuts, so that it remains free to slide on the bolts to accommodate thermal expansion and contraction. The two cylindrical shells are then bolted together at their longitudinal flanges.

The resulting assembly leaves a half annular hole at each end of the shield. If the flexible pipe breaks, debris ejected outward from the pipe strikes the shells, while escaping fluid is confined within the shells until it reaches the end holes, where it passes into the atmosphere at reduced pressure, directed along the pipe instead of outward toward nearby persons and equipment.

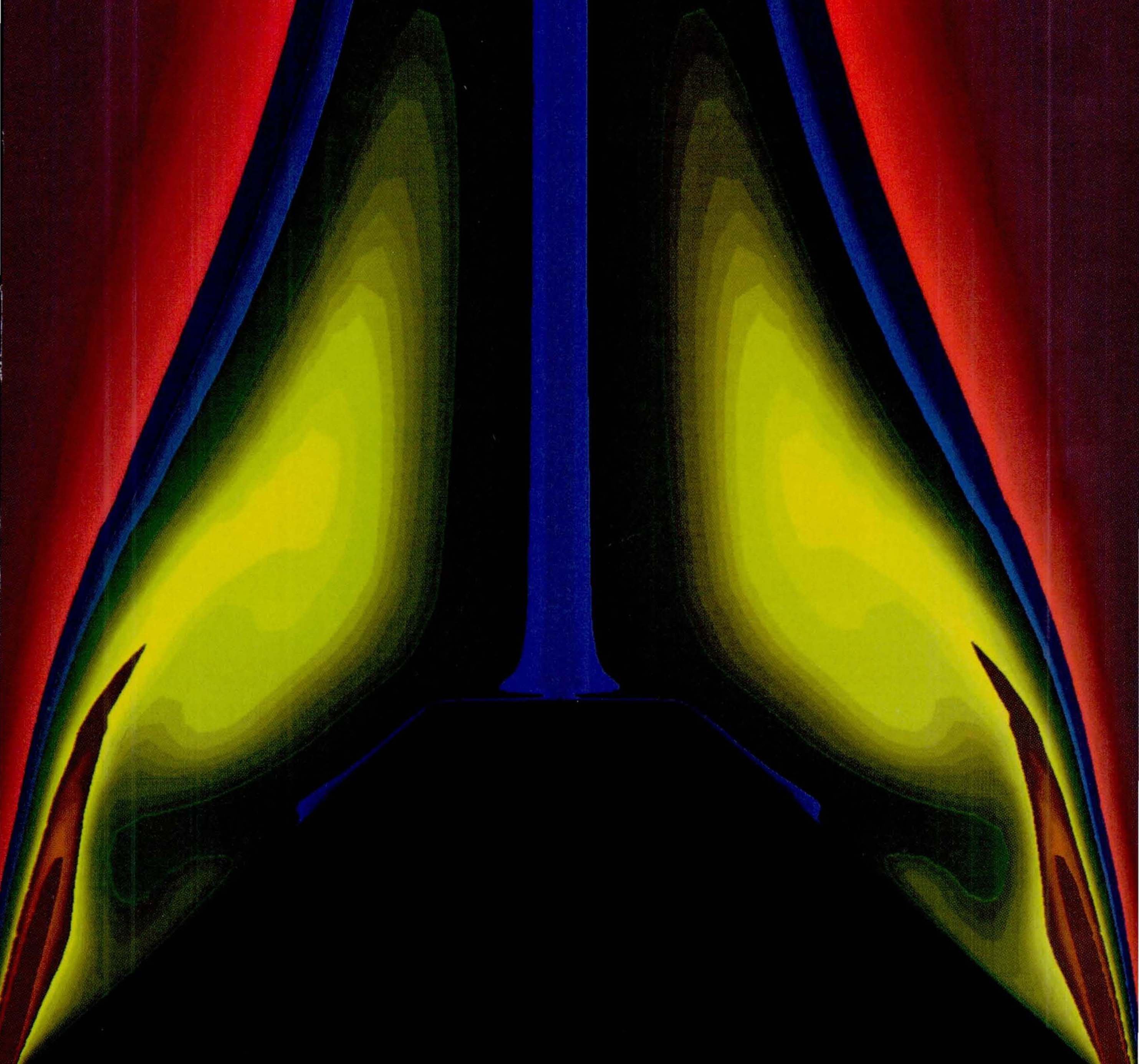
This work was done by Michael K. Ponton and Clifford B. Williford of **Langley Research Center** *and Nicholas T. Lagen of Lockheed Engineering and Sciences Co. No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Langley Research Center; (804) 864-3521. Refer to LAR-15157.



The **Shield Around the Flexible Pipe** catches debris if the pipe breaks. The shield also defines a channel that is only half closed at each end so that escaping fluid can flow out safely.

FEDERAL LAB Computing TECH BRIEFS



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COMPUTING TECH BRIEFS

On the cover

The pseudocolor image is derived from one of NASA's computational studies of heat patterns created by the Mars Pathfinder vehicle. Here the different colors represent mass concentrations of the ablation product silicon oxide as it blows off the forebody and is captured in the vehicle's wake. Photo courtesy NASA Langley.

EDITORIAL NOTEBOOK

News of the Industry and Federal Labs

• Scientists from Sandia National Laboratories and Intel Corporation achieved a new world speed record for supercomputing, claiming to leapfrog the Japanese performance record set in 1994 by more than half again. The team's system, hyperlinking two Intel Paragon computers, established a record performance of 281 Gflops (billions of floating-point operations per second), on the Linpack benchmark, surpassing the 170.4 Gflops a Japanese Fujitsu numerical wind-tunnel computer reportedly performed. The Intel Paragon massively parallel supercomputer also achieved 328 Gflops on an electromagnetic code used for radar signature calculations, more than three times the previous record of 102 Gflops. The code used a Sandia-developed double precision LU (lower/upper) factorization routine. For more information, contacts at Sandia are Ed Barsis at (505) 845-8938 or Art Hale at (505) 845-7802.

• The Technology Transfer Information Center (TTIC) of the National Agricultural Library (NAL) of the Department of Agriculture is soliciting possible solutions to equipment manufacturing industry problems in two areas: hazardous atmospheres and injuries from equipment. Working with a list of needs developed by the Equipment Manufacturers Institute, TTIC will collaborate with experts to identify off-the-shelf solutions or pinpoint federal laboratories, universities, and other research organizations already working on technologies to solve the problems. For more information, contact Kate Hayes, TTIC, National Agricultural Library, USDA, 4th Floor, 10301 Baltimore Blvd., Beltsville, MD 20705; (301) 504-6875; FAX: (301) 504-7098; Internet: ttic@nalusda.gov.

• The Idaho National Engineering Laboratory (INEL), run by Lockheed Inc. for the Department of Energy, is testing an innovative plan to promote lab spin-off companies' chances of success. The plan permits Lockheed INEL to use Master Task Agreements to contract with spin-off companies that have unique intellectual-property capabilities, rather than go through formal procurement processes. The agreement, to last no more than three years, must involve one or more of the following: a technology held by the company; skills or capabilities not available in the regional business market, defined as within a 200-mile radius; or a specialized piece of equipment held or developed by the company. The company must file annual plans to show that it is seeking other business, and its personnel must leave INEL and work full time in the new business. For more information, contact Charles Briggs at (208) 526-0441.

This column was prepared with the assistance of the Federal Laboratory Consortium for Technology Transfer. Established in 1974 to promote the transfer of federal R&D capabilities into the private sector and state and local governments, the FLC consists of more than 600 member laboratories and research centers from 16 federal departments and agencies. For further information, phone the FLC Management Support Office; (206) 683-1005.

ERRATUM:

In the Federal Lab Test and Measurement Tech Briefs supplement to the May issue, the brief entitled "A Highly Capable Facility for Antenna Testing" was inadvertently left incomplete on page 14a. The final paragraph should have read: "The Antenna Test Facility is located at the Naval Air Warfare Center Weapons Division, China Lake, CA. For more information about capabilities, scheduling, cost of services, or opportunities for Cooperative Research and Development Agreements (CRADA), contact Terry Fitzwater; (619) 939-7403."

Computer-Assisted Dynamic Data Monitoring and Analysis System (CADDMAS)

A revolutionary system increases jet-engine test data acquisition.

Engineering Development Center, Arnold Air Force Base, Tennessee

Development of CADDMAS, a system that applies computer processing in parallel and reduces customer test data turnaround time from days to seconds, continues at Arnold Engineering Development Center (AEDC). CADDMAS is a multichannel real-time parallel-processing-based dynamic data (up to 50 kHz) acquisition and complex data analysis system.

AEDC has successfully used earlier versions of CADDMAS (up to 20 kHz) to support aeromechanical testing of General Electric's F-110 engine and Pratt & Whitney's F-119 core engine. A 24-channel 20-kHz system is also supporting the aeromechanical portion of Pratt & Whitney's F-119 test program at AEDC by analyzing and displaying, in real time, complex frequency-domain turbine engine stress data.

CADDMAS provides AEDC engineers the information necessary to make on-line test decisions and immediately alerts them to anomalous or dangerous stress conditions. Additionally, CADDMAS has generated thousands of hard-copy plots on-line during test program support, a process that previously took from days to weeks to accomplish off-line. AEDC has received several requests for CADDMAS units to be used in various user test facilities.

CADDMAS can take more than 20 million measurements each second during an average aircraft engine stress test. Over a typical 10-hour test period, more than 700 trillion measurements occur.

CADDMAS operates using strain-gauge sensor readings whose signals are recorded and displayed on oscilloscopes with additional processing performed in real time by the system's hardware and software. Additional processing consists of analog-to-digital conversion, aeromechanical analysis of the strain-gauge data, engineering unit conversion, digital storage of incoming data, and output of various types of analysis plots, such as frequency-envelope plots, frequency waterfall plots, and correlations, as well as on-line Campbell and modified Campbell diagrams (Figure 1).

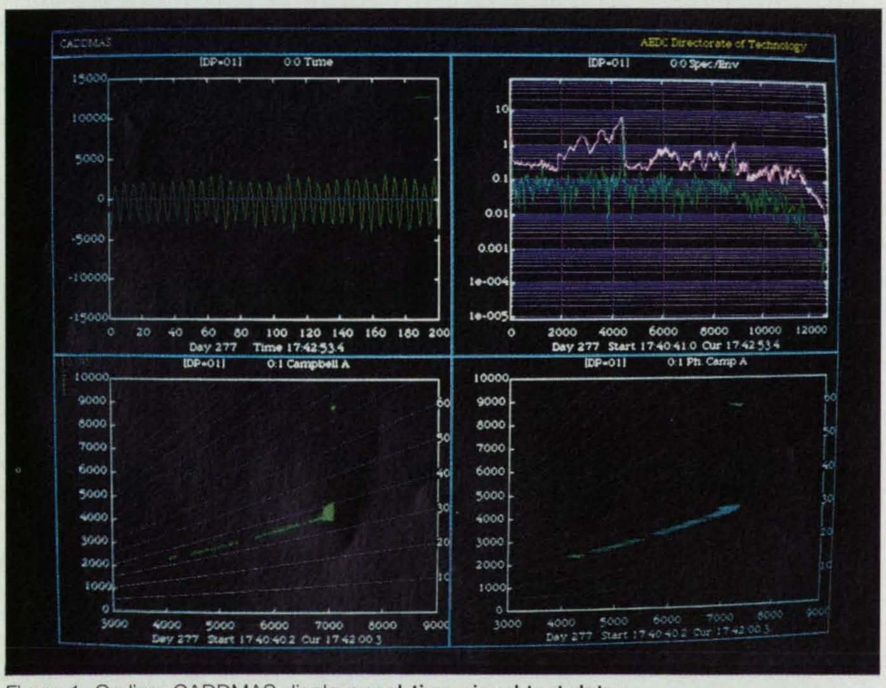

Figure 1. On line, CADDMAS displays **real-time visual test data.**

Digital storage allows users to replay a recent event while the system continues to gather and update current engine performance. Special limit monitoring features allow programmable levels of significance to be set up that can trip alarms if various vibrational energy levels are exceeded.

High-speed analog-to-digital (A/D) front-end hardware collects hundreds of thousands of samples from each data channel (strain gauge) each second, performs a frequency-domain analysis on the data, and compares the results to preset limits. Knowing when an engine has exceeded, or is about to exceed, a vibration limit allows engineers to alter the test conditions or possibly abort a critical maneuver before damage to the engine or test cell occurs.

State-of-the-art research and development has created a flexible software system that enables instrumentation and system engineers at AEDC to define the data acquisition problem in graphical form. Figure 2 shows its components and capabilities schematically. Once the data system and the desired data processing tasks have been defined in this way, the specialized software creates many separate programs, which are then sent out to the various processing elements throughout CADDMAS. These programs then execute in parallel, each doing its part in the overall process. The software coordinates the flow of data between these processing elements.

In standard computers, only one processor handles all the computations. When multiple pieces of data are calculated--such as on-line stress data from an engine test--each calculation must be sequenced through the processor one at a time. In contrast, parallel processing applies many processors to the problem, with each handling a small part of the calculations. Traditional systems require the use of extremely expensive high-speed processors. By dividing the workload, the parallel processing system can handle

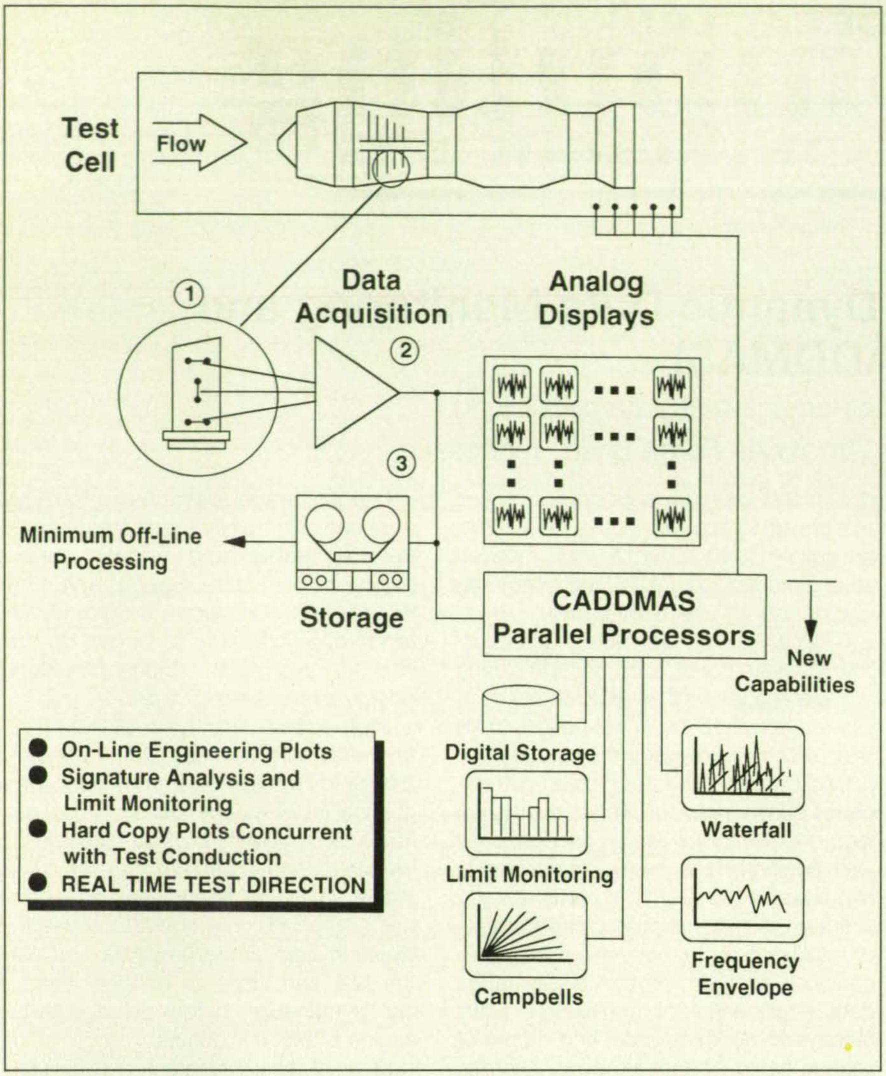

Figure 2. **Data acquisition and processing** with CADDMAS.

more data using relatively slow and inexpensive processors. More processors can be added to the new system to adapt to expanding test requirements.

Advancement of capabilities is continuing, with a 48-channel 50-kHz system expected to be operational this fall. Demonstration of the potential of CADDMAS in other areas such as real-time health monitoring, image processing, and engine-performance validation has been initiated and is scheduled for completion next year.

The system's return on investment for AEDC aeromechanical testing alone has been estimated at 7 to 1 over a 10-year period. When the technology development and transition to full use of CADDMAS are complete, the return on investment across the Department of Defense is expected to be orders of magnitude above that. In addition, avenues for technology transition into private industry are being pursued.

This work was done by an integrated team for the U.S. Air Force's **Arnold Engineering Development Center**. *It consisted of Air Force and Sverdrup Inc. engineers involved in data acquisition system design, software design, members of the analysis and evaluation community, and consultants from Vanderbilt University and the University of Tennessee Space Institute.*

Inquiries concerning rights for the commercial use of this invention should be addressed to James Mitchell, AF/DOT, Arnold Engineering Development Center, Arnold AFB, TN 37389; (615) 454-6910.

Time-Domain Computation of Electromagnetic Fields in MMICs

Maxwell's equations are solved on three-dimensional, conformed orthogonal grids by finite-difference techniques.

NASA's Jet Propulsion Laboratory, Pasadena, California

A method of computing the frequency-dependent electrical parameters of a monolithic microwave integrated circuit (MMIC) involves a time-domain computation of the propagation of the electromagnetic field in response to excitation by a single pulse at an input terminal, followed by computation of Fourier transforms to obtain the frequency-domain response from the time-domain response. The parameters that can be computed in this way include the electric and magnetic fields, voltages, currents, impedances, scattering parameters, and effective dielectric constants. The method is a powerful and efficient means for analyzing the performance of even a complicated MMIC.

The propagation of the electromagnetic field is computed by solving Maxwell's equations (in curl form) by finite-difference numerical-integration techniques on a three-dimensional, conformed orthogonal grid. In the derivation of the equations for this method, the finite-difference versions of Maxwell's curl equations are first formulated on a uniform orthogonal grid, then adapted to a nonuniform grid that comprises subgrids that conform to the dimensions of various conductive and dielectric elements of the MMIC. The modifications are necessary to suppress the errors that would otherwise occur at the boundaries between subgrids of different mesh sizes.

The following assumptions apply to the mathematical model of a MMIC that can be analyzed by this method:

- The MMIC consists of a conducting ground plane, multiple dielectric substrates on top of the ground plane, and metal strips (microstrip conductors) on top of some areas of the dielectric substrates.

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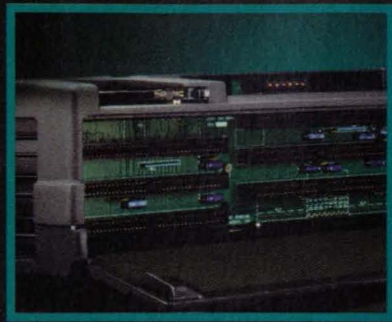

Patented backplane/card cage design allows three full size, six half-size (or a combination) of standard XT/AT ISA cards in half the normal height.

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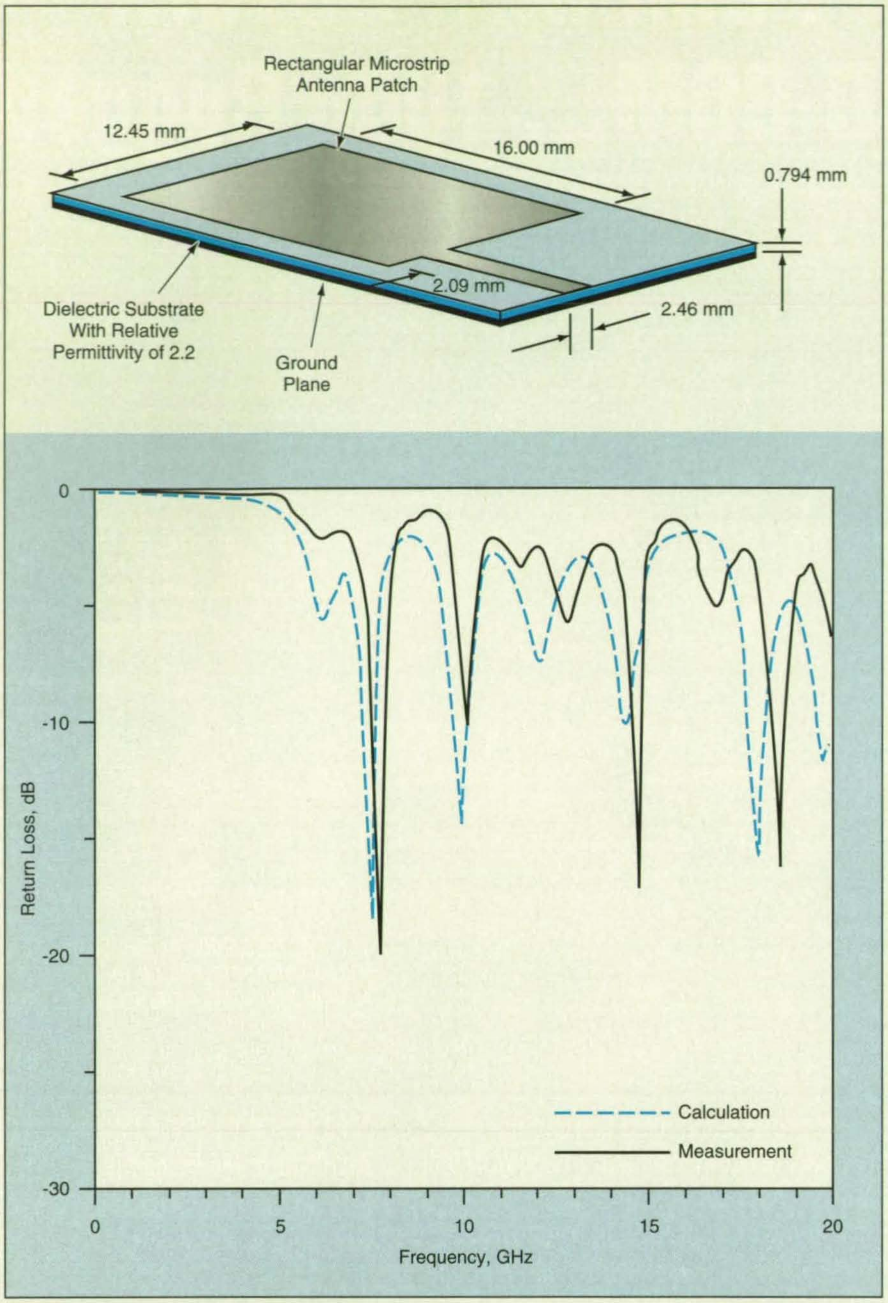
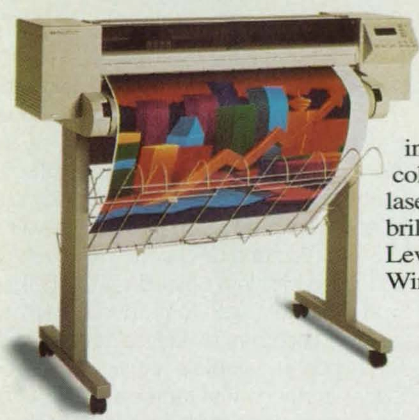


The **Frequency Dependence of Return Loss** of a rectangular-patch microstrip antenna was computed by the method described in the text and measured in an experiment.

- The conductors have zero thickness.
- The components of electric fields tangential to the conductors are zero, except as in the next assumption.
- The conformed orthogonal grid is fitted to the circuit such that the edges of each conductor are modeled with components of the electric field in the plane of the conductor lying exactly on the edges of the conductor.
- The dielectric materials are isotropic in a plane parallel to the ground plane.
- A Gaussian-shaped pulse is chosen as the excitation at time $t = 0$. This choice is advantageous because its frequency spectrum is also Gaussian. By adjusting the duration of the pulse, one can obtain a spectrum that provides frequency-domain information from dc to the desired cutoff frequency.
- The Gaussian-shaped excitation is assumed to result in the propagation of only the fundamental mode along each microstrip conductor in the frequency range of interest.
- To minimize the effects of numerical dispersion and truncation errors, the duration of the pulse is chosen as 20 nodes per wavelength at the highest frequency represented.

The method has been tested experimentally by comparison of its predictions with measurements on several MMICs, including a line-fed rectangular-patch antenna, a low-pass filter, a 3-dB branch-line coupler, a dual-stub filter, and a superconductor band-pass filter. As illustrated in the figure for the example of the return loss in the rectangular-patch antenna, the method provides for easy and accurate calculation of the performance of MMICs.

This work was done by Faiza S. Lansing and Daniel L. Rascoe of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 87*** *on the TSP Request Card.*
NPO-19187



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Computational Fluid Dynamics Software with Adaptive Meshing Capability

A new analytical tool optimizes complex inlet design.

Sandia National Laboratories, Albuquerque, New Mexico

To reduce costly wind-tunnel tests on the inlet of a missile engine, Sandia engineers wanted to refine the design with computational fluid dynamics (CFD) before progressing to physical testing. They ruled out structured mesh CFD packages because the complexity of the inlet geometry would have required days of meshing time. Instead, they used the unstructured mesh CFD package called RAMPANT from Fluent, Inc. of Lebanon, NH.

This software automatically generates a volume mesh using solution-adaptive triangular and tetrahedral elements. The mesh for the inlet took only four hours to complete, and the resulting analysis saved $100,000 in wind-tunnel time by pointing out some problems in the initial design. More importantly, the use of RAMPANT provided the first opportunity to use CFD on a problem with such complex geometry. Since this analysis was first done in 1992, meshing times have been reduced even further: Meshing time today would be a matter of minutes, not hours.

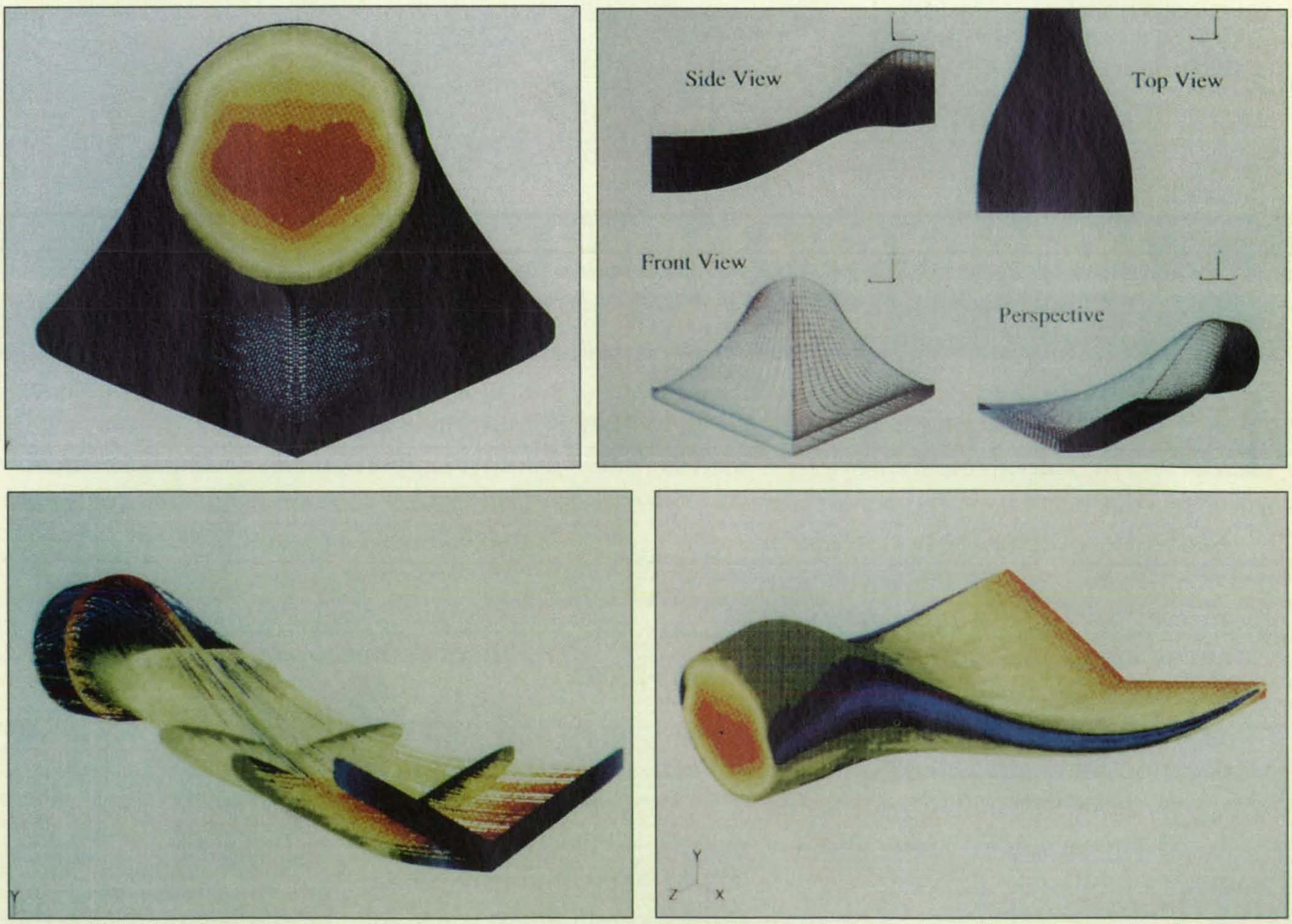
One of Sandia's overall goals is to reduce testing, because the lab's budget for it has decreased. With flight tests costing about $25,000 each and wind-tunnel time costing as much as $20,000 a day, there is a great deal of incentive to move analysis further forward in the design process as a way of refining designs before proceeding to physical testing.

In the case of the missile-system inlet, engineers needed a new design that would be "stealthy"--not detectable by radar--yet still provide good performance characteristics such as a uniform air flow with no separation. The air coming out of the inlet and into the turbine had to be uniform as well. In the past, this kind of problem would have required use of the transonic wind tunnel. Testing different configurations of inlet geometry would have consumed at least two weeks in the tunnel.

The design of the new inlet was quite complex. Instead of a standard rectangular channel, the cross-sectional area of the inlet varies from a high-aspect-ratio V-shape at the front to an almost circular outlet at the back end (see isometric views).

Structured grid CFD codes were rejected for this problem because of the difficulty and time required to produce the mesh for this geometry. Nearly all commercial CFD codes employ either a simple Cartesian mesh that represents the world as a cellular-like structure or an assembly of curvilinear, mapped cubes. Structured mesh generators, however, are only semi-autonomous at best. And with an irregular geometry such as this inlet's, structured codes have trouble with the streamwise geometry transition and the boundary curvature. For this inlet, engineers estimate the meshing would have taken several days using a structured code.

RAMPANT is the first of a new genera-



(Above left) **Hybrid inlet** total pressure contours at exit created using an unstructured mesh CFD package. This software automatically generates a volume mesh using solution-adaptive triangular and tetrahedral elements. (Above right) Isometric views of final design of hybrid subsonic inlet/diffuser. (Bottom left) Hybrid inlet particle paths. (Bottom right) Hybrid total pressure surface contours.

tion of CFD software that uses an unstructured grid to provide truly automatic mesh generation. Once the surface is defined, the grid is generated without user intervention. Unstructured grids also offer the possibility of adapting the grid distribution in space to optimally solve a given problem. Adaptive mesh refinement also allows important flow features to be resolved locally while retaining a more cost-effective coarse mesh in regions of smooth flow. For some production runs, CPU time savings on the order of 10 to 1 can be achieved.

For this inlet problem, the first step was to import an I-DEAS-generated surface mesh into RAMPANT. There, engineers created an initial concept model with approximately 200,000 cells in about four hours. At the time they were running a beta version of RAMPANT. They estimate that the same model might be created in as little as 15-20 minutes with the current version of the software.

The initial analysis showed a region of air separation, but the primary problem was that the pressure did not recover well at the outset and was not uniform. They went back to I-DEAS and made some adjustments to the geometry in about half an hour. The next analysis showed a much more uniform distribution of pressure at the outlet.

The solution time for these analyses was about 200 hours on a Cray supercomputer, but that too is improved in the current version of RAMPANT. An unstructured grid can take longer to solve than a structured grid when the application involves internal flow, assuming that capturing the boundary layer is important. With most problems, however, the opposite is true--the unstructured grid requires fewer cells and a shorter solution time.

Besides being one of the few CFD codes that can handle complex geometries in a timely manner, RAMPANT is also being used by Sandia for aerodynamics analysis. Sandia engineers have found that even those who have not used the package for six months can pick it up again in five minutes.

This work was done by Jim Nelsen et al. at **Sandia National Laboratories** *in Albuquerque, NM. Inquiries about the RAMPANT software may be directed to Rick Sam at Fluent Inc., 10 Cavendish Court, Centerra Resource Park, Lebanon, NH 03766; (800) 445-4454; (603) 643-2600; FAX (603) 643-3967; E-mail: info@fluent.com.*

Computed Tomography Measuring Inside Machines

Approximate measurements can be taken without disassembly.

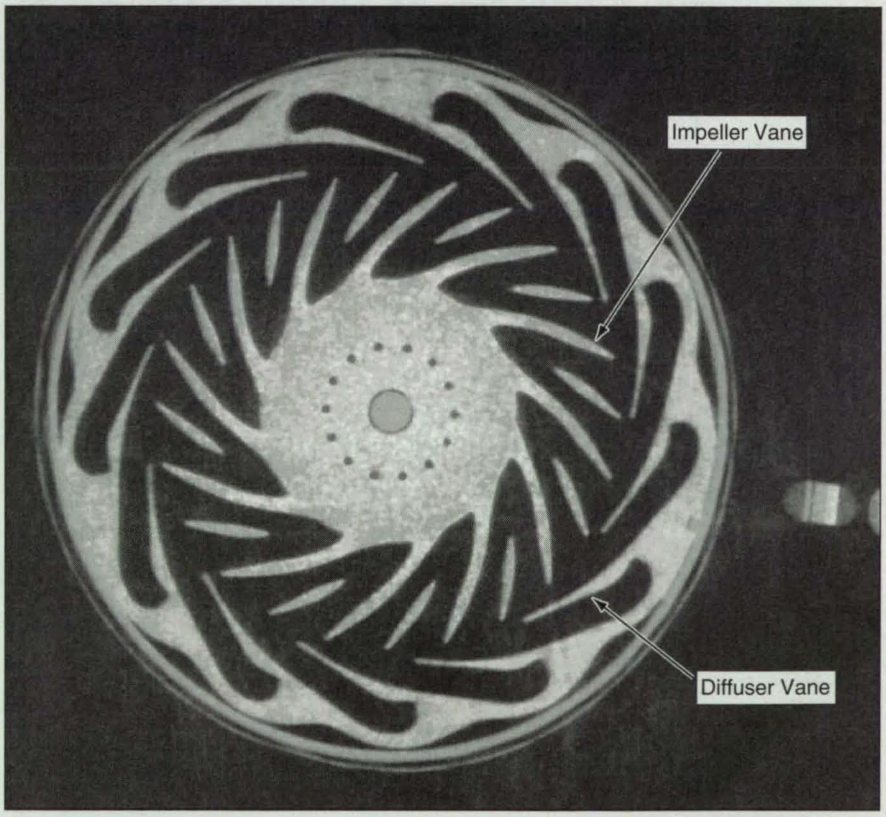
Marshall Space Flight Center, Alabama

Computed tomography has been applied to obtain approximate measurements of the radial distances from the centerline of a turbopump to the leading edges of the diffuser vanes in the turbopump. This use of computed tomography has significance beyond the turbopump application: it is an example of a more general concept of measuring internal dimensions of an assembly of parts without having to perform the time-consuming task of taking the assembly apart and measuring its internal parts on a coordinate-measuring machine.

In the original application, the turbopump was first disassembled and measured in the conventional way on a coordinate-measuring machine to provide a basis for comparison. The turbopump was reassembled, then mounted vertically on a computed-tomography machine, positioned to intercept the bremsstrahlung x-ray beam from a 2.5-MeV linear accelerator. Axial digitized radiographs made from the beam were used to determine the location to take transverse cross-sectional images (tomographs) using the beam.

A computer program analyzed the tomographs to compute the radial distance of the leading edge of each diffuser vane from the axis of the turbopump. For this purpose, the axis of the turbopump in each tomograph was deemed to be located at the centroid of the innermost points on the vanes. By comparison with the conventionally measured radii, the radii determined via computed tomography were found to exhibit an overall error of ±0.010 in. (±0.25 mm). In a conservative approach to inspection, this error figure would be added to or subtracted from each estimated dimension to obtain a worst-case value.

This work was done by James F. Wozniak, Henry J. Scudder, and Jeffrey E. Anders of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information,* ***write in 19*** *on the TSP Request Card.*
MFS-30031



This **Tomograph of a Turbopump** presents an axial view of a slice about 1 mm thick.

Test Project Archival System

CD-ROM multimedia technology facilitates project documentation.

Engineering Development Center, Arnold Air Force Base, Tennessee

To provide a better means of delivering and archiving test information, Arnold Engineering Development Center (AEDC) personnel have developed the capability to document ground tests electronically. Under this Test Project Archive System (TPAS), test data and related information can be stored and delivered using recordable CD-ROM technology.

The CD-ROM format provides a durable high-density random access medium for archiving and distributing information. The multimedia capabilities of TPAS support the inclusion of many different types of test documentation. Multimedia software included on the CD-ROM allows the user to view digitized photographs of test articles and configurations, and electronic versions of drawings.

In addition to the test documentation, the CD-ROM includes the digital data from the test along with an analysis software package. This places a plotting and data analysis capability on the user's desktop.

The plotting and analysis software includes capabilities such as creating calculated parameters, performing integrals and transforms, and plotting equations. Plot output controls include scaling, labeling, colors, linetypes, symbols, etc. Test data from multiple tests or experiments can be archived on a single CD-ROM, allowing analysis and comparison of the data from different tests within a program.

Test project information is organized into logical groups such as project documentation, financial records, correspondence, safety documents, quality documents, and technical test information.

Standard test reports converted to hypertext documents allow the user to retrieve test information in a nonlinear fashion, jumping to areas of interest at the click of a mouse button. Links to items such as photographs, plots, or drawings allow the integration of text and graphical data, creating a more effective means of conveying information.

AEDC's multimedia CD-ROM capability has been used to archive and distribute data and project documentation for recent Minuteman and Peacekeeper rocket motor and F-119 turbine engine tests at AEDC, as well as BMDO experiments such as COMET and OMS.

The collection of many different types of information such as project documentation, test information, and test data combined on a single compact disk with multimedia, hypertext, and analysis tools gives the user a powerful single source for information about ground tests at AEDC.

AEDC supports a full range of national and international missile, aircraft, and space vehicle programs. The Center's propulsion test cells, aerodynamic and propulsion wind tunnels, space chambers, and ballistic ranges can simulate virtually every aspect of flight from ground level to deep space.

This work was done by Sverdrup Technology Inc., propulsion contractor at the U.S. Air Force's **Arnold Engineering Development Center.** *Inquiries concerning rights for the commercial use of this invention should be addressed to Dale Bradley, AF/DOM Arnold Engineering Development Center, Arnold AFB, TN 37389; (615) 454-4242.*

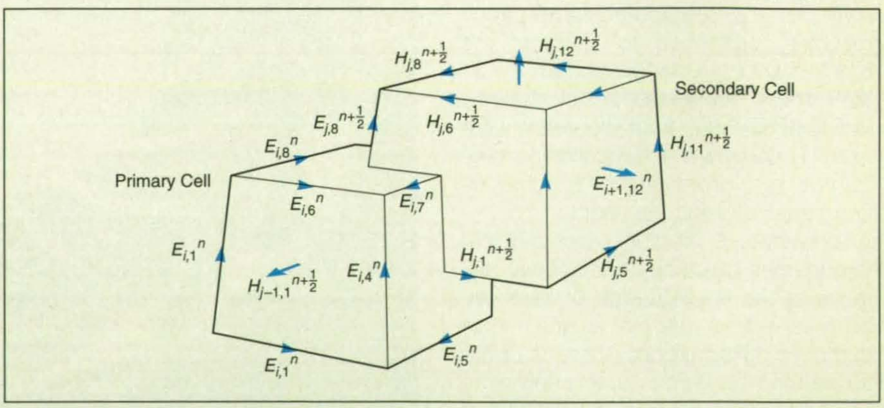
Full-Wave Analysis of MMICs Using a Generalized Yee Algorithm

Complex circuit geometries can be accommodated by use of unstructured and irregular grids.

NASA's Jet Propulsion Laboratory, Pasadena, California

An improved method of temporal analysis of the propagation of electromagnetic waves in monolithic microwave integrated circuits (MMICs) is implemented by a generalized version of the traditional Yee algorithm, which computes a finite-difference time-domain solution of Maxwell's equations on a regular orthogonal grid. Like the traditional Yee algorithm, the generalized Yee algorithm is highly computationally efficient because it is highly vectorizable and has a high degree of parallelism that can be exploited by use of massively parallel, high-performance computers.

In comparison with the traditional Yee algorithm, the generalized Yee algorithm provides more accurate mathematical modeling for analysis and design of MMICs. This is because the generalized Yee algorithm is based on unstructured (in the sense of arbitrary and not necessarily orthogonal) and otherwise irregular grids. Unlike the regular orthogonal grids of the traditional Yee algorithm, unstructured and irregular grids can be readily fitted to conductive and dielectric circuit elements that have realistically complex three-dimensional shapes. Thus, unstructured and irregular grids are better for modeling important and geometrically complex phenomena like fringing fields.



An **Unstructured and Irregular Dual Grid** composed of a primary grid and a secondary grid is used to discretize electric and magnetic fields. Each *E* or *H* symbol with superscripts and subscripts denotes the discretized electric or magnetic field, respectively, at the location of the adjacent arrowhead.

In the generalized Yee algorithm, the electric and magnetic fields are discretized within a closed, three-dimensional volume filled with an unstructured and/or irregular dual grid composed of a primary grid and a secondary grid, as shown in the figure. The primary grid is assumed to be composed of general fitted polygons distributed throughout the volume. The secondary grid is built from those closed polygons, the edges of which are the lines that connect the centroids of adjacent cells of the primary grid; these lines penetrate the faces of the cells of the primary grid. An electric-field vector is defined along each edge of each cell of the primary grid. Similarly, a magnetic-field vector is defined along each edge of each cell of the secondary grid. The amplitude of each such vector is assumed to be constant along its respective cell edge.

The temporal aspect of the Yee algorithm is an explicit time-marching scheme for solving Maxwell's equations in their integral form, using the spatial discretization described above and a central-difference approximation for the time derivative. The surface integrals of Faraday's law and the line integrals of Ampère's circuital law are approximated by discretizing these integrals over each face of each cell of the primary and secondary grid, respectively. For this purpose, the fields are assumed to be constant within their respective faces.

The time-marching scheme updates the magnetic and electric fields perpendicular to faces of the cells of the primary and secondary grids, respectively. However, what are needed are updates of these fields on the cell edges, which, because of the nonorthogonality of the grids, can differ from the perpendiculars to the faces that they penetrate. Therefore, the updated fields are projected onto the edges, using correction factors to maintain accuracy to second order and to maintain the zero divergence of the electric and magnetic fields in the source-free regions.

Since the generalized Yee algorithm is based on unstructured grids, the numerical specifications of the grids must be stored. In addition, each iteration in time involves a significantly greater number of floating-point operations than are needed in the traditional Yee algorithm. Therefore, a method of minimizing the amount of computer memory needed while also minimizing the total number of floating-point operations has been developed. In this method, the time-marching generalized Yee algorithm is treated as a series of linear operations on the fields perpendicular to the faces of the cells. These linear operations can be expressed as a series of matrix·vector multiplications. The matrices are sparse and therefore memory can be conserved by storing only their nonzero values. Furthermore, each matrix need be computed only for the first time iteration, and can be stored and reused for the remaining iterations; this reduces the number of floating-point operations.

The generalized Yee algorithm can be structured in a manner that is highly parallel. For this purpose, the sparse matrices are constructed as an assembly of submatrices that represent the interactions of the field within the cells of the primary grid. By spatially decomposing the global domain into a set of contiguous subdomains, a sparse matrix that represents each subdomain can be constructed, again using an efficient cell-by-cell assembly, completely in parallel. Finally, the sparse-matrix·vector multiplications of these matrices can be performed in a highly parallel fashion, requiring interprocessor communication only to concatenate the solution vectors that represent fields on shared edges and faces.

This work was done by Faiza S. Lansing, Stephen D. Gedney, and Daniel L. Rascoe of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 41*** *on the TSP Request Card.*
NPO-19186

Flow Simulation Software for Flight Aerodynamics

The NPARC package helps solve aerodynamic and propulsion problems before flight.

Engineering Development Center, Arnold Air Force Base, Tennessee

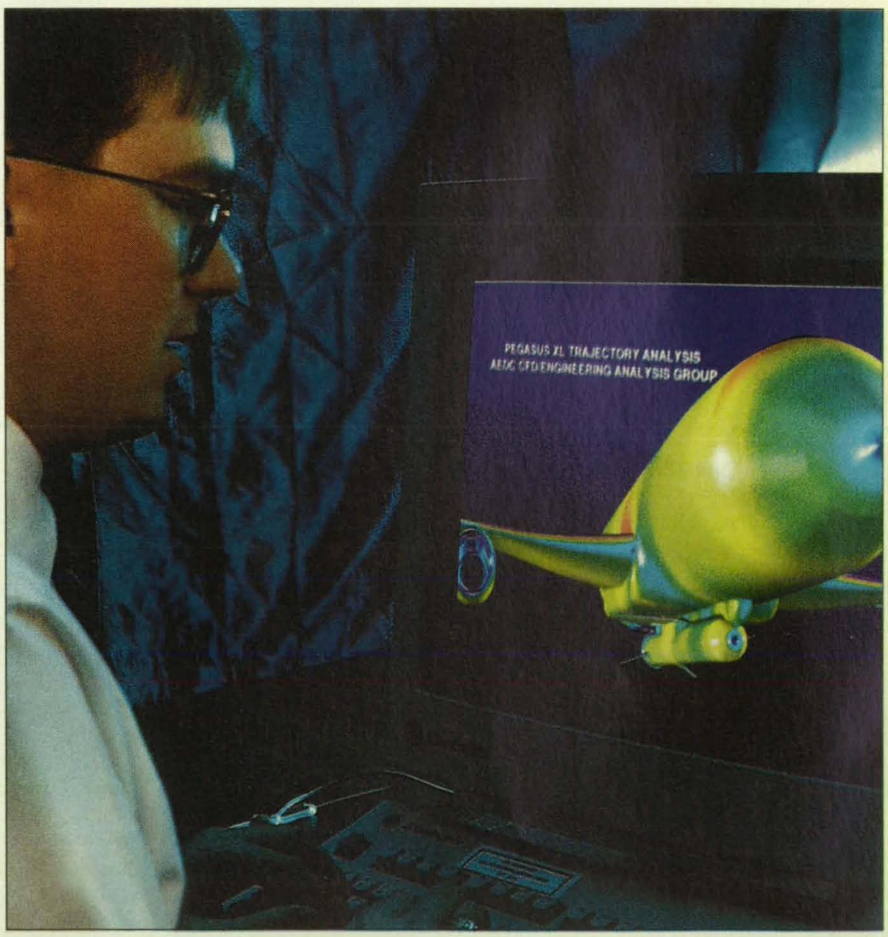
Through an alliance between the Air Force's Arnold Engineering Development Center (AEDC) and NASA's Lewis Research Center, a unique flow simulation software package known as NPARC serves as a national aerospace resource for both government and industry.

The NPARC code is a computational fluid dynamics (CFD) tool that can be applied to a wide variety of aerospace design and analysis problems involving fluid flow. Recent applications of NPARC have contributed to the solution of propulsive problems in areas as diverse as supersonic and hypersonic inlet design, rocket nozzle failure analysis, and turbine engine exhaust mixer design. The code has also proven capable of treating other aerodynamic problems, including missile nose-cone analysis, instrumentation probe design, and ducted flow analysis.

The NPARC code has developed a wide following outside AEDC: more than 100 governmental, industrial, and academic institutions have acquired it.

The alliance that produced NPARC was formed in response to a national need for a productive, user-friendly, well-maintained and documented CFD tool. Further development and support of the NPARC code are intended to address the goals of both the military and the commercial aspects of US competitiveness.

The NPARC code was developed by Sverdrup Technology Inc., the propulsion contractor at the US Air Force's **Arnold Engineering Development Center**. *Inquiries concerning rights for the commercial use of this invention should be addressed to Dr. Ralph Jones or Capt. J. Cossentine, AEDC, Arnold AFB, TN 37389-1099; Jones (615) 454-6876, Cossentine (615) 454-3720.*



An engineer at Arnold Engineering Development Center uses computational fluid dynamics to determine **flow fields** around an aircraft.

Associative Pattern Recognition in Analog VLSI Circuits

A winner-take-all circuit selects a best-match stored pattern.

NASA's Jet Propulsion Laboratory, Pasadena, California

Prototype cascadable very-large-scale integrated (VLSI) circuit chips have been built and tested to demonstrate a concept of electronic associative pattern recognition. Based on low-power, subthreshold analog complementary oxide/semiconductor (CMOS) VLSI circuitry, each chip can store 128 sets (vectors) of 16 analog values (vector components), the vectors representing known patterns as diverse as spectra, histograms, graphs, or brightnesses of pixels in images.

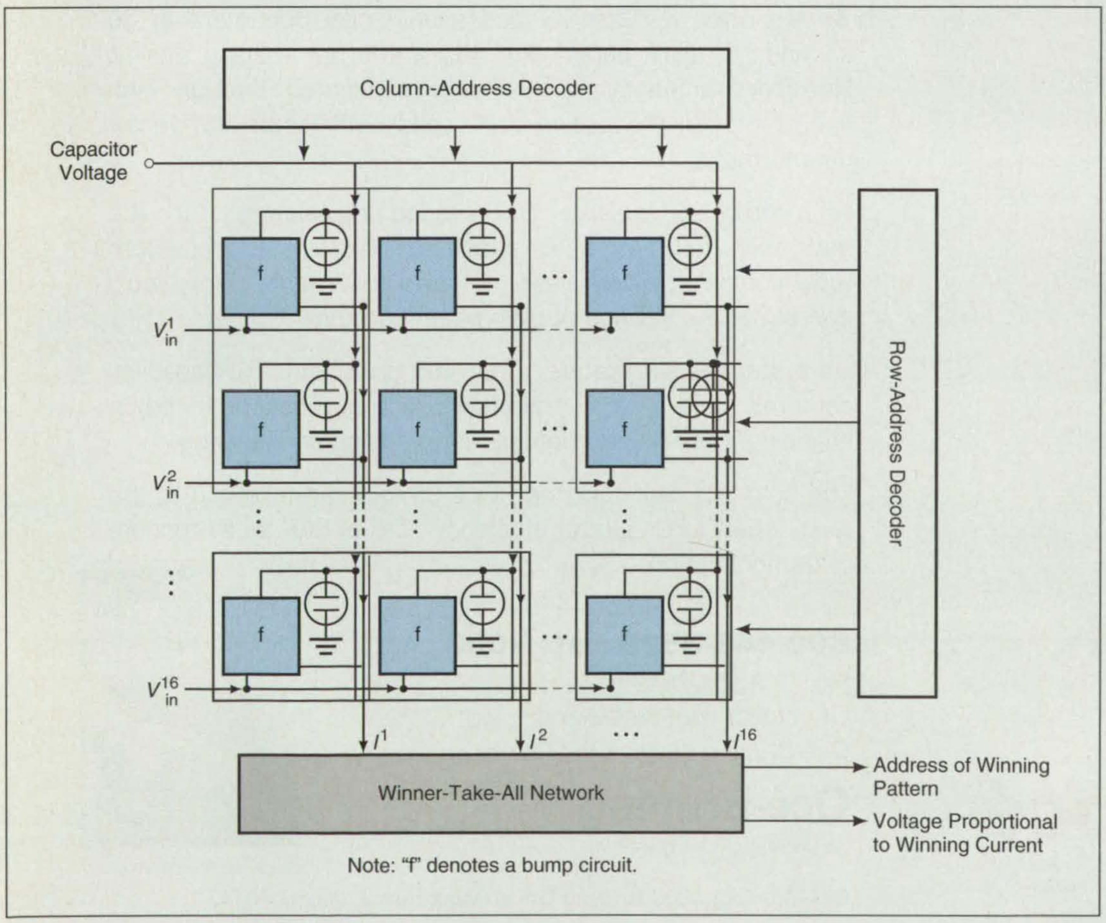
The chips exploit the parallel nature of vector quantization architecture to implement highly parallel processing in relatively simple computational cells. Through collective action, these cells can classify an input pattern in a fraction of a microsecond while consuming a power of a few microwatts. The ultra-low-power characteristic of these chips is due to the subthreshold regime of transistor operation.

In operation, a 16-component input vector that represents a pattern to be recognized is presented to a chip. The input pattern can be partial, fuzzy, or corrupted by noise. In this case, recognition would consist in classification in the sense of establishing a partial or complete match between the input vector and one of the 128 stored 16-component vectors. For this purpose, computational cells in the chip simultaneously produce signals indicative of the closeness of match of each of the 16 components of the input pattern to each corresponding component of each of the 128 stored patterns.

The outputs of the computational cells are currents that are summed over all 16 components of each stored pattern to obtain a total current indicative of the closeness of match of that stored pattern with the input pattern. The total of such currents for all 128 stored patterns are fed to a winner-take-all network, which then chooses the best-match pattern — that is, the one that corresponds to the greatest current.

In the layout of a chip (see figure), the computational cells are arranged in cross-bar matrix fashion in 16 rows and 128 columns, corresponding to the 128 16-component stored vectors. The known vectors are stored in the form of voltages on capacitors in the cells, which voltages are coupled from external circuitry into the cells via row- and column-address decoders. All the cells in the *i*th row receive the *i*th input voltage (V^i_{in}), which represents the *i*th component of the input vector. The cell in the *i*th row and the *j*th column puts out a current indicative of the closeness of match between V^i_{in} and the corresponding voltage of the *i*th component of the *j*th stored vector. This is done in each cell by a "bump" circuit, which generates a current proportional to the square of the hyperbolic secant (approximately a Gaussian function) of the difference between these two voltages. Thus, the output current of each cell is maximum for zero difference (a perfect match) and falls off with increasing difference (decreasing closeness of match). The output currents from all the cells in the *j*th column are summed to obtain a total current I^j, which is fed to the winner-take-all network.

This work was done by Raoul Tawel of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 32*** *on the TSP Request Card.* *NPO-19082*



In the **Associative-Pattern-Recognition Chip**, analog computations take place simultaneously in all cells of the 16 x 128 array. Implemented in CMOS VLSI circuitry, this circuit operates at high speed: When prompted with a 16-component vector of noisy input voltages V^i_{in}, it can recall one of 128 stored vectors in a time <100 μs.

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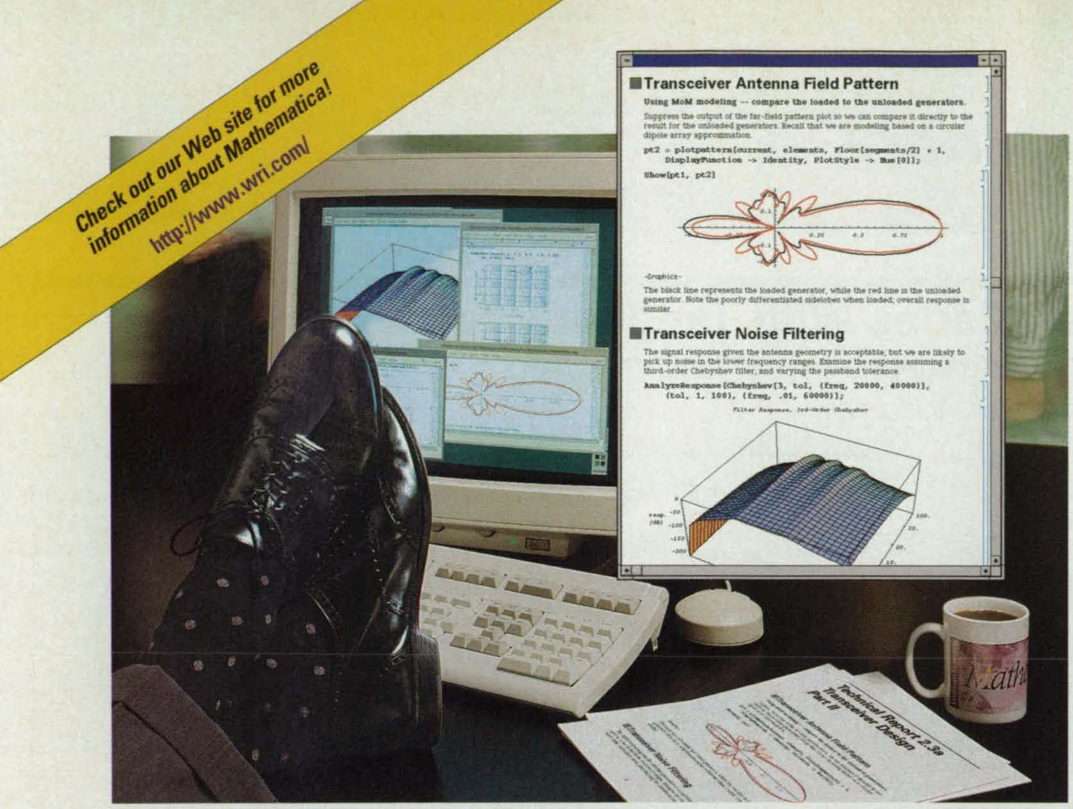

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For More Information Write In No. 561

Swept Inducer Blades With Tandem Radial Slots

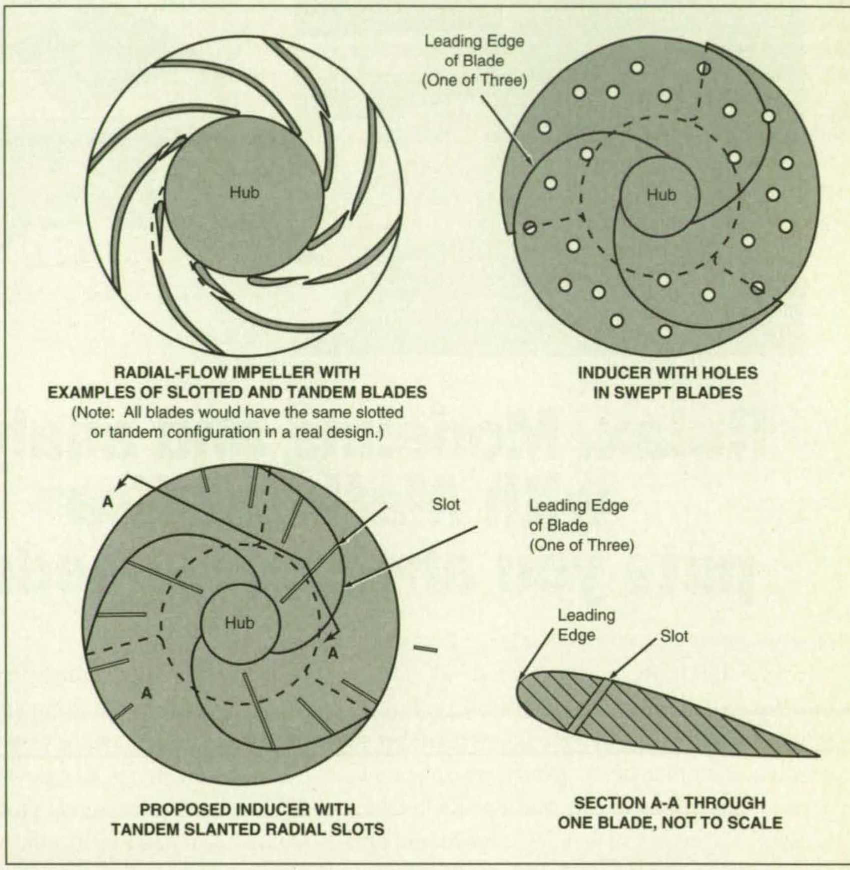
Suitably designed slots would suppress oscillations.

Marshall Space Flight Center, Alabama

Slanted radial slots at tandem positions along approximate streamlines would be incorporated into swept inducer blades in a turbopump, according to a proposal. With suitable design, these slots are expected to suppress low-frequency oscillations induced by cavitation, without causing excessive loss of inducer head. The slots could be cut into the solid blades by wire electrical-discharge machining.

The concept of the tandem radial slots is derived partly from experiments that showed that the amplitudes of the cavitation-induced oscillations were reduced by incorporating round holes into previously solid blades; the oscillations became smaller with increasing total hole area per blade, but so did the loss of inducer head. The concept is also derived partly from previous developments concerning the use of tandem cascades to optimize the performances of turbomachines. According to the concept (see figure), the radial slots would suppress oscillations similarly to the holes in the experiments, while the tandem arrangement of the slots would minimize the loss of inducer head.

The radial configuration of the slots was chosen because, in comparison with other configurations, it would cause the least increase in stresses in the blades. The number of slots per blade would depend on required design margins for protection against stresses and vibrations. The widths, the lengths, and the slant and divergence angles of the slots would be chosen according to design requirements with respect to stresses, dynamics of flow, and total slot area needed to suppress oscillations to the specified degree. In a blade with holes or slots, the loss of inducer head is caused by flow through the holes from the compression side to the suction side; in effect, leakage. In the proposed tandem design, this loss would be minimized by choosing the sizes, shapes, and locations of the slots so that the slots would constitute optimized streamline flow passages.



Slanted Tandem Radial Slots would be added to the swept blades of a turbopump inducer (essentially, an axial-flow impeller). These slots would provide the oscillation-suppression capability of holes, while the tandem configuration would minimize the attendant loss of inducer head.

This work was done by Sen Y. Meng of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information,* ***write in 85*** *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; (205) 544-0021. Refer to MFS-29956

Robotic Bladder Joint

Joints are moved hydraulically, without need for cylinders or gears.

Marshall Space Flight Center, Alabama

Figure 1 illustrates a reliable, lightweight robotic joint that is suitable for a variety of applications. The joint is actuated hydraulically, without need for heavy mechanical cylinders or gears on the joint itself.

The joint includes two members; the first member can rotate about a pin at the end of the second member. The first member includes a cam, over which a tension line (e.g., a rubber band) is stretched. The ends of the tension line are anchored at the end of the second member opposite the end that holds the pin. A bladder is placed on each side of the second member, squeezed between the second member and the tension line. The pressures and/or the amounts of fluid in the bladders are controlled by use of conventional equipment like pumps, valves, and reservoirs.

The bladder on one side can be inflated more than is the bladder on the other side; the greater inflation on one side causes greater stretching of the tension line on that side. The greater tension pulls on the cam, turning the first member toward that side. Thus, the angle of the joint can be controlled by controlling the differential inflation of the two bladders.

A robot hand could be made of fingerlike members with joints of this type. For example, Figure 2 shows a robot hand with a one-joint thumblike member and a two-joint fingerlike member grasping a cylinder.

The basic design of the joint can be modified to suit specific applications. For example, a joint could contain only one bladder, the other one being replaced by a rubber band or spring, which would provide additional tension to oppose the tension generated by the bladder.

This work was done by Glen A. Robertson of **Marshall Space Flight Center.** *For further information,* ***write in 140*** *on the TSP Request Card.*

This invention has been patented by NASA (U.S. Patent No. 5,245,885). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Marshall Space Flight Center; (205) 544-0021. Refer to MFS-28682.

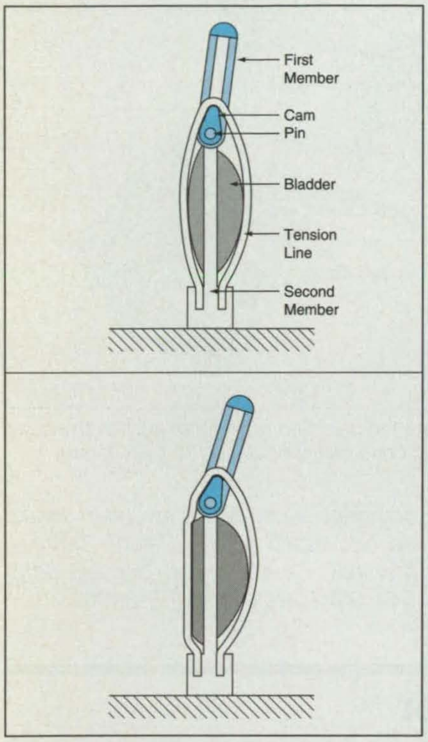


Figure 1. **The First Member Is Turned** to the right by inflating the right bladder more than the left bladder.

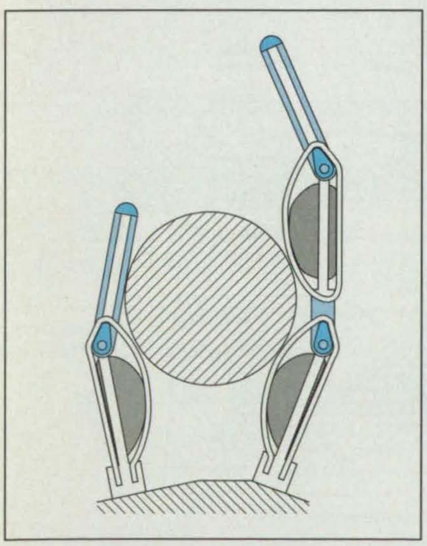
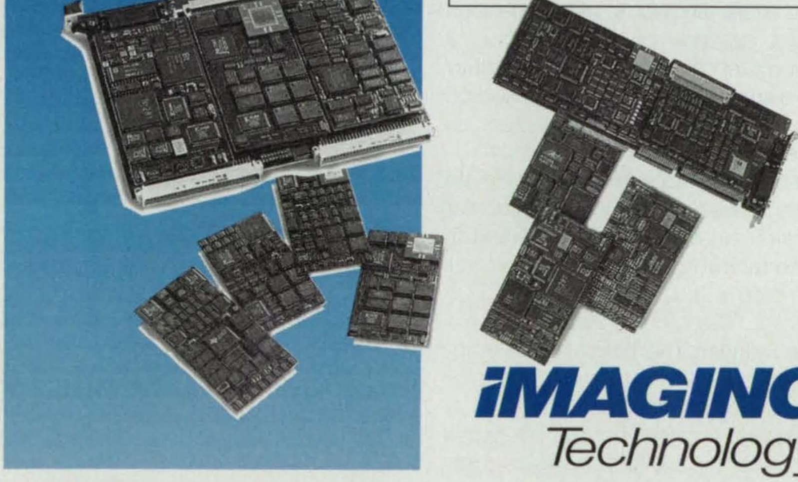


Figure 2. **Bladder Joints in This Robotic Hand** enable it to grasp a cylinder.



Manufacturing/Fabrication

Antident Bearing-Ball Retainer

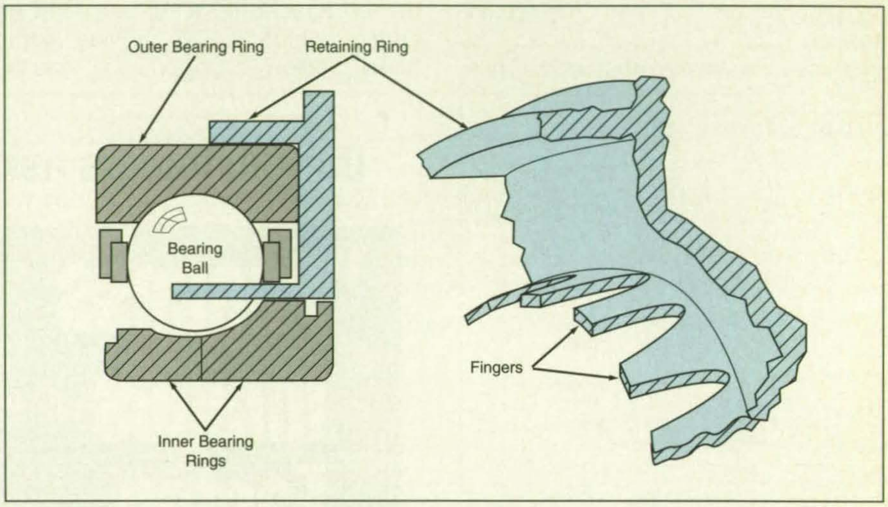
A retaining ring is temporarily attached to the outer bearing ring to prevent indentation.

Marshall Space Flight Center, Alabama

A jig prevents indentation of bearing balls by hard contact with the edges of the inner bearing rings during assembly. The jig is a retaining ring that holds the balls so that they clear each other and clear the inner ring.

The retaining ring eliminates the need for ball-retaining tabs on the bearing cage. The tabs, if used, would have to be sized loosely so that they did not interfere with the balls when the bearing was operating. Also, they cannot always ensure clearance between the balls and the inner ring during assembly.

The retaining ring is positioned with an interference fit on the outer ring (see figure). The retaining ring includes fingers that fit between the balls and force them against the raceway on the outer ring, holding them away from the inner rings during assembly. After the inner rings have been assembled, the retaining ring is removed, and the bearing is ready for service.



The **Retaining Ring** includes fingers that separate the balls and push them against the outer bearing and out of contact with the inner bearing rings during assembly of the bearing.

This work was done by Larry L. Thomas, Jr., of United Technologies 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; (205) 544-0021. Refer to MFS-28902.

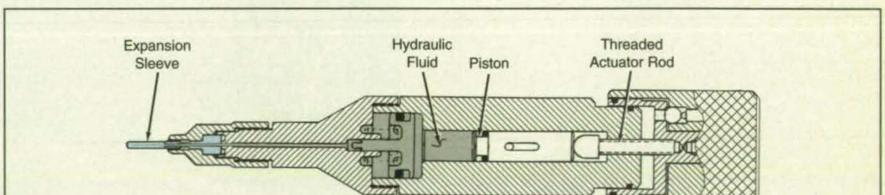
Hand-Operated Hydraulic Tube Expander

A sleeve is expanded hydraulically inside a tube.

Marshall Space Flight Center, Alabama

The figure shows a hand-operated tool that expands an end portion of a narrow metal or plastic tube to a slightly larger diameter. The tool can be used on tubes with original inner diameters as small as 0.060 in. (about 1.5 mm).

The tool includes a replaceable tip that comprises a ferrule and a tubular expansion sleeve sized for a sliding fit into the tube to be expanded. The wall of the sleeve is 0.010 in. (about 0.25 mm) thick. The tool also includes a hydraulic cylinder. The piston in the cylinder is advanced by a threaded actuator rod that is turned by use of an adjustable-torque knurled handle. Because the inside of the expansion sleeve communicates with the hydraulic cylinder, it is subject to the hydraulic pressure generated by turning the handle to advance the piston.



The **Expansion Sleeve** swells in response to internal hydraulic pressure generated by turning the handle and thereby advancing the piston.

In operation, the tool is positioned with the expansion sleeve inside the tube to be expanded. The handle is turned to build up hydraulic pressure, which causes the sleeve to expand against the inside of the tube. The handle is turned until it has been tightened to the breakaway torque, which is set at a level that yields the desired hydraulic pressure, which corresponds to the desired amount of expansion.

In the original application, the torque setting was 10 lb · in. (about 1.1 N · m, corresponding to a hydraulic pressure of 60 kpsi (414 MPa) and an expansion of about 0.0015 in. (about 0.038 mm) per pressure cycle. The expansion sleeves in that application were found to last about 50 cycles, after which it was necessary to anneal them to get further use out of them.

This work was done by David W. Hagan and Edwin D. Wolff of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information,* ***write in 48*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center; (205) 544-0021. Refer to MFS-29979.

Niobium-Matrix-Composite High-Temperature Turbine Blades

Reinforcing fibers can be chosen from among several refractory materials.

Lewis Research Center, Cleveland, Ohio

High-temperature composite-material turbine blades that comprise mainly niobium matrices reinforced with refractory-material fibers are being developed. Of the refractory fibrous materials investigated, FP-Al_2O_3, tungsten, and polymer-based SiC fibers appear to be most promising.

A blade of this type is hollow and is formed in nearly net shape by wrapping a mesh of reinforcing refractory fibers around a molybdenum mandrel, then using thermal-gradient chemical-vapor infiltration (CVI) to fill the interstices with niobium. The CVI process is controllable and repeatable, and the kinetics of both deposition and infiltration are well understood.

After CVI, the end of the blade is cut and the molybdenum mandrel is chemically etched away, leaving the free-standing, hollow niobium/fiber-composite turbine blade. Finally, a layer of iridium about 25 μm or more thick is deposited on both the inside and outside surfaces of the hollow blade for protection against oxidation at temperatures as high as 1,500 °C.

This work was done by Richard B. Kaplan, Robert H. Tuffias, Raffaele La Ferla, Sangvavann Heng, and John T. Harding of Ultramet for **Lewis Research Center**. *For further information,* ***write in 151*** *on the TSP Request Card. LEW-15542*

Robotic-Vehicle Perception Control for Detecting Obstacles

Obstacle-detection systems are designed to make the most of limited data-processing resources.

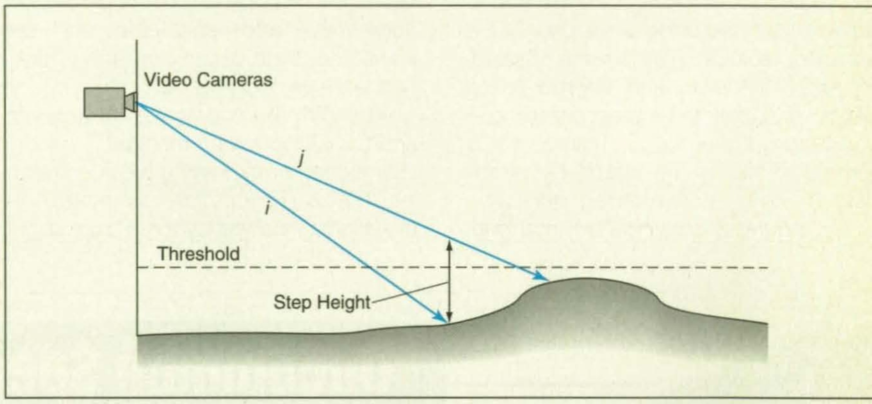
NASA's Jet Propulsion Laboratory, Pasadena, California

A concept of perception control is guiding the continuing development of obstacle-detection systems for cross-country navigation of robotic vehicles that are equipped with stereoscopic machine-vision systems. Perception control consists of optimally tuning sensor or processing parameters to increase efficiency of perception under design constraints and design requirements while adjusting to the environment. This particular concept of perception control is oriented toward the need to maximize vehicular safety at a given speed or, conversely, to determine the maximum speed for a given level of safety.

An obstacle-detection system according to this concept uses computing resources efficiently, without resorting to "brute-force" obstacle-detection techniques that often involve more computation than is necessary. Such a system is designed to implement a focus-of-attention approach, in which data are processed from subwindows of the stereoscopic video images of the path ahead, instead of from the entire images, to reduce the computational cost of perception. The image data are processed in the following main steps:

1. Pyramids (in a symbolic sense) of ver sions of the stereoscopic images that are band-pass-filtered in a succession of spatial-frequency bands are constructed from the stereoscopic pairs of images.
2. Cross-correlations are computed on any single level of an image pyramid to estimate stereoscopic disparity at every pixel of the pair of images.
3. The range (that is, the distance from the video cameras on the robotic vehicle) is computed from the disparity at every pixel.
4. An obstacle-detection algorithm is applied to the resulting range image.

The obstacle-detection algorithm assumes that an obstacle consists of a nearly vertical step displacement on an otherwise nearly flat ground plane. The algorithm does this by using pairs of pixels in the same column of the range image (see figure). If the difference in height between the two pixels in any such pair exceeds a prescribed step height, then an obstacle is deemed to exist at the affected location.



A **Bump or Step** is identified, from stereoscopic images of the scene ahead, by an obstacle-detection algorithm. If the bump or step exceeds a specified step height, it is marked as an obstacle, and control actions are taken to avoid the obstacle.

The obstacle-detection system manages the computing resources by adjusting variables at three levels: image resolution, subwindows of attention (steps 2, 3, and 4 can be performed in subwindows), and detection threshold (which can be varied over the scene). The system takes into account its current look-ahead requirements and determines the part of the path ahead that must be examined for obstacles at each processing step. The system assumes that the vehicle must stop before colliding with an obstacle, and allowance must be made for image-acquisition and -processing time, actuation delay before brakes can be applied, and the braking time to reduce the speed from its current value to zero.

A velocity controller could be designed to operate in conjunction with an obstacle-detection system of this type. The velocity controller could be designed to try to reach the maximum allowable speed, provided that it always checked for the distance to the end of the last processed path segment and applied brakes if necessary (that is, if data on the next path segment did not come in time).

This work was done by Pierrick C. Grandjean and Larry H. Matthies of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 30*** *on the TSP Request Card.*
NPO-19079

Planning Complex Projects Automatically

Artificial-intelligence techniques enable novices to develop practical plans and schedules.

John F. Kennedy Space Center, Florida

The Automated Manifest Planner (AMP) computer program applies a combination of artificial-intelligence techniques to assist both expert and novice planners, reducing planning time by orders of magnitude. It gives planners the flexibility to modify plans and constraints easily, without need for programming expertise.

AMP was developed specifically for planning space shuttle missions 5 to 10 years ahead, but with modifications, it should be applicable in general to planning other complex projects that require scheduling of activities that may depend on other activities and/or timely allocation of resources. AMP should be adaptable to a variety of complex scheduling problems in manufacturing, transportation, business, architecture, and construction, for example.

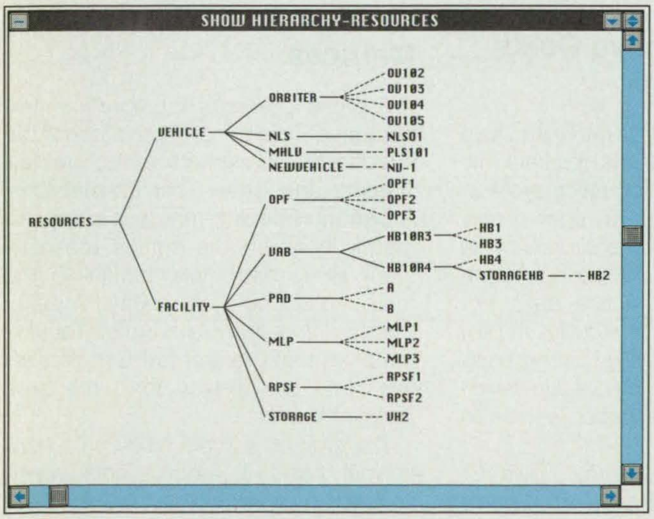
In the original space shuttle application, AMP is used to establish flight manifests; define the objectives, capabilities, and constraints of missions; and translate all of the foregoing into hardware, software, and flight requirements. In formulating plans for a given mission, AMP takes account of plans for other missions, available facilities and workers, and maintenance between missions. AMP can plan the space shuttle missions for one year in about one minute on a personal computer.

AMP contains expert-system software that captures the experience of expert manifest planners and provides comprehensive, interactive manifest planning assistance. Planners can choose among different planning methods for use at various levels of the scheduling process. The resulting manifest has no resource conflicts, breaks no ground rules, and schedules processes in the proper sequences. With help from AMP, even a novice planner can produce a manifest of quality.

AMP follows an object-oriented approach for capturing representations of ground rules, constraints, activities, missions, and resources. The heuristics that planners use to generate and analyze manifests are represented as rules. The planning techniques combine object-oriented programming and rule-inference strategies. The objects are organized into a hierarchical structure (see figure), in which objects in the same class share characteristics. The objects are not passive data but individual intelligent entities that can perform actions on themselves and on each other. They know how to schedule and unschedule themselves and plot and erase themselves.

This work was done by Andrea L. Henke, Richard H. Stottler, and Timothy P. Maher of Stottler Henke Associates, Inc., for **Kennedy Space Center**. *For further information,* ***write in 11*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Kennedy Space Center; (407) 867-3017. Refer to KSC-11742.



Objects Are Organized Into a Hierarchy in AMP. This display shows part of the hierarchy of resources [vehicles (that is, spacecraft) and facilities] in the original space shuttle application.

Books & Reports

These reports, studies, and handbooks are available from NASA as Technical Support Packages (TSPs) when a Request Card number is cited; otherwise they are available from the NASA Center for Aerospace Information.

Electronic Systems

Adaptive Attitude Control System for Space Station

A report presents the theoretical foundation for an attitude control system for the proposed Space Station *Freedom* in orbit around the Earth. The system is intended to maintain the space station in torque equilibrium with designated axes of its structure aligned with the local vertical, local along-trajectory horizontal, and local across-trajectory horizontal axes, respectively. The conceptual control system is required to provide the desired combination of control performance and stability in the presence of disturbances (e.g., variations in masses of payloads, movements of astronauts and equipment, atmospheric drag, gravitational anomalies, and interactions with docking spacecraft).

This work was done by Dhemetrios Boussalis, David S. Bayard, and Shyh J. Wang of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Adaptive Spacecraft Attitude Control With Application to Space Station,"* ***write in 109*** *on the TSP Request Card. NPO-19422*

Transponders for Use Aboard Distant Spacecraft

A report proposes three advanced architectures for transponders to be used in deep space. In comparison with older deep-space transponder architectures, the proposed architectures would offer greater reliability, faster acquisition of and better performance in tracking weak signals, and better telemetry performance on the downlinks.

This work was done by Tien M. Nguyen, Selahattin Kayalar, Hen-Geul Yeh, and Charles Kyriacou of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Advanced Transponders for Deep Space Applications,"* ***write in 65*** *on the TSP Request Card. NPO-19189*

Materials

Replacing Chlorinated-Solvent-Based Cleaners and Adhesives

A brief report describes tests that were conducted to assess the feasibility of using selected chemicals as replacements for selected cleaners, primers, and adhesives that contain chlorinated solvents. The cleaners, primers, and adhesives in question are used in bonding insulating material in steel cases of solid-fuel rocket motors. It is necessary to phase out the use of chlorinated solvents because of concerns over toxicity and adverse effects on the ozone layer in the upper atmosphere.

This work was done by Harley Heaton and Fred Davidson of Atlantic Research Corp. for **Marshall Space Flight Center.** *To obtain a copy of the report, "Development of Environmentally-Friendly Bondline Processing Procedures,"* ***write in 70*** *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; (205) 544-0021. Refer to MFS-28875.

Tests of Protective Coats for Carbon Steel

A report describes laboratory and field tests of candidate paints (primers, tie coats, and topcoats) for use in protecting carbon-steel structures against corrosion in the seaside environment at Kennedy Space Center. Coating materials were selected for these tests, not only because of their likely utility in preventing corrosion but also on the basis of legal requirements, imposed in several urban areas, for reduction of volatile organic contents.

This work was done by Louis G. MacDowell III of **Kennedy Space Center.** *To obtain a copy of the report, "Volatile Organic Content (VOC) Compliant Coating for Carbon Steel Exposed to the STS Launch Environment — Application, Laboratory and 18-Month Exposure Results,"* ***write in 73*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Kennedy Space Center; (407) 867-3017. Refer to KSC-11656

Properties and Potential Applications of NiAl

A report provides a critical assessment of the literature on nickel aluminide. This intermetallic compound has a crystalline structure that consists of two interpenetrating cubic lattices. The high melting temperature and high thermal conductivity make NiAl useful as a coating on turbine blades and vanes. NiAl is being studied as a candidate for replacement of conventional superalloys in jet engines, and NiAl interconnections are being embedded in semiconductor devices.

This work was done by Ronald D. Noebe, Randy R. Bowman, and Michael V. Nathal of **Lewis Research Center.** *To obtain a copy of the report "Review of the Physical and Mechanical Properties and Potential Applications of the B2 Compound NiAl,"* ***write in 68*** *on the TSP Request Card. LEW-15911*

Mathematics and Information Sciences

Asymptotic Spectra of Banded Quasi-Toeplitz Matrices

A paper presents a theoretical and numerical study of the asymptotic spectra of the eigenvalues of banded Toeplitz and quasi-Toeplitz matrices. A banded Toeplitz matrix is a square matrix in which the entries are constant along diagonals parallel to the main diagonal. A quasi-Toeplitz matrix differs from a banded Toeplitz matrix in that the first few and the last few rows are altered from the pure Toeplitz form.

The emphasis in the study is on non-normal banded Toeplitz and quasi-Toeplitz matrices of arbitrarily large order and relatively small bandwidth: such matrices appear in connection with finite-difference approximations of partial differential equations. Quasi-Toeplitz matrices arise from non-Dirichlet boundary conditions for the finite-difference approximations. The eigenvalue problem for a banded Toeplitz or quasi-Toeplitz matrix of large order is, in general, analytically intractable and, in the nonnormal case, numerically unreliable.

This work was done by Richard Beam and Robert Warming of **Ames Research Center.** *For further information,* ***write in 59*** *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; (415) 604-5104. Refer to ARC-13222.

Total-System Approach to Design and Analysis of Structures

A paper presents an overview and study of, and a comprehensive approach to, the multidisciplinary engineering design and analysis of structures. The paper emphasizes issues related to the design of semistatic structures in environments in which spacecraft are launched, but the underlying concepts are applicable to other structures within their unique terrestrial, marine, or flight environments. The purpose of the study was to understand the interactions (essentially, the flows of information and tasks) among traditionally separate engineering design disciplines with a view toward optimizing not only the structure but also the overall design process.

This work was done by V. Verderaime of **Marshall Space Flight Center.** *To obtain a copy of the report "Total Systems Design and Analysis of High Performance Structures,"* ***write in 111*** *on the TSP Request Card. MFS-28942*

Uses and Characteristics of Dynamic Tradeoff Evaluation

A report discusses the basic concepts, some applications, and performance characteristics of dynamic tradeoff evaluation (DTE). The basic concepts of DTE were also described in "Dynamic Restructuring of Problems in Artificial Intelligence" (NPO-18488), *NASA Tech Briefs*, Vol. 16, No. 10 (October, 1992), page 103. DTE is a method of enhancing the real-time performance of an artificial-intelligence system such as might be used to monitor data from multiple sensors in a factory, aircraft, spacecraft, or other complex system of equipment. The essence of the DTE approach is to (1) detect situations in which real-time constraints exclude optimal problem-solving strategies and (2) effect tradeoffs among nonoptimal strategies in such a way as to minimize adverse effects. The report presents an evaluation of DTE as applied to spacecraft-monitoring problems.

This work was done by Ursula M. Schwuttke of Caltech for **NASA's Jet Propulsion Laboratory.** *To obtain a copy of the report, "Improving Real-Time Performance of Intelligent Systems with Dynamic Trade-off Evaluation,"* ***write in 10*** *on the TSP Request Card. NPO-19314*

Electronic Components and Circuits

Designing a Mode Converter for Use With a Gyrotron

A report describes the process of designing a corrugated, circular-cross-section length of waveguide that converts input electromagnetic radiation at a frequency of 34.5 GHz in the TM_{11} mode to output radiation in the HE_{11} mode. The TM_{11}-mode input radiation is to be supplied by (1) a gyrotron that generates continuous-wave power of 200 kW at 34.5 GHz in the TE_{01} mode followed by (2) a TE_{01}-to-TM_{11} mode converter. Together, the gyrotron and mode converters constitute a prototype high-power transmitter for long-distance free-space communication.

This work was done by Daniel J. Hoppe of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "A 34.5-GHz 200 kW CW TM_{11}-HE_{11} Mode Converter for Gyrotron Applications,"* ***write in 119*** *on the TSP Request Card. NPO-19352*

Analysis of Performance of a Thick Dichroic Microwave Panel

A report describes theoretical and experimental studies of the performance of a thick dichroic microwave panel that comprises a honeycomblike planar array of cross-shaped, waveguidelike apertures separated by thin metal walls. Except for some small changes in dimensions, the design of this panel is identical to one of the designs described in "Two Thick Microwave Dichroic Panels" (NPO-18887), *NASA Tech Briefs*, Vol. 18, No. 11 (November, 1994), page 33. The design was formulated to provide high transmissivity at frequencies of 7.165 and 8.425 GHz and high reflectivity from 2.0 to 2.32 GHz, both with low insertion loss and an angle of incidence of 30°. In the theoretical study, a modal analysis of the electromagnetic field was performed, using a thin-wall approximation and an integral-equation, method-of-moments approach, with matching of rectangular-waveguide modes inside the apertures to exterior Floquet modes. As a check on the error introduced by the thin-wall approximation, the same approach was applied to a similar panel in which the crosses were reduced to limiting square shapes. As a final check, a prototype of the panel was built and tested.

This work was done by Larry W. Epp and Philip H. Stanton of Caltech, and Roy E. Jorgenson of Sandia National Laboratory for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Experimental And Modal Verification of an Integral Equation Solution for a Thin-Walled Dichroic Plate With Cross-Shaped Holes,"* ***write in 60*** *on the TSP Request Card.* *NPO-19195*

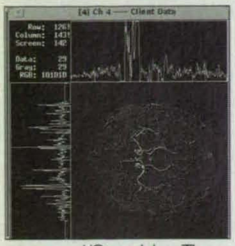
Manufacturing/ Fabrication

Assembly Platform for Use in Outer Space

A report describes a conceptual platform or, more precisely, a framework for use in assembling other structures and spacecraft in outer space. The platform would consist of three fixed structural beams comprising a central beam and two cross beams. Robotic manipulators could be spaced apart on the platform to provide telerobotic operation of the platform by either space-station or ground crews. It is expected that the platform and attached vehicles would function synergistically to achieve maximum performance for their intended purposes.

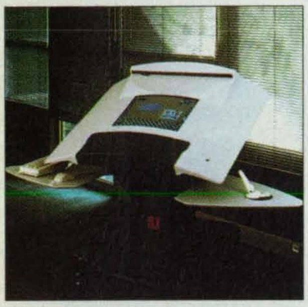
This work was done by Niranjan S. Rao and Patricia A. Buddington of Boeing Co. for **Marshall Space Flight Center.** *To obtain a copy of the report, "I-Beam Assembly Platform Concept for the Mars Transfer Vehicle,"* ***write in 2*** *on the TSP Request Card.* *MFS-28912*

Product of the Month



General Imaging Corp., Billerica, MA, has introduced what it calls the world's fastest **signal/image processor**. Capable of 30 billion operations/second, the MegaPIPE integrates object-oriented design/control software with CPU-I/O balance hardware within a single, scalable environment. Included are a mother card and up to 15 daughter cards within a 19" rackmount-sized enclosure. Daughter cards can be multiple C80 DSPs, neural network cards, convolver cards, warper, or I/O modules. They can communicate via a non-blocking 32x32 or 64x64 serial I/O design that supports 5 gb/second of I/O communication and dynamic reconfiguration. Applications include on-demand video, machine vision (inspection/defect analysis), medical imaging, and remote sensing.

For More Information Write In No. 700



Graphic Instinct™, **a computerized drawing board** from Lectra Systems, Marietta, GA, is a fully interactive, high-resolution (1280x1024) sketch pad for product designers. It features a pressure-sensitive, electronic pen that can simulate a felt-tip marker, pencil, pen, or brush for natural sketching. The system allows designers to draw freehand while providing the advantages of a computer, such as creating and saving a concept, modifying the concept, and importing and exporting from and to other design systems and computers.

For More Information Write In No. 701

Leica Inc., Deerfield, IL, offers two models of **stereomicroscopes**: the MS5 with a five-step magnification changer, and the MZ6 with a 6:1 zoom. Both are ergonomically designed, modular, combinable, and have a range of accessories such as a photomicrographic or video system. Features include easy-to-use control knobs for incident and transmitted light, a choice of six binocular tubes with various viewing heights, and a system of two parallel beam paths and a common main objective for fatigue-free observation.

For More Information Write In No. 702

Schneeberger Inc., Bedford, MA, has announced the MRZ **stainless steel sealing plug** for its Monorail Guideways with rollers. The plug is used in machine applications where effective sealing of the rail mounting holes is critical to ensure long operational linear bearing life. The two-piece plug provides a leakproof seal above the mounting screws in the rail, and is used in applications where plastic or brass plugs cannot, such as machine assemblies with rails uncovered and exposed to chips and/or coolants.

For More Information Write In No. 703

The Models XP-300 and XP-301 **pencil/pen plotters** from Mutoh America Inc., Mt. Prospect, IL, feature a maximum plotting speed of 45 inches per second and an acceleration rate of 4 Gs. Features include automatic pencil loading so a plot is never interrupted, a plotter carousel that holds up to eight drawing devices and mixes pen ink and pencil lead in the same drawing, and an adjustable Y-axis paper setting that accommodates any paper width. The plotters have mechanical resolution of 0.0002" per step, repeatability of ±0.004", and an end-point accuracy of ±0.2%.

For More Information Write In No. 704

A VGA, multi-color, electroluminescent (EL) **flat panel display** from Planar Systems Inc., Beaverton, OR, features a wide viewing angle, high brightness, fast response time, and an operating temperature range of -25° C to +65°C. The 10-inch-diagonal, 640.480 display is resistant to shock, vibration, and humidity, and offers eight colors on a black background. The combinations of red, yellow, and green produce a light output of 23 cd/m2.

For More Information Write In No. 705

A **PVA sponge material** for engineers designing new or upgraded OEM products requiring liquid absorption or application is available from Shima American Corp., Elmhurst, IL. The synthetic, hydrophilic, polyvinyl alcohol material is chemical-resistant for use with solvents, gasolines, acids, and alkalis. It can be custom-formed in a variety of shapes, colors, porosities, and hardness levels, in sheet, block, or tube/roller configurations.

For More Information Write In No. 706

MicroScribe-3D™ from Immersion Corp., Santa Clara, CA, is a high-resolution **3D digitizing device** that allows users to generate detailed computer models by tracing the surface of physical objects, clay models, or mechanical parts. The models can be saved in standard file formats and exported to 3D graphics products and CAD/CAM packages. Its lightweight, graphite mechanical arm is optimized for accuracy and range of motion. The system provides a 50" spherical work space with a mean accuracy of 0.02".

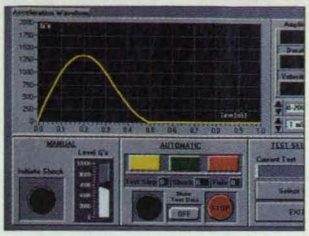
For More Information Write In No. 707

The OF Series of **photoelectric sensors** from efector inc., Exton, PA, measures 12 mm in diameter and provides self-diagnostic features normally not available in larger sensors. The three-wire DC sensors are available in thru-beam, retroreflective, polarized retroreflective, diffuse reflective, and a tightly focused diffuse reflective configuration with a range of 800 mm.

For More Information Write In No. 708

Cambridge AccuSense Inc., Shirley, MA, offers the MDPS line of **differential pressure sensors** for measurement ranges as low as 0-0.1 inch of water. The devices are temperature-compensated to remain within a 10 percent error rate, and are available in standard and custom-calibrated ranges. They feature input tolerance of 9 to 18 volts. Suited for monitoring or controlling constant differential pressures in isolation rooms, cleanrooms, and laboratories, the sensors feature stability over time, shock and vibration resistance, and mounting flexibility.

For More Information Write In No. 709

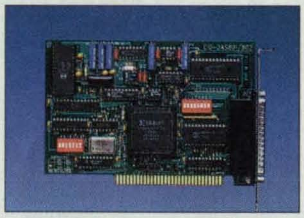


The BW-MST-E5000 **mechanical shock test system** from B&W Engineering Corp., Costa Mesa, CA, tests electronic components such as ICs, switches, relays, fiber-optic devices, cellular phone handsets, computer disk drives, PC boards, keyboards, and remote controls. The benchtop system, priced at $12,995, delivers up to 3000 Gs half sine and generates test reports for documentation.

For More Information Write In No. 710

Berkeley Process Control Inc., Richmond, CA, has introduced the MachineWorks™ **machine control system** for direct multitasking machine control without programming or control expertise. Designed for sequential machine applications from flying shears to complex machine tools, the system uses the Direct Machine Control (DMC) technique to design and diagnose tasks. The system breaks down the elements of motion, I/O, math, and logic into manageable increments for selection and sequencing.

For More Information Write In No. 711



The CIO-DAS801 eight-channel, 12-bit **analog-to-digital board** from ComputerBoards Inc., Mansfield, MA features 50 KHz speed under Windows, channel-by-channel input mode selectivity, a 256-sample FIFO buffer, a choice of high or low gains, an improved channel sequencer, digital I/O, and three 16-bit, on-board counters. Single-ended or differential mode inputs on individual channels in a variety of bipolar and unipolar ranges can be selected.

For More Information Write in No. 712

Farmington Engineering Inc., Madison, CT, has announced a line of Cv **expansion plugs** for sealing cross-drilled holes in metal manifolds and castings. The single-piece assembly is available in both English and metric diameters from 0.156" to 0.562" and from 4 mm to 14 mm. Manufactured from carbon steel, 303 stainless steel, 416 stainless steel, brass, or aluminum, the plug material can exactly match the installation hole material.

For More Information Write In No. 713

New Literature

Sci-Tech International Inc., Chicago, IL, has released a catalog of **scientific, engineering, and technical software** featuring 1850 products, including 100 new instructional products, for DOS, Windows, Macintosh, and UNIX workstations. The 166-page publication also carries articles on visualization and data analysis tools.

For More Information Write In No. 725

A catalog of new **data acquisition** products and applications from Keithley MetraByte, Taunton, MA, includes a new, portable data acquisition chassis; a set of integrated Visual Basic custom controls; the Field PC, a rugged, portable data acquisition system for harsh environments; and portable solutions such as 1 GHz waveform digitizer boards.

For More Information Write In No. 726

Plastic Design Library's Rapra Abstracts CD-ROM, from William Andrew Inc., Norwich, NY, is the world's largest compilation of **plastics and rubber information**, containing over 450,000 abstracts. With references collected from over 500 journals in 30 countries, as well as books, reports, and other literature, the Windows™ single-screen interface database comprises indexed summaries encompassing technical, academic, commercial, and marketing aspects of plastics and rubbers industries.

For More Information Write In No. 727

ASM International, Materials Park, OH, has published *Nondestructive Testing*, a 225-page book featuring a wide range of **NDT methods and techniques** covering problems and defects that arise in mechanical devices, electrical equipment, hydraulic systems, and transportation mechanisms. Besides practical hints for resolving day-to-day problems, the text provides the theory behind each method so the most appropriate one can be selected and used.

For More Information Write In No. 728

A Windows-based CD-ROM electronic **motor and drives catalog** from Baldor Electric Company, Fort Smith, AR, carries information on over 4000 of the company's motors and drives, including AC and DC motors; inverter, vector, and DC drives; servo drives; and soft-starters. For each product, the database holds a dimension drawing; performance specs, a connection diagram, and information on replacement parts.

For More Information Write In No. 729

Pentek Inc., Norwood, NJ, offers an 87-page catalog of **data acquisition and DSP products** for VMEbus and Multibus applications. Products include MIX modules such as floating point DSP processors, digital I/O, T1/CEPT, multichannel A/D conversion, very high-speed A/D conversion, telecommunication interfaces, SCSI and RS-232C interfaces, multichannel digital audio, and a prototyping module; processor products; and software.

For More Information Write In No. 730

An **automation components** catalog introduced by Techno-Sommer Automatic, New Hyde Park, NY, features over 650 automation components, with major sections on grippers, tool changers, swivel units, linear actuators, rotary actuators, vacuum cup devices, and lubrication products. The 98-page pneumatic gripper section presents 112 models such as pivoting arm, parallel, minifinger, and 3 jaw.

For More Information Write In No. 731

Galco Industrial Electronics, Madison Heights, MI, has published a new version of its **industrial electronics repair capabilities** manual, which includes repair pricing for over 32,000 electronic products from more than 1200 manufacturers. The company has added calibration and remanufactured circuit board purchase/exchange programs to its existing specialty repair of AC/DC drives, CNC controls, and PLC products.

For More Information Write In No. 732

New Literature

The ActionJac™ **electric cylinder actuator** design guide from Nook Industries Inc., Cleveland, OH, provides detailed engineering drawings and data. Made for precise positioning of heavy loads, the electric cylinders are alternatives to traditional hydraulic systems.

For More Information Write In No. 733

StacoSwitch Inc., Costa Mesa, CA, has released its 24-page **single lamp lighted and unlighted switches** catalog. Withstanding severe environments in military, industrial and commercial settings, these switches offer rugged field-proven performance at a reasonable price. A variety of lighting and legend options are available.

For More Information Write In No. 734

A **high-temperature epoxy, electronic and structural adhesives** handbook offered by Cotronics Corp., Brooklyn, NY, presents technical data, typical applications, literature, photos, and illustrations concerning epoxies, ceramics, and specialty adhesives for uses up to 2205° C. Duralco adhesives adhere to metals, ceramics, and plastics and offer corrosion resistance and dielectric properties for applications such as assembly, castings, tooling, potting, and repair.

For More Information Write In No. 735

Setra Systems Inc., Acton, MA, has introduced a free **pressure transducer** handbook to help design engineers understand, specify, and apply capacitive pressure transducers. The book includes a selection guide, a comparison of strain gauge vs. capacitive technology, and in-depth information on transducer accuracy, stability, and circuitry.

For More Information Write In No. 736

Nolo Press, Berkeley, CA, offers *Patent, Copyright and Trademark: A Desk Reference to Intellectual Property Law* for inventors, programmers, and anyone who needs to understand the complexities and terminology of intellectual property law. It provides an overview and straightforward explanations of **patent and copyright law protection**, concise definitions of terminology with contextual examples, and sample nondisclosure agreements.

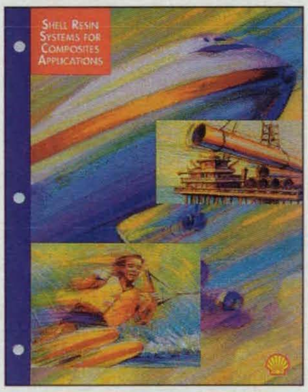
For More Information Write In No. 737

Mat-Vac Technology Inc., Flagler Beach, FL, has announced its 30-page 1995 **thin film materials** catalog, with a selection of high-purity sputtering targets, target bonding, evaporation materials, rods, sputtering systems parts, and electron beam gun crucible liners.

For More Information Write In No. 738

The 2nd Edition *1995 Master Source-Book* from Industrial Computer Source, San Diego, CA, is a 192-page catalog of more than 1500 **data acquisition and control** items, including computer, I/O, networking, and software products. The catalog features CPUs, rack-mount bays, instrumentation cards, peripherals, controllers, and accessories.

For More Information Write In No. 739



Shell Chemical Co., Houston, TX, has introduced *Shell Resin Systems for Composite Applications*, an eight-page brochure describing **resin systems** for use by composite part fabricators. Included are epoxy resins, epoxy modifiers, curing agents, and a technical summary chart of physical properties.

For More Information Write In No. 740

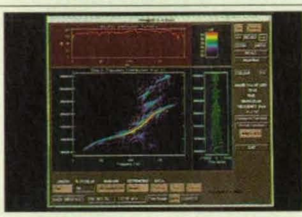
The 1995 IC Master CD-ROM Plus from Hearst Business Publishing, Garden City, NY, includes product information on 108,000 **integrated circuits**, including more than 20,000 new devices. The catalog includes an alternate source directory, manufacturers' data pages, and a manufacturers and distributors directory.

For More Information Write In No. 741

New on Disk

Westing Software, Corte Madera, CA, has released Computer-Aided Research and Development (CARD™) **experiment design software** for scientists and engineers in product, process, and quality R&D. The user selects a number of design options, and CARD provides the information content of each option in simple terms. A Navigator guides the user to the right experiment design based on research goals and resource limitations. The package costs $495.

For More Information Write In No. 751



IDL 4.0 **scientific/engineering software** from Research Systems Inc., Boulder, CO, enhances data analysis and visualization and accelerates application development. The program includes mathematics and statistics that meet or exceed dedicated analysis package capabilities. Application connectivity allows users to call outside programs. The price for Windows, Windows NT, Macintosh, and native Power Macintosh versions is $1500; UNIX and VMS versions start at $3000.

For More Information Write In No. 752

DEA, a division of Brown & Sharpe Manufacturing Co., North Kingstown, RI, has introduced Chorus™ **measuring and inspection software.** A DMIS-based operator interface incorporates point-and-click selection of functions such as dimensional measurement, surface generation and analysis, elementary measuring cycles, part alignment compensation, and automatic calibration of multiple probe configurations.

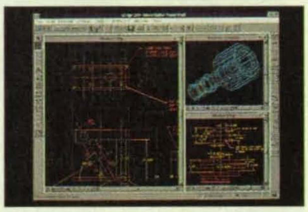
For More Information Write In No. 756

MicroStation PowerDraft™ 2D and 3D **production drafting software** from Bentley Systems Inc., Exton, PA, reduces time spent detailing designs by providing focused drafting capabilities and the ability to customize with the MicroStation BASIC language. The program is available for $1950 in Windows, Windows NT, and DOS platforms, and will be available on Windows 95.

For More Information Write In No. 757

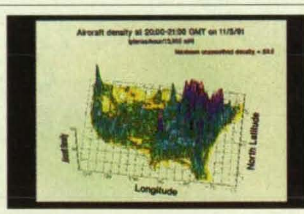
MLAB (Modeling LABoratory) **mathematical modeling software** from Civilized Software Inc., Bethesda, MD, features curve-fitting and differential equation capabilities, dynamic system modeling capabilities, and a range of mathematical and statistical functions. Differential equations are solved by an algorithm that automatically selects the method and step size for each solution, minimizing errors and computer time. It offers more than 400 built-in functions from the areas of mathematics, probability and statistics, and signal analysis. Prices start at $1495 for the DOS version.

For More Information Write In No. 755



InfoNow Corp., Boulder, CO, offers EvaluWare™ Try-Before-You-Buy, a **CD-ROM of engineering software packages** that simplifies the process of searching for, evaluating, and purchasing technical software. More than 80 fully functional software packages include shareware and NASA-developed applications from the COSMIC library. Users can test-drive each package, purchase the software from the CD-ROM, and have it downloaded to their PC. The CD-ROM costs $29.95, which is refunded with the first purchase.

For More Information Write In No. 754



GraphiC™ **scientific drawing software** from Scientific Endeavors Corp., Kingston, TN, is a platform-independent C library that encompasses over 240 functions, enabling users to write scientific graphing programs without GUI programming. Linear and logarithmic X-Y plots; 3D surfaces; and polar, pie, bar, and Smith charts can be created. Three-dimensional surfaces are shaded to allow color changes. Various C procedures and functions are combined with sample graphs to write original programs. Program output can be converted to most file formats, and can be imported to desktop publishing packages or used directly in scientific publications. The DOS version costs $465; all other platforms are $495.

For More Information Write In No. 753

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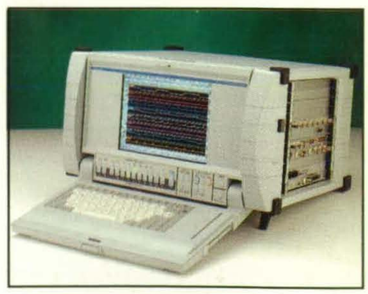

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