NASA Tech Briefs

Official Publication of the
National Aeronautics and
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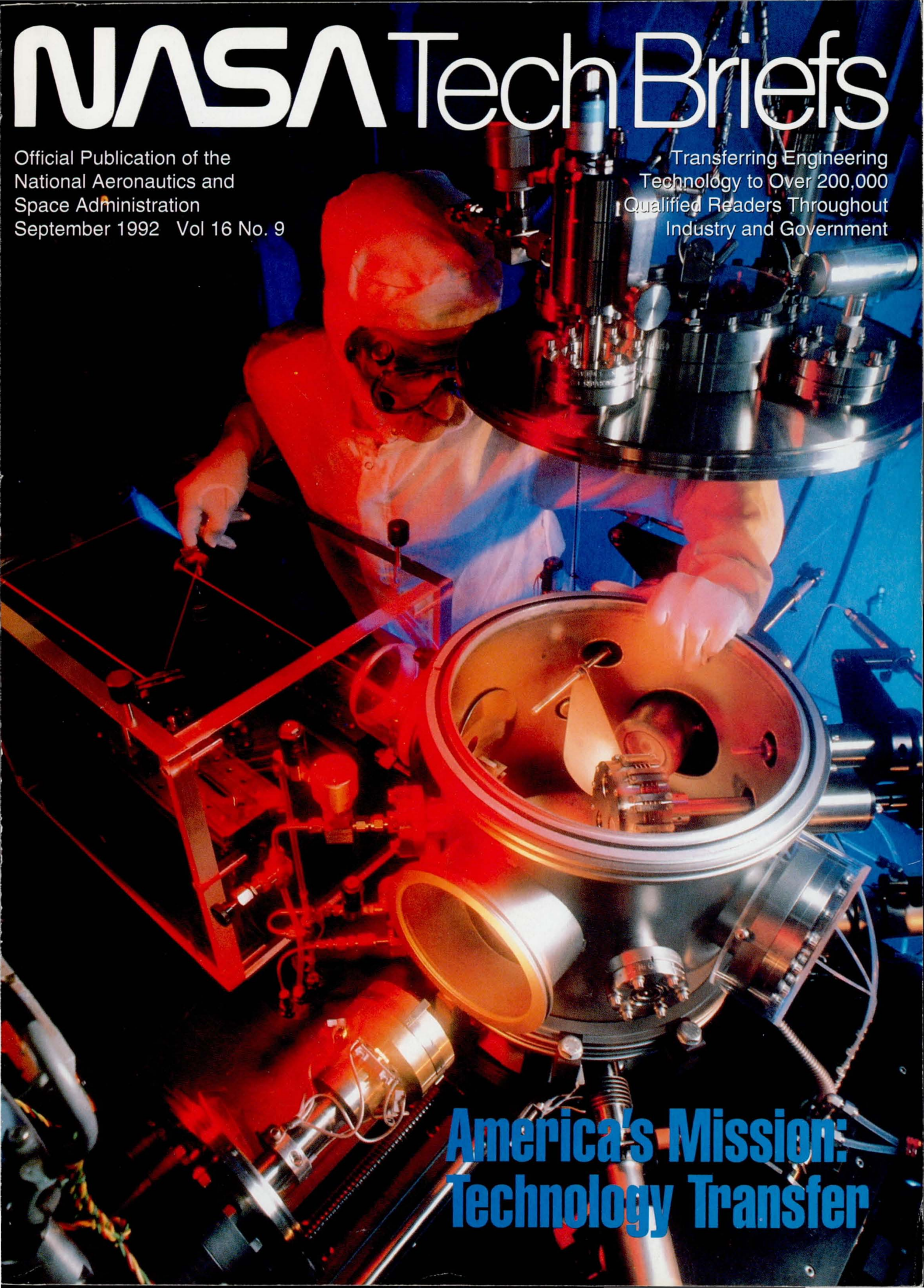

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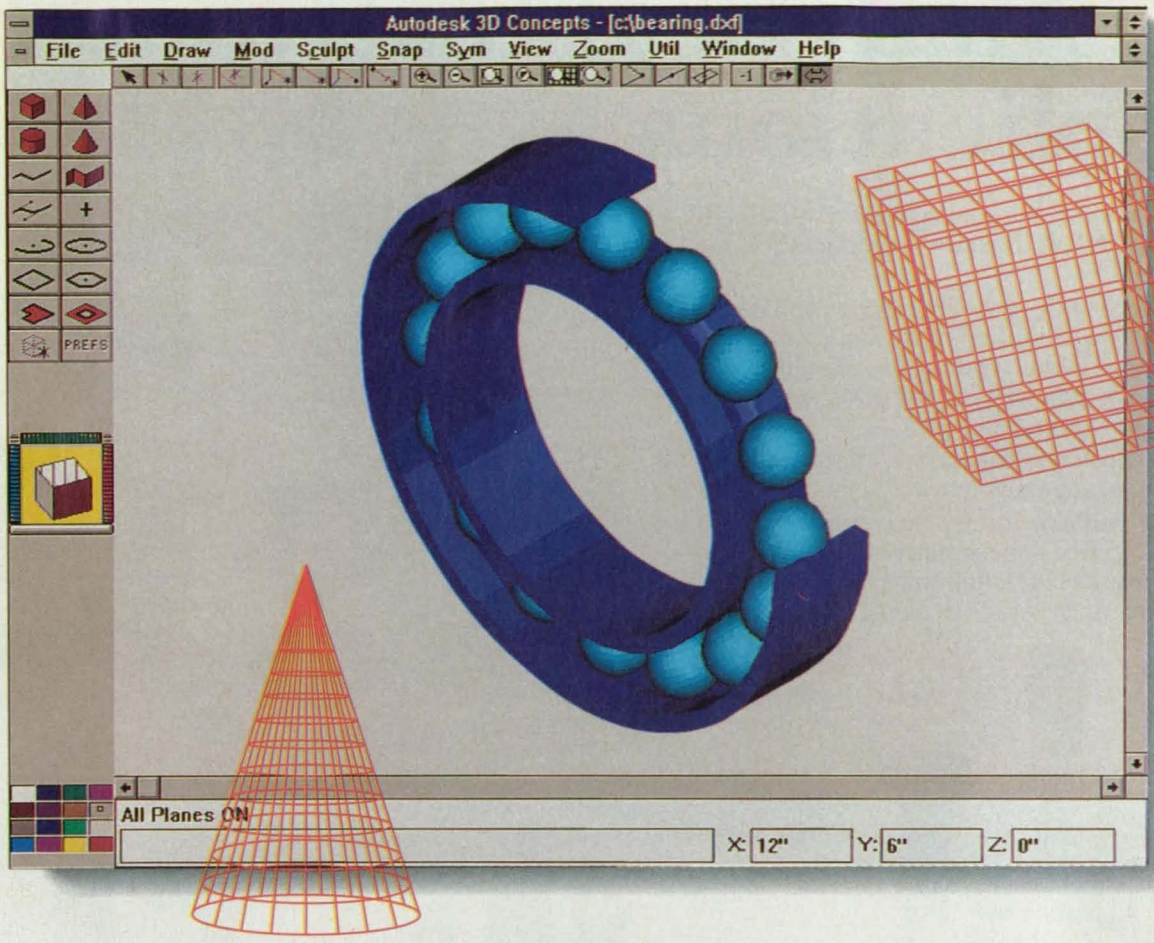

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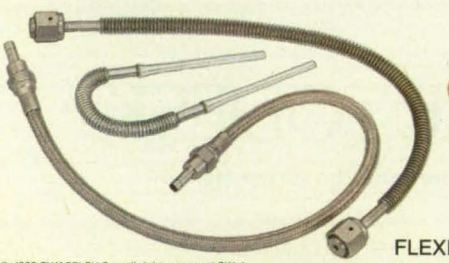

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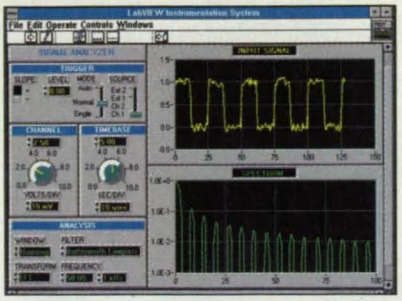

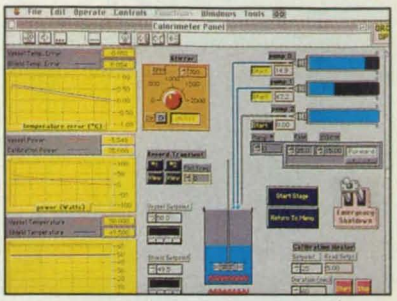

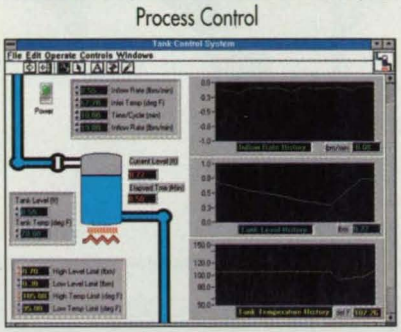

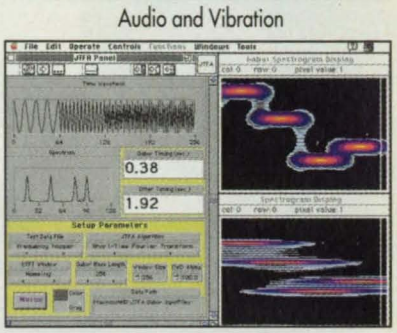

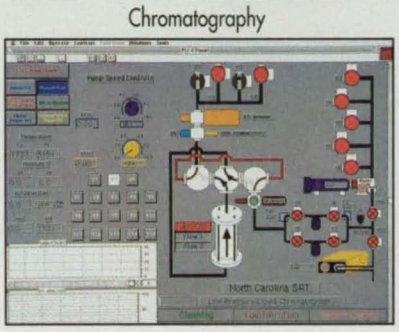

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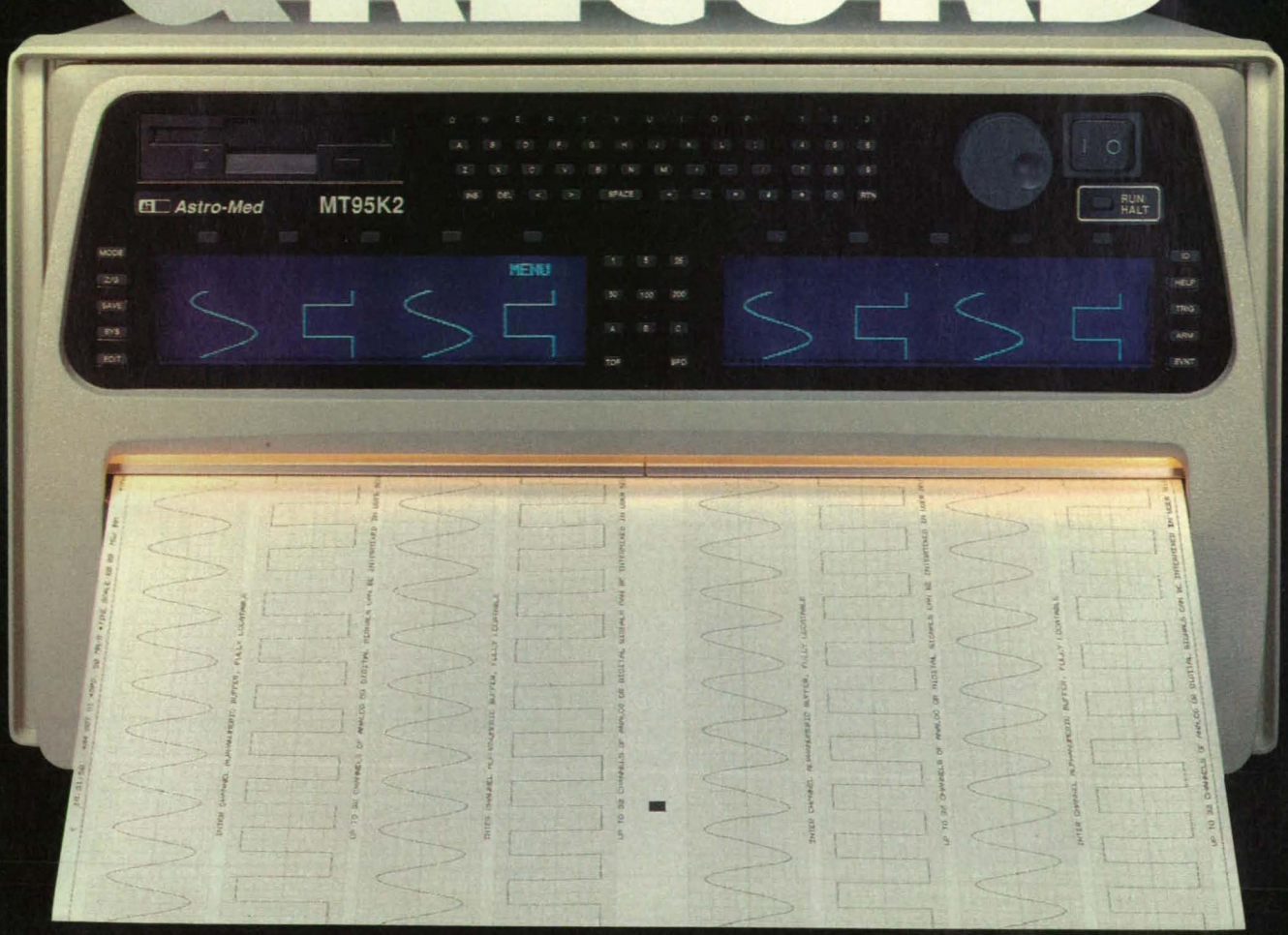

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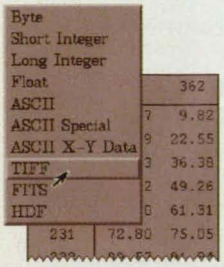

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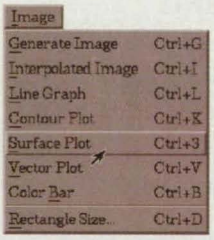

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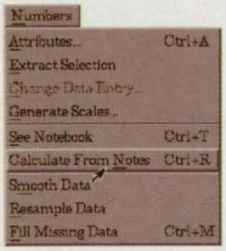

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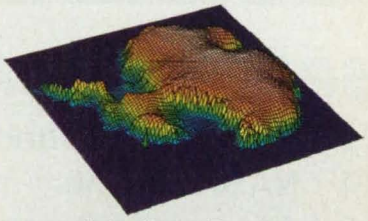
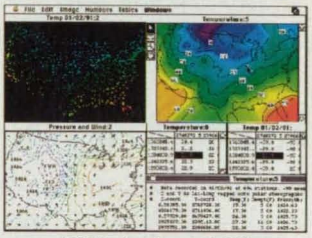
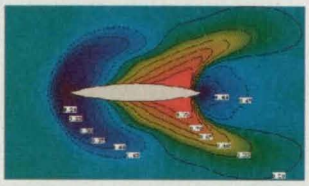


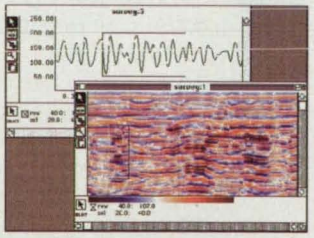
Surface elevation of Antarctica
Data: Professor Doug MacAyeal, Univ. of Chicago



U.S. Weather, January 2, 1991
Data: University of Illinois at Urbana-Champaign Dept. of Atmospheric Sciences



Simulation of wind flow over an airfoil at Mach 0.5
Data: Dr. Mark Christon, Lawrence Livermore Labs



Slice from 3D seismic survey
Data: Halliburton Geophysical Services, Inc.

The Data Handbook

A Guide to Understanding the Organization and Visualization of Technical Data

by Brand Fortner ($39.95)

This indispensable reference provides an overview of the data universe. You'll also find useful information on specific formats like SEG-Y, Plot 3D, ACR-NEMA, netCDF, PICT, IGES, DXF, and others. *FREE* when you purchase Spyglass Transform, or order separately (allow 4-6 weeks for delivery).

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DEPARTMENTS

on the cover:

With the Cold War over and aerospace budgets shrinking rapidly, U.S. defense/aerospace contractors are moving into new commercial markets. The cover photo shows an aerospace-based technique for laser deposition of superconducting thin films that its developer, TRW Inc., is transferring to such industries as medicine and computing. Turn to our special report on page 16.

Photo courtesy TRW Space & Technology Group

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Managing masses of information on global, environmental change — a major goal of NASA's Earth Observing System (EOS) — is one of the world's most formidable information management system challenges. The Hughes Aircraft Company solution for the EOS Data and Information System (EOSDIS) will electronically interconnect NASA and other government agencies with researchers worldwide — facilitating research collaboration through a distributed federation of heterogeneous computer systems. Historically, global change data has been awkward to access, tough to translate and difficult to distribute. However, with EOSDIS, scientists in faraway places can easily work closely together, analyzing our fragile planet and recommending ways to preserve its environment and natural resources.

Now in its third cycle of mapping the surface of Venus, the spacecraft Magellan is close to its goal of producing a complete map of the planet. The key to gathering data is the Hughes-built synthetic aperture radar, the sole scientific instrument aboard Magellan. Even before the first cycle ended, in mid-1991, Magellan had mapped 84% of Venus' surface, returning more digital data than all previous U.S. planetary missions combined, with resolutions 10 times better than those provided by earlier missions. To optimize radar performance, Hughes also designed a computer software program capable of handling the nearly 950 commands required per cycle. Each cycle takes one Venusian "day," the equivalent of 243 Earth-days.

In what is likely the most intricate satellite replacement scenario ever, Hughes will soon launch its first pair of dual-payload satellites, Galaxy IV and Galaxy VII. They will replace Hughes' existing Ku-band and C-band satellites at the orbital positions of 99 degrees and 91 degrees, respectively. What makes this especially complicated is that they will be launched within four months of one another, requiring an unprecedented feat of choreography that includes backup satellites both in orbit and on the ground. This will enable Hughes to maintain ongoing, uninterrupted service to existing customers, who collectively have more than 25,000 satellite dishes — mostly in fixed positions — pointed at their existing fleet.

GM's prototype electric car, called Impact, will have Hughes-built electronics powering the motor and controlling the recharging. This all solid-state system requires no scheduled maintenance and will appear in the showrooms well ahead of the 1998 date when California will require auto manufacturers to begin selling zero pollution cars. Recharge points will be installed at buyers' homes and will also appear in other locations, including employee parking lots, downtown parking facilities, malls, and restaurants. With its Hughes-built "Inverter," the Impact will be a model for cars that help protect our environment.

Hughes is now producing the world's first interactive entertainment simulators which offer the excitement of a true simulation environment through integrated real-time control of vision, motion, and CD quality sound. These simulators use many of the same technologies Hughes developed for sophisticated flight simulators used in training pilots of Boeing 747-400s and military aircraft. The Commander simulator capsules are hydraulically operated as you steer through the computer image-generated screen experience. Because the graphics are generated as the adventure is experienced, you can go wherever you want in the scenario. The Commander includes a variety of safety features and will be located at arcades, shopping malls, bowling alleys, leisure centers, amusement/theme parks, as well as airports and museums.

For more information write to: P.O. Box 80032, Los Angeles, CA 90080-0032

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Published by ..... **Associated Business Publications**
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Editorial Notebook

National Technology Transfer Week

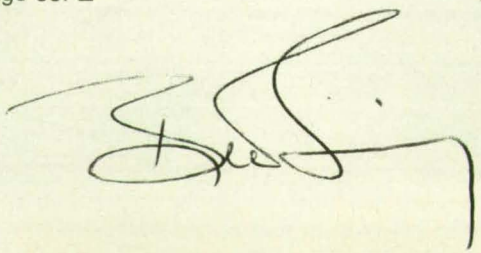
Back in January when I reported to you the phenomenal success of the Technology 2001 conference, I promised that we would do our best to make Technology 2002 even better.

As optimistic as I am bent to be, little did I know then that this December Technology 2002 would be the centerpiece of National Technology Transfer Week. We have been fortunate to have two of the most prestigious organizations in the country agree to dovetail their efforts with Technology 2002 to maximize the return on our nation's investment in R&D and help U.S. industry retain its global leadership.

The President's National Technology Initiative (NTI), a federal initiative supported by the Secretaries of Commerce, Energy, Transportation, and NASA's Administrator, will lead off National Technology Transfer Week on December 1 with a conference designed to foster partnerships between the government and private sector that will yield new goods and services to boost the economy. The NTI will segue into Technology 2002, with its hundreds of exhibits and symposia, and all the excitement generated by the 6000+ engineers and executives who will attend this premier technology transfer show.

Technology 2002 will flow into the MIT Enterprise Forum's Entrepreneurial Technology Transfer Conference, to be held at the Baltimore Hyatt Hotel from December 4-6, which will focus on techniques and strategies for effective tech transfer. The NTI, Technology 2002, and the MIT Enterprise Forum will jointly sponsor a press conference and reception on Monday evening, November 30, and will officially kick off the week's activities with a plenary session the next morning. All three groups will participate in this year's technology transfer awards banquet on Wednesday, December 3, at which achievement awards will be presented to federal employees and contractors who have made major strides in turning taxpayer-supported research into new products and processes that benefit daily life. We are honored to have as our dinner speaker Norman Augustine, Chairman and CEO of Martin Marietta Corporation.

The convergence of these activites signals the coming of age of technology transfer. Everyone who wants to be competitive in the high-tech arena in coming years should plan to attend National Technology Transfer Week in Baltimore, November 30-December 5. For further details about this unique opportunity, turn to the section beginning on page 83. ❑



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For More Information Circle No. 594

NASA PATENTS

Over the past three decades, NASA has granted more than 1000 patent licenses in virtually every area of technology. The agency has a portfolio of 3000 patents and pending applications available now for license by businesses and individuals, including these recently patented inventions:

Method of Fabricating Composite Structures

(US Patent No. 5,084,219)

Inventor: **Wanda A. Sigur**, Marshall Space Flight Center

Ms. Sigur offers a way to fabricate large, lightweight, and strong laminated structures without the use of costly autoclaves. The composite structure is positioned about a high-coefficient-of-thermal-expansion material and then wrapped in a graphite fiber. Heating the assembly causes the material to expand and forcibly compress the composite structure against the graphite overwrap.
For More Information Circle No. 696.

Optical Joint Correlator for Real-Time Image Tracking and Retinal Surgery

(US Patent No. 5,029,220)

Inventor: **Richard D. Juday,** Johnson Space Center

Mr. Juday has developed a method for tracking an object in a sequence of images, such as a sequence of television frames. Using an optical joint correlator, the object's position in a frame is correlated with its position in the previous frame to determine its relative location. The correlator can be used in laser eye surgery to track the involuntary movement of the eyeball. With knowledge of the eyeball's position, a surgical laser can be precisely pointed toward a location on the retina.
For More Information Circle No. 691.

Metallic Threaded Composite Fastener

(US Patent No. 5,090,857)

Inventor: **Thomas J. Dunn**, Johnson Space Center

Suited for high-temperature applications such as thermal protection systems, Mr. Dunn's fastener has a body made of temperature-resistant composite material with a ceramic coating, a non-circular shank, and an externally threaded split collar of metal alloy secured to the shank by a lock ring. When torque is transmitted from the body to the collar, the tapered connecting surface between the collar and the shank allows the collar to apply a tensile load to the shank without damaging the ceramic coating.
For More Information Circle No. 693.

Rolling Friction Robot Fingers

(US Patent No. 5,120,101)

Inventor: **John M. Vranish**, Goddard Space Flight Center

End effectors, or hands, for robotic arms have proved a limiting factor for efficient use of robot grippers. Mr. Vranish has designed an end effector that, with very low frictional forces, reliably guides, aligns, and seats an object without contaminating it. The device comprises a pair of gripper fingers that move towards each other to trap an object between them. A centering roller positions and holds the object symmetrically about the X axis and clamping rollers position and hold it with respect to the Y and Z axes.
For More Information Circle No. 692.

Superconducting Bearings with Levitation Control Configurations

(US Patent No. 5,117,139)

Inventors: **Yury Flom** and **James D. Royston**, Goddard Center

An innovative design and incorporation of Type II superconductors enhance the stability of radial superconducting bearings, provide a means to counteract the effects of gravity on the rotating shaft, and permit levitation forces within the bearings to be varied. The bearing is designed for a shaft with magnets embedded at each end. A cylindrical hole is drilled into the superconducting material and the shaft is inserted into it. The bearing exerts levitational forces on the magnets at both ends of the shaft.
For More Information Circle No. 694.

Solar Thermal Energy Receiver

(US Patent No. 5,113,659)

Inventors: **Karl W. Baker** and **Miles O. Dustin**, Lewis Research Center

A receiver designed for a solar heat management system collects, stores, and distributes heat to a Stirling engine. Concentrated solar energy is received by a collection of heat pipes in a shell and stored in canisters on the pipes. Between the canisters and the engine heater head is a cavity through which the pipes extend to exchange heat with the heater head. The receiver provides uniform distribution of energy despite uneven impingement of solar energy on the heat pipes, absence of solar energy at times, or failure of one or more heat pipes.
For More Information Circle No. 695.

Method and System for Monitoring and Displaying Engine Performance Parameters

(US Patent No. 5,050,081)

Inventors: **Terence S. Abbott** and **Lee H. Person, Jr.**, Langley Center

Conventional aircraft instrumentation can result in cluttered control panels that increase pilots' workload in reading and interpreting the instrument output. The Langley system simultaneously monitors and displays many engine performance parameters, permitting a pilot to make direct changes in thrust or power, and thereby to enhance performance. On a single display, the system calculates the differences between predicted and actual parameter values, such as available thrust and thrust actually being produced, for multiple jet engines.
For More Information Circle No. 690.

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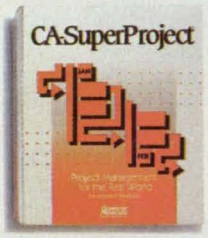
The #1 Rated Project Manager Now Available For Windows.

Power changes people.
Especially project managers.

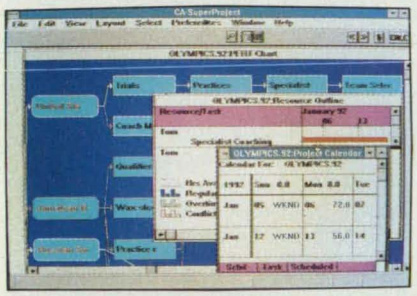


They're working smarter and faster with new CA-SuperProject® For Windows.

It's the world's most advanced, efficient and reliable project management software – and now it's incredibly easy to use.

Total power is yours with just a few mouse clicks. Create and edit projects. Specify resources, task types and durations. Define integrated sub-projects. Build top-down hierarchies and task-

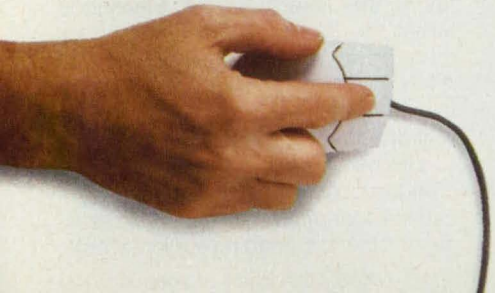
1992 W 100 WINDOWS MAGAZINE ANNUAL WIN AWARD

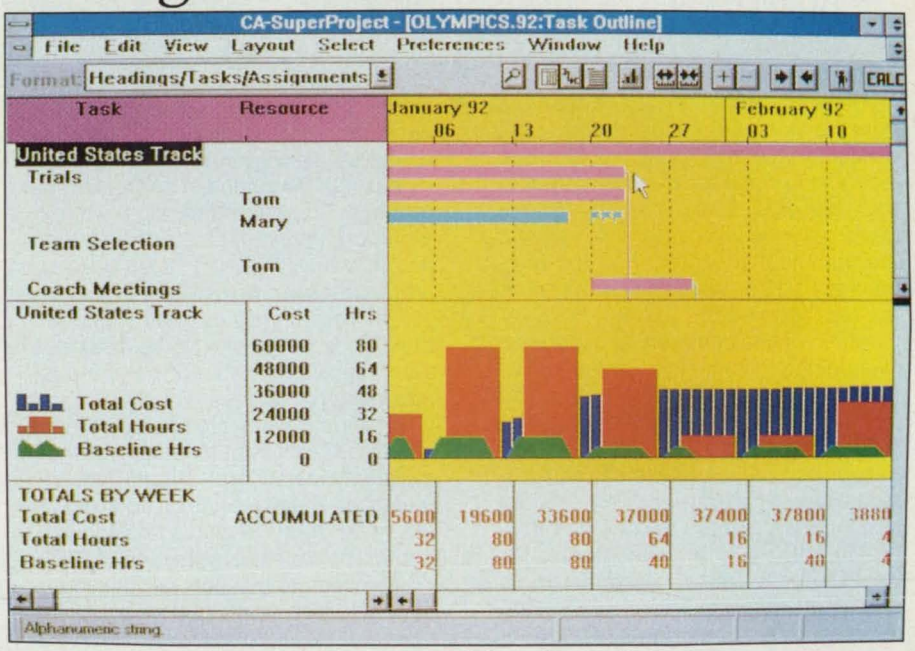


Report the status of your project with detailed Gantt, PERT, WBS and Cost/Resource charts.

dependency relations. Link multiple projects together for cross-project leveling. Perform extensive "what-if" analysis, revising schedules as projects progress.

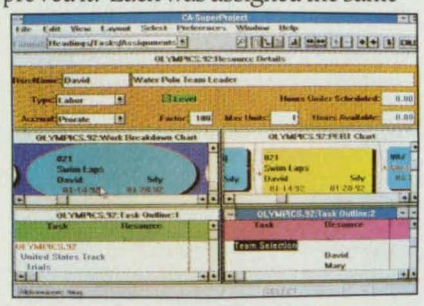
You can bet your career on its advanced and efficient scheduling algorithms.





Manage with power, using tools for sophisticated planning, comprehensive resource management, tracking and controlling.

A recent study of the five leading project managers proved it. Each was assigned the same



Show multiple views of the same project or different projects simultaneously.

project, but the finish dates varied by as much as five months. CA-SuperProject For Windows finished first in 214 working days–leaving Microsoft Project, Timeline 4.0, Project Workbench and Project Scheduler in the dust.

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For More Information Circle No. 615

MISSION: TECHNOLOGY TRANSFER

For the US aerospace industry, the recent end to the Cold War and downturn in defense/space spending signal the arrival of a new era and, with it, new business challenges. To prosper in coming years, aerospace companies must find innovative ways to transfer the technologies gained in aerospace and military endeavors to commercial applications. Here's how some industry giants are beginning to make the transition:

TRW's smart struts (the long black cylinders) dampen structural vibration that could disturb the pointing accuracy of this space-based laser. The same technology now is being used to relieve stress and compensate for vibrations in earthbound equipment.

Ball Corporation

Ball's involvement in space missions from the Mars and Venus probes to the space shuttle has provided a broad technology base for transfer to industry. This year, approximately 15% of Ball's revenue will come from sales to the commercial sector, with expectations of 15-20% growth per annum over the next few years.

Much of this commercial expansion is expected to come in the telecommunications market. Promising products include the AIRLINK® antenna system that enables flight crews and passengers on commercial jetliners to communicate over land and sea via phone, fax or computer; global positioning system (GPS) antennas; and synchronization devices for telephone systems. In its Efratom Division, Ball is answering the telecommunication industry's need for more accurate timing devices to handle the increasing transfer of data over telecommunications lines.

Antennas from Ball's communication systems division, used during the Persian Gulf war to keep track of US soldiers, are now being marketed to the commercial airline industry for traffic collision and avoidance. The antennas can aid navigation in the air, on the oceans, and even on the congested highways of metropolitan areas. Ball's GPS antennas are being used for surveying and one—the "fish finder"—helps fishermen navigate back to their favorite fishing spots.

Further, the company is adapting visual image generation systems for use in flight and truck-driving simulation and is using its systems expertise to devise means to reduce traffic congestion in the Los Angeles basin.

Contact: Alexander Bracken, Ball Corp., 10 Longs Peak Drive, Broomfield, CO 80021-2510; (303) 460-2259.

Grumman Corporation

Recently, after assessing its portfolio of US and foreign patents, Grumman established a corporate licensing office to maximize the value of its intellectual property. The office's mission is to extend Grumman's success in securing patents: the corporation's 22,000 employees received 80 US patents in 1991.

The licensing office retains external brokers, experienced in the business and technical climates of other industrial sectors, to handle negotiations. Licensing activities are coordinated by an extensive office automation network: a Patent Review and Status System® maintains status reports on each of 700 inventions, and a revenue tracking system will be installed by the end of 1992.

The company is now negotiating licenses for two production tools: a quick change right angle drill head, which lets a mechanic change drill head cutting tools with one hand, and improved end mill cutters. Long Island Futuristic Toys recently licensed Grumman's Maglev know-how for development of educational toys. Grumman also is pursuing external interests in its wiring harness fabrication technology and is commercializing a composite analyzer probe developed for nondestructive inspection of composite parts.

Grumman's composite analytical tester nondestructively analyzes and tests several properties of graphite-resin materials including thickness, sonic velocity, and relative electrical conductivity.

In another approach, Grumman is seeking a commercial partner to develop commercial aviation and factory test applications for an optical test equipment device. Developed to support the test and alignment of display avionics for military aircraft, the device serves as a "calibrated eyeball," automatically evaluating display symbology for clarity, brightness, and position. A partner is also being sought for development of a technique that significantly improves the corrosion-resistance of aluminum honeycomb material.

Contact: Charles G. Pieroth, Grumman Corp., Bethpage, NY 11714-3580; (516) 575-0738.

Hughes Aircraft Company

Decades of R&D by Hughes' Electron Dynamics Division has generated innovative products such as the CROSSATRON®, a plasma discharge switch originally developed for military use in both line type and hard tube modulators. The switch offers several advantages: in a line type modulator, the pulse-forming network can be eliminated and the pulse-length varied, while in a hard tube configuration, the CROSSATRON consumes less power than a triode or tetrode.

The CROSSATRON's unique properties make it well-suited for industrial heating systems, electrostatic precipitators, and laser systems. Electing to target the laser market first, Hughes developed a high-speed CROSSATRON switch for CO_2 and excimer laser pulsed-power modulator systems that dramatically extends switch life.

Hughes also has begun designing cryogenic coolers for commercial applications. Manufacturers of infrared sensing and thermal imaging equipment can

have affordable coolers incorporating Hughes' quiet, low-vibration linear drive design for long life and high reliability. The coolers are ideal for a wide range of environmental monitoring, medical thermal imaging, security, and superconductivity applications.

Employing technology in high-power TWT amplifiers and solid-state millimeter-wave products, Hughes is developing commercial millimeter-wave transmitter modules for line-of-sight video, voice, and data transmission. Applications include wireless, interactive communications as a supplement to cable television and a microwave extension for fiber-optic systems to connect computers within a LAN.

Contact: Marilyn Talley, Bldg. 232, M/S 4225, Hughes Aircraft Co., 3100 West Lomita Blvd., Torrance, CA 90509-2999; (310) 517-6141.

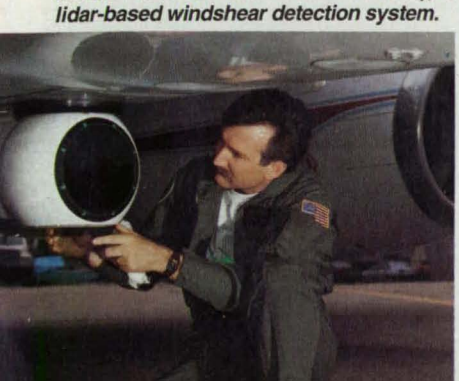
Lockheed Corporation

Lockheed Missiles & Space Company is drawing on its extensive satellite experience to produce two new families of lightweight and low-cost modular spacecraft. Taking a modular approach to satellite design permits Lockheed to address simultaneously the needs of a wide variety of commercial, military, and NASA satellite applications. The company also is designing spacecraft buses for satellites in the 1000-pound and 3000-pound classes.

One promising venture is the application of Lockheed's laser technology in a windshear detection device. Windshears are sudden and violent changes of wind direction near the ground that can impede aircraft takeoff and landing, thereby posing severe risks to passengers and crew. Flight tests of the NASA/Lockheed-developed lidar system, called CLASS (Coherent Lidar Airborne Shear Sensor), indicate that it can detect microbursts two to three kilometers ahead of an aircraft, giving pilots at least 20-40 seconds to take evasive action. The system is intended to fulfill a mandate from the FAA, effective December 1995, that all commercial aircraft carry windshear detection equipment.

Contact: Keith Mordoff, Lockheed Missiles & Space Co., P.O. Box 3504, Orgn. 24-01, Bldg. 101, Sunnyvale, CA 94089; (408) 742-6688.

A Lockheed engineer checks CLASS (Coherent Lidar Airborne Shear Sensor), a lidar-based windshear detection system.



Martin Marietta Corporation

The expertise that has enabled Martin Marietta to control cost and quality for its military customers is now being applied to automation systems for the US Postal Service. Under five contracts totaling $265 million, Martin Marietta is automating the service's mail-sorting process, which currently handles more the 500 million pieces of mail each working day. The system is expected to save more than $4.5 billion annually.

Earlier this year, the company established the Martin Marietta Postal Systems business unit, drawing on its experience in systems engineering and integration, computer software development for offices and factories, computer-integrated manufacturing, printed circuit board assembly, built-in diagnostics for electro-optics, and precision machining. The advanced automation equipment uses bar-code readers, high-speed transporters, and computer software to enable postal workers to sort and forward up to 35,000 letters per hour.

Martin Marietta is pursuing a range of other industry and civil government markets for existing technologies: parallel processing techniques used in the postal automation system may have criminal justice applications. Advanced infrared and radar sensors and sophisticated computers could be used by air cargo carriers, search and rescue aircraft, drug interdiction agencies, and cancer detection systems. In addition, the company is developing technologies that will significantly lower sensor and computer costs, such as advanced electronics packaging, and gallium arsenide microelectronics for active radar components and signal processors.

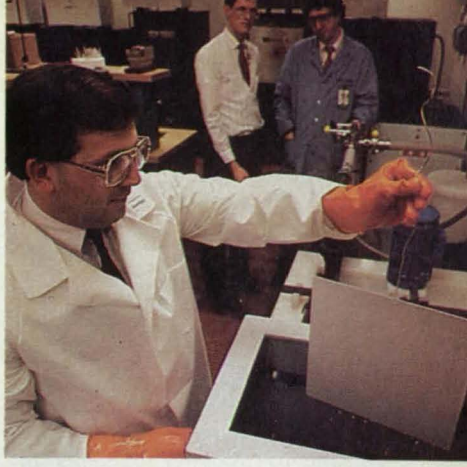
Contact: Charles Manor, Martin Marietta Corp., 6801 Rockledge Drive, Bethesda, MD 20817; (301) 897-6000.

McDonnell Douglas Corporation

Recognizing the need for new manufacturing processes to reduce or eliminate use of toxic materials, McDonnell Douglas has expanded R&D to find replacements for smog-producing paints and cleaners, ozone-depleting degreasers, and heavy metals such as lead and chrome.

A new aircraft paint-stripping process, developed in conjunction with the Air Force, employs common dry ice, a heat flash lamp, and a vacuum system. These elements are contained in a device that is passed over a painted surface: the heat lamp pyrolyzes the paint and the ice pellets chip it off to be vacuumed away. Once refined, the system will have applications in commercial aviation and promises to cut costs by dramatically reducing the time required to prepare an aircraft for stripping.

A second project is adapting old-fashioned electroplating to paint metal alloy detail parts. Called electrocoating,



A McDonnell Douglas engineer dips a part into a vat of primer to demonstrate how electrocoating saves paint.

the process involves dipping parts into an electrically-charged vat of primer. Electrocoating reduces waste, using approximately 99% of a gallon of primer as compared to 30% in conventional spray-painting methods. Moreover, it applies primer evenly, even in the tiniest nooks and crannies.

Contact: Ellen LeMond-Holman, McDonnell Douglas Corp., Mail Code 100-1195, P.O. Box 516, St. Louis, MO 63166; (314) 232-6496.

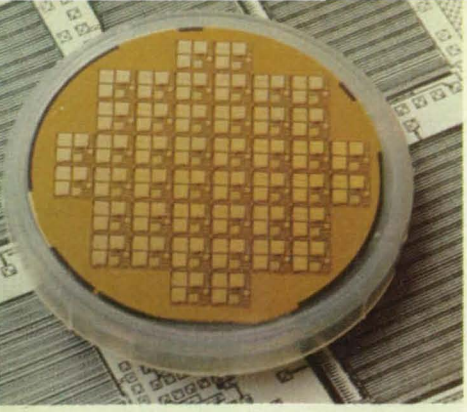
Rockwell International

While maintaining close associations with NASA and the Department of Defense, Rockwell's long-term strategy anticipates that its commercial businesses, especially in the automotive, and electronics markets worldwide, will become increasingly dominant. At the company's Rocketdyne Division, continuous process improvement techniques and Total Quality Management programs that reduced costs in the space shuttle program are now playing a role in commercial pursuits.

GPS receiver technology developed for the defense department has been reapplied by the Digital Communications Division (DCD) in the NavCore V line of low-cost, high-performance "core" receivers for land, sea, and air applications including trains and trucking. The NavCore V receivers also marked the commercial introduction of Rockwell's gallium arsenide technology.

Computational fluid dynamics (CFD) techniques used to design the space shuttle, and now the National Aero-Space Plane, are being utilized in automotive and printing press design. For Rockwell's graphics business, CFD programs aid in calculating the design of press paper flow over rollers and folders.

Rockwell's commercial avionics businesses are tapping into the expertise of military suppliers to develop an enhanced vision system for commercial air transport applications. The system will employ a "heads-up display" to increase pilots' ability to land with limited visibility. Further, Rockwell has been applying its sensor, automated controls, and system integration skills to an



This three-inch gallium arsenide wafer developed by Rockwell contains 144 ultra-high-speed analog-to-digital converters that can sample at 1.2 Gigabit-per-second with 8-bit resolution.

Intelligent Vehicle Highway System that could alleviate traffic congestion and air pollution.

Contact: Bill Blanning, Rockwell International, P.O. Box 4250, 2201 Seal Beach Blvd., Seal Beach, CA 90740-8250; (310) 797-5819.

TRW Inc.

TRW's commercialization strategies include licensing agreements, joint ventures, and penetration of new markets. Current targets include active smart structure technologies originally designed for large space structures. Featuring piezoceramic actuators/sensors embedded within their structure, the company's "Smart Patch" and "Smart Strut" technologies can sense and react to deformations and vibrations that cause poor performance and early failure in many structures and components. The technology can be used to monitor equipment stability during seismic activity, to relieve stress and compensate for vibrations and loads, and even to suppress vibration in skiing and bicycle racing.

TRW's expert systems currently provide self-diagnosis and fault resolution in unmonitored spacecraft, detecting component failure, rerouting commands, and managing equipment to avert mission failure. This work has culminated in the creation of MARPLE, a model-based autonomous-reasoning tool for producing intelligent diagnostics. With MARPLE, systems could easily be tailored to monitor power utility grids, hydro-electric stations, mass transit systems, and test equipment.

TRW's efforts to build solid-state data recorders for NASA's Cassini Saturn Orbiter Mission yielded high-speed architectures and high-density, low-power DRAMs that are now being applied to commercial image processing workstations. This same data storage technology offers real-time, 3D data viewing and manipulation for flight simulation, geologic exploration, and special effects film animation.

Development of superconductive electronics for advanced computing and communications, instruments and sensors, and medical imaging and diagnostics has focused on insertion of high-leverage microwave/millimeter wave analog and digital components and products in integrated circuit form. Other promising TRW inventions include a radiometer and camera utilizing passive millimeter wave technology that may provide a means for aircraft to operate more safely in fog and low cloud ceilings, and highly reliable, lightweight, and low-cost NITINOL shape-memory alloys that can be used in oil wells, underwater, mining, and parachute releases on race cars.

Contact: Steve Bayrd, TRW, One Space Park, Redondo Beach, CA 90278; (310) 812-4804.

United Technologies Corporation

Earlier this year, United Technologies formed a technology center (the UTTC) to support the creation of small, technology-based companies, or spinoff units, that will expose technology to new applications and markets. The UTTC's businesses include United Technologies Photonics, formed in February. The new unit designs, builds, and sells a variety of integrated-optic components, modules, and subsystems for such fiber-optics applications as optical navigation systems, cable television signal distribution, antenna interconnects, and instrumentation.

Another newly-formed unit is Engineered Coating Inc. (ECI), spun off from the United Technologies Research Center where it provided materials coating technology to UTC's aerospace units and the US government for 15 years. ECI offers a full range of thermal spray services, design of automated production coating installations, and production of coated parts for applications such as diesel engines, automobiles, turbomachinery, and electronic components.

Commercialization efforts also are underway at United Technologies Industrial Lasers, a global supplier of 6- to 25-kilowatt CO_2 laser systems, and Vaisala Technologies Inc., a joint venture between UTC, Vaisala Oy, and the Finnish National Fund for Research and Development. The latter group develops and manufactures silicon capacitive microsensors primarily for automotive manufacturers in Europe, Japan, and North America.

Contact: Karen M. Breckbill, United Technologies Research Center, East Hartford, CT 06108; (203) 727-7248.

USBI Company

Pratt & Whitney's USBI Co. has successfully transferred its waterjet processing from the manned space program to aviation and other industries. Under NASA's guidance, USBI developed automated high-pressure waterjet systems that were brought on line in 1985 at Kennedy Space Center and have resulted in a 96% reduction in man-hours. Recognizing its broad potential, USBI began developing spinoffs of the technology to address environmental challenges facing the commercial airline industry and US government equipment maintenance facilities.

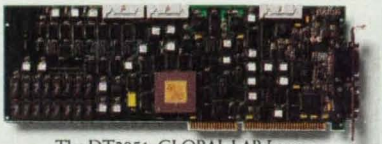
Current stripping methods require the use of chemicals hazardous to both workers and the environment. USBI's Automated Robotic Maintenance Systems™ (ARMS) integrates high- or ultra-high-pressure waterjetting with precision robotics to provide a coatings removal system that leaves behind only water and the coating itself. The system can strip tenacious plasma-sprayed coatings such as ceramics and magnesium zirconate using just water at ultra-high pressures up to 55,000 psi without damaging the substrate. USBI has demonstrated that waterjet processing can reduce coating removal time for engine components by as much as 90% while increasing service life.

Potential applications include stripping paint and coatings from helicopter blades, transmission housings, gearboxes, ships and submarines, and railway equipment. Spurred by enthusiastic industry response, Pratt & Whitney is structuring a new organization dedicated to the automated high-pressure waterjet work begun by USBI.

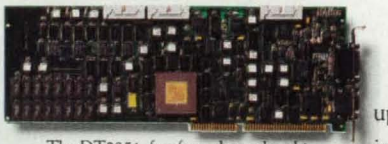
Contact: Becky Burroughs, USBI, P.O. Box 1900, Huntsville, AL 35807; (205) 721-5517. ❑

USBI's waterjet processing uses water alone to strip coatings from engine components, reducing coating removal time by as much as 90%. Here, the phenolic rub-strip liner is removed from the titanium fan inlet ring of an aircraft jet engine.

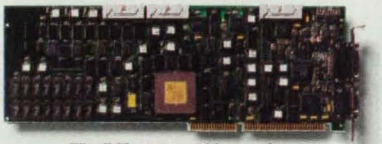
We have a perfect board for every image processing application.



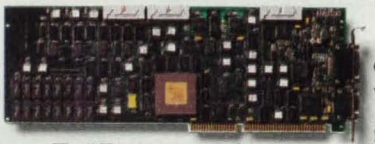
The DT3851: GLOBAL LAB *Image* software for Microsoft Windows.



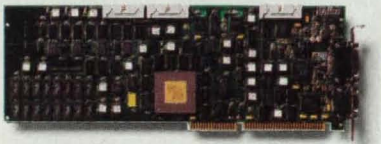
The DT3851: fast four-channel multiplexer for inspection with multiple cameras.



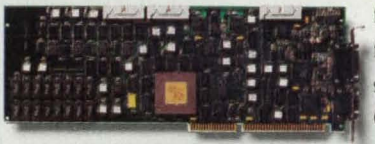
The DT3851: variable scan for inspection with nonstandard cameras.



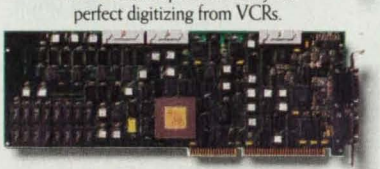
The DT3851: up to 8M of memory for motion analysis.



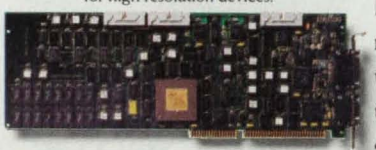
The DT3851: special circuitry for perfect digitizing from VCRs.



The DT3851: 1K x 1K input for high resolution devices.



The DT3851: precise image digitization for microscopy.



The DT3851: integrated graphics for one-monitor systems.

It just happens to be the same board.

As you can plainly see, our new DT3851 image processing board is a multi-talented performer.

That's why anyone who knows image processing will agree that the DT3851 Series is far and away the best choice for the vast majority of applications. This Jack of all trades masters any task, because it has features, flexibility and software support that equal or exceed your single-purpose boards.

The DT3851 combines the industry's most flexible and precise frame grabber with a very powerful display controller. It can capture images from any input device as precisely as needed – up to 1,024 x 1,024 resolution.

DT-Open Layers FOR MICROSOFT® WINDOWS™

What's more the DT3851 can either display images on a single monitor, integrated with Windows graphics, or be used in a traditional dual monitor configuration.

With this versatile board, input parameters are software-programmable. Display parameters are software-selectable

- Displays live video in a window
- Gain, offset, and reference adjustment
- Perfect synchronization to VCRs in pause mode
- Lowest pixel jitter of any PC-based system
- Supports standard or nonstandard input devices to 1K x 1K
- Displays multiple images anywhere on the screen
- Accelerates Windows graphics with onboard TMS34020 processor
- DT-Connect® interface

up to 1,024 x 768, in interlaced or non-interlaced format.

The DT3851 comes with a free Windows DLL and a free DOS library that control all board functions and perform frame averaging. It is supported by our GLOBAL LAB® *Image* 2.0 application and library software. That means it also conforms to DT-Open Layers,™ the Windows standard, so you know your software investment is protected.

And perhaps best of all, since you really can't afford not to have the DT3851, we made it very affordable.

Call us today. We'll send you more information on the DT3851, and our 3-Book Set filled with other great product and application information.

Call now. Because in this case, if you've seen one great image processing board, you've seen them all.

DATA TRANSLATION®

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New Product Ideas

New Product Ideas are just a few of the many innovations described in this issue of *NASA Tech Briefs* and having promising commercial applications. Each is discussed further on the referenced page in the appropriate section in this issue. If you are interested in developing a product from these or other NASA innovations, you can receive further technical information by requesting the TSP referenced at the end of the full-length article or by writing the Technology Utilization Office of the sponsoring NASA center (see page 24). NASA's patent-licensing program to encourage commercial development is described on page 24.

CCD With Back-Side Illumination and Charge Steering

A proposed imaging array of photodetectors would have features of both a back-side-illuminated and an interline-transfer charge-coupled device (CCD). Such a CCD would be particularly useful in imaging rapid transient phenomena, such as chemically reacting flows, with interframe intervals in microseconds.
(See page 30)

Sorbent-Bed Crop-Drying System

A proposed aeration system would reduce spoilage of stored grain or other crops stored in bulk. The system would maintain appropriate temperature and relative humidity in the vessel to suppress the growth of mold and insects.
(See page 116)

Multilayer Monochromator for Hard X Rays and γ Rays

A compact monochromator provides high spectral resolution with high throughput. Capable of operating at photon energies between 8 to about 140 keV, the device could be used in nuclear, astronomical, biomedical, materials, and x-ray-laser research.
(See page 58)

Shape-Memory Probe Grasps Small Objects

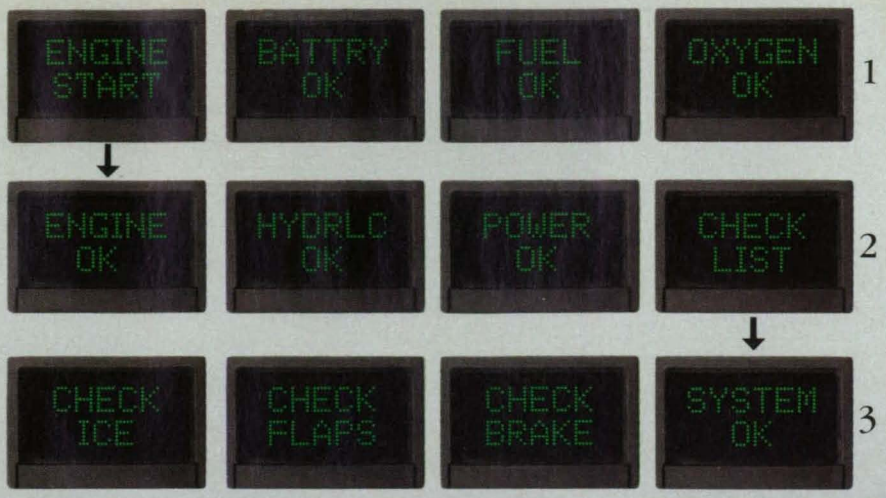
A device uses shape-memory alloys to grasp and remove foreign objects from ear canal, nose, or throat with little risk of damage to the tissue. As a commercial product, this probe may become an important instrument in hospital emergency rooms, pediatricians' offices, and electronic and mechanical repair shops.
(See page 134)

Ambient-Temperature Sputtering of Composite Oxide Films

A multiple-target, sequential-sputter-deposition technique is compatible with low-temperature microelectronic processing. Individual control of each metal is obtained down to a fraction of a monolayer thickness in individual layers.
(See page 125)

Electrophoretic Process for Purifying Wastewater

This process uses combinations of electric fields to remove microbes, poisons, and colloidal particles from wastewater. In addition to its potential applications in recycling domestic, agricultural, and industrial wastewater, the process concentrates wastes sufficiently for easier monitoring and detection.
(See page 134)



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

SEQUENCE ONE: The four-pushbutton display reads "ENGINE START," "BATTERY OK," "FUEL OK," OXYGEN OK." The operator selects "ENGINE START."

SEQUENCE TWO: The four-pushbutton display now changes to read "ENGINE OK," "HYDRLC OK," "POWER OK," "CHECK LIST." The operator selects "CHECK LIST."

SEQUENCE THREE: The four-pushbutton display now reads "CHECK ICE," "CHECK FLAPS," "CHECK BRAKE," "SYSTEM OK." In this manner, the designer can program in as many sequences as required.

Design flexibility: The programmable display system.

Vivisun Series 2000, now the leading programmable display pushbutton system, interfaces the operator with the host computer. The user-friendly LED dot-matrix displays can display any graphics or alpha-numerics and are available in green, red or amber. They can efficiently guide the operator through any complex sequence with no errors and no wasted time.

They also simplify operator training as well as control panel design. One Vivisun Series 2000 programmable display system can do the work of 50 or more dedicated switches. In short, Vivisun Series 2000 gives the design engineer more control over the design.

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3201 Sandy Lane, Fort Worth, Texas 76112
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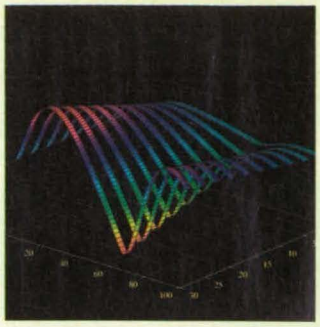
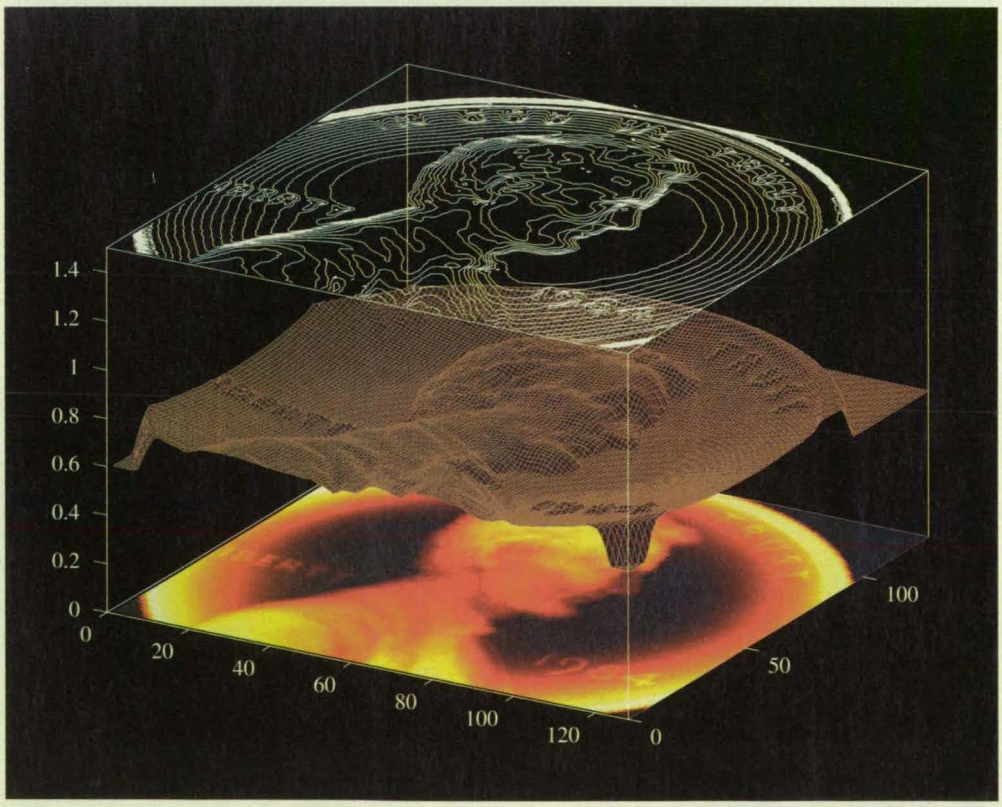
Vivisun Series 2000 programmable displays. The intelligent communications system.

SERIES
VIVISUN 2000™

Frequency responses of a family of control systems, modeled, simulated and visualized in MATLAB 4.0.



We see your expectations of visualization and we raise them.



Three views of the surface height of a penny show user customizable object-oriented graphics in MATLAB 4.0. Data courtesy of NIST.

Combine advanced visualization with the powerful computation of MATLAB, and gain new insight into your most challenging problems.

The MathWorks introduces MATLAB 4.0

MATLAB 4.0 blends visualization techniques and numeric computation into a seamless interactive environment that redefines how you can solve complex problems. You can analyze data numerically and visually, simulate models and see the results immediately, or explore ideas and test them interactively.

More than meets the eye

MATLAB 4.0 provides you with an extensive library of built-in computational tools, combined with a powerful fourth-generation language.

It thereby offers the convenience of a pre-packaged application program and the extensibility and flexibility of a high-level language. Much easier to use than Fortran or C, MATLAB 4.0 yields tremendous gains in productivity and creativity.

New high-level functions enhance these gains—functions in areas ranging from advanced graphics to powerful sparse matrix support to integrated program development tools.

Add SIMULINK™ to MATLAB 4.0 and you can perform dynamic system simulation of nonlinear models in a graphical mouse-driven environment. And with specialized application toolboxes, you can tailor the MATLAB environment to address your specific needs.

We've devoted the next page to giving you a more complete picture.

MATLAB® 4.0

Picture the Power

Broadly applicable, widely used

Over 100,000 technical professionals use MATLAB in diverse applications areas, including signal processing, control engineering, chemistry, economic modeling, and data analysis. They use it as their primary analysis tool in industrial, academic, and government settings in over 50 countries.

Flexible & extensible

With the open system architecture of MATLAB, you can see the algorithms, edit them, and create your own to address specific needs. MATLAB provides multi-platform interoperability, so you can use your applications and data across platforms without modification. As a result, MATLAB has become the ideal way to create and communicate algorithms and ideas—a *lingua franca* for technical professionals.

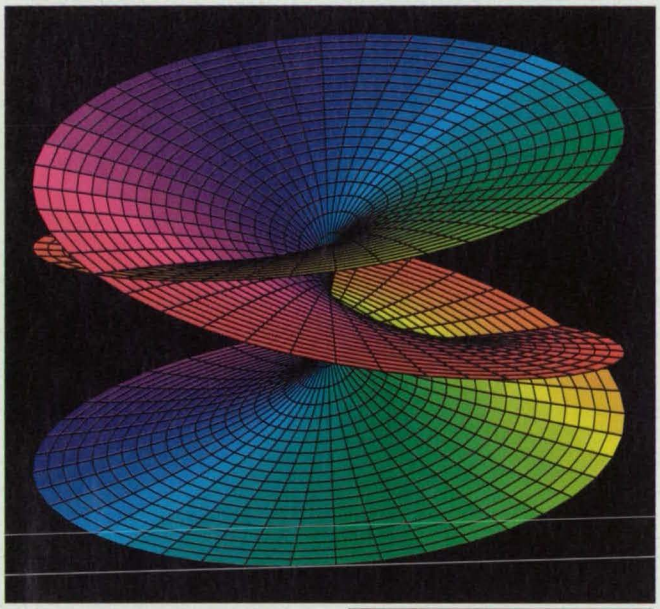
Easy to use

MATLAB has always been powerful, yet easy to use—a fast and accurate number-cruncher, a high-level prototyping environment, and a complete programming language. MATLAB 4.0 adds many new features that make it more powerful and even easier to use.

Image representation of Southeastern New England altitude data created in MATLAB 4.0. Data courtesy of NOAA.

New feature highlights

The most visible changes to MATLAB are graphical. NEW With our new object-oriented Handle Graphics™ system, you can customize virtually every conceivable attribute of your MATLAB plots.



Riemann surface of the complex cube root function shows the capability of MATLAB 4.0 for mathematical visualization

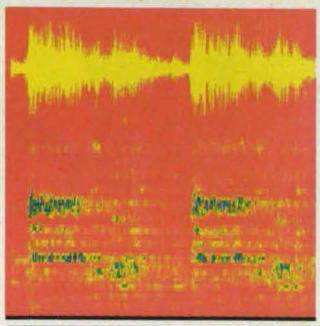
New graphics capabilities include:

- *3-D shaded color surface graphs*
- *3-D contour plots*
- *3-D data trajectories*
- *Image display*
- *Light sources*
- *Faceted and interpolated surface rendering, plus texture mapping*
- *Animation*
- *Color and black & white PostScript® output (Level 1 & Level 2)*

Beyond the visual

Other new features in MATLAB 4.0 include:

- ***Over 100 new functions***
- ***Graphical user interface controls***
  Add "widgets"—such as sliders, buttons, and menus—to create customized MATLAB graphical user interfaces easily.
- ***Enhanced file I/O***
  Import and export your data in any format.
- ***Sound output***
  Play data and functions as sound (SPARC only).
- ***Integrated debugging environment***
  Create MATLAB functions and scripts more quickly and easily.
- ***Sparse matrix support***
  Compute quickly and efficiently with very large matrices.
- ***Compute engine interface***
  Call MATLAB from your C and Fortran programs as a computation engine.
- ***Faster interpreter and graphics***
  Draws graphics up to two times faster than MATLAB 3.5.
- ***Enhanced on-line help***
- ***New, expanded documentation***



Spectrogram of Handel's Hallelujah Chorus, *computed and displayed with MATLAB 4.0 and the Signal Processing Toolbox.*

Powerful, versatile toolboxes

Application toolboxes, designed and written in MATLAB by world-class experts in their fields, provide specialized solutions. They're based on MATLAB, and they combine pre-packaged functionality with an open systems approach that allows you to see the algorithms and to modify them to suit your needs.

The comprehensive MATLAB toolbox family includes:

- *Signal Processing*
- *Control System Design*
- *Robust-Control Design*
- *Mu-Analysis and Synthesis Design*
- *System Identification*
- *Neural Networks* NEW
- *Nonlinear Optimization*
- *Spline Analysis*
- *Chemometric Analysis*

MATLAB 4.0 is available now for Sun SPARCstations, and will soon ship for other standard MATLAB platforms including: 386/486 PCs, Macintosh, HP/Apollo, DECstation, VAX/VMS, IBM, Silicon Graphics, Convex, & Cray.

For more information, please call us at (508) 653-1415.

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

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

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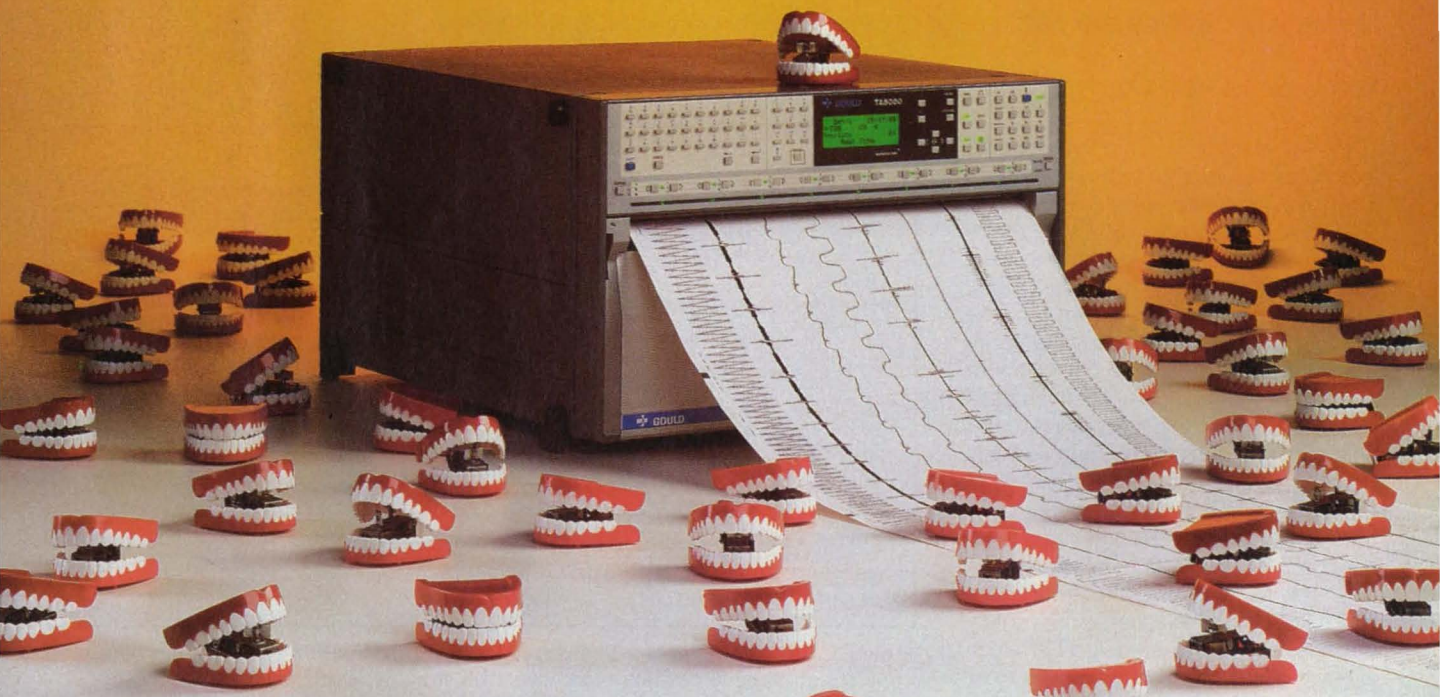
Electronics



Gould's newest recorder. With 48 megabytes.

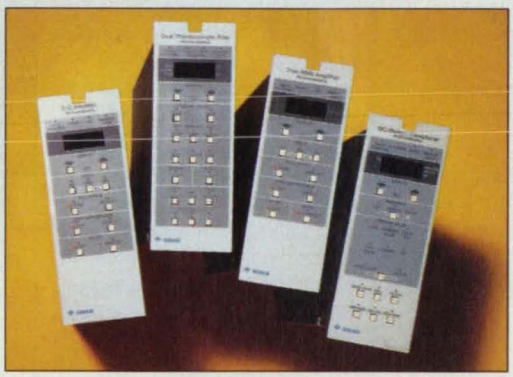
The new Gould TA5000 offers an unprecedented memory capacity that's bound to make you smile. This is the only 24-channel recorder with a 15″ thermal array printhead and up to 48MB of on-board memory. Which means you can record over longer periods of time *and* increase your sample rate to 250kS/s on all channels. So you're guaranteed the bandwidth you need for comprehensive analysis.

And when we say the TA5000 has the flexibility to record what you want, how you want it, we're hardly making idle chatter. Modular design allows for easy configuration or expansion for 8, 16 or 24 channels. The widest selection of the most accurate signal conditioners are yours to choose from. And our single, thermal array printhead lets you position traces anywhere in full overlap or discrete channels – with no blank zones.

In addition, Gould's Micropulsing™ technology provides reliable operation and the resolution you need to see your signals clearly, at every frequency and chart speed.

All this in a rugged, economical package backed by the largest sales and support organization in the recorder industry. It's the kind of value you can really sink your teeth into. Just remember, it's only from Gould.

Call Gould today at (216) 328-7000 or, for immediate response, complete the coupon and FAX it to us today.



NTB 9/92

Yes! ☐ Have a Gould Representative call me to arrange a demonstration

☐ Rush me a free TA5000 brochure

(Please print, or affix business card.)

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Title: _____

Company: _____

Street: _____

City: _____ State: _____ Zip: _____

Telephone: _____

Send to: Gould Inc., Test and Measurement Group, 8333 Rockside Road, Valley View, Ohio 44125. Fax: (216) 328-7400.

For More Information Circle No. 484

Coupled-Cavity Traveling-Wave Tube Has Phase-Adjusted Taper

Lengths of cavities are chosen for greater power-conversion efficiency.

Lewis Research Center, Cleveland, Ohio

In the electron-beam/microwave interaction structure of an improved coupled-cavity traveling-wave tube amplifier, the lengths of the cavities (see Figure 1) are chosen according to a computer-generated, nonlinear taper to increase the efficiency of conversion of power from the electron beam to the microwave. To increase this efficiency, it is necessary to prolong the energy-conversion process as the beam and the microwave travel along the structure; for this purpose, it is necessary to make the phase velocity of the microwave equal or nearly equal to the velocity of the electron bunches (regions of high electron density) along as much of the length of the structure as possible. This can be done by making succeeding cavities shorter to slow the microwave in step with the decelerating electron bunches.

Heretofore electron-beam/microwave interaction structures have been designed to consist of sequences of cavities of equal length with the addition of cavity sequences of linearly tapering length. Such piecewise-linear tapers were chosen by time-consuming, expensive trial-and-error procedures and did not maximize power-transfer efficiency. Such a taper also tends to entail relatively large differences between the lengths of adjacent cavities, giving rise to impedance mismatches and consequent reflections and distortions of the output as a function of frequency.

The improved design calls for a "phase-adjusted taper," which is calculated so that the phase of the electron bunches with respect to the phase of the microwave changes gradually along the structure from a value (about 0°) conducive to the formation of strong bunches at the input end of the taper to a value (about 90°) conducive to the strong transfer of power to the microwave at the output end of the taper.

This phase-adjusted taper is nonlinear and is more gradual than the corresponding conventional linear taper (see Figure 2). The premature dissipation of the electron bunches that occurs in the linear taper is prevented in the phase-adjusted taper. This permits power transfer to occur over a greater number of cavities, resulting in a significant increase in power-conversion efficiency. The extra number of cavities add only an insignificant percentage to the total cost of the traveling-wave tube. A program that computes the phase-adjusted taper contains a previously-developed computer model of a coupled-cavity traveling-wave tube with additional code that calculates the gradually changing lengths needed to enhance efficiency.

To represent bunching in the model, the

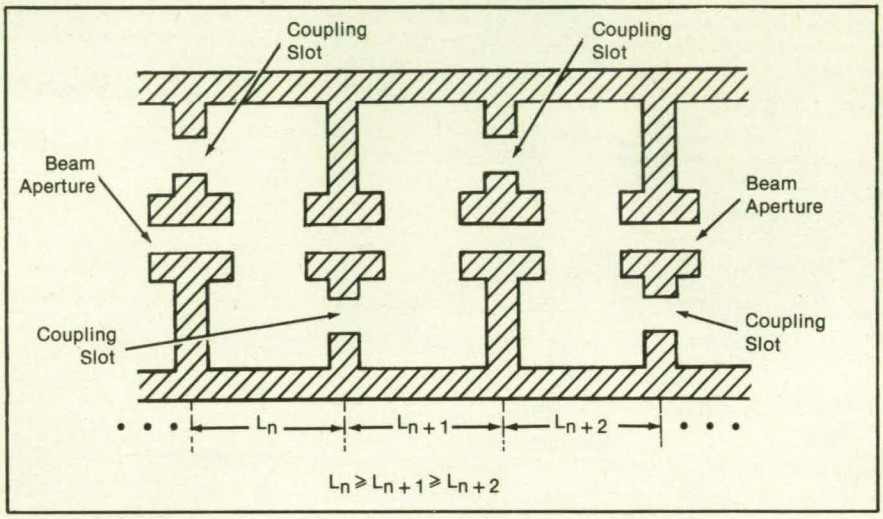

Figure 1. The **Electron-Beam/Microwave Interaction Structure** of a traveling-wave tube consists of coupled cavities of successively monotonically decreasing length.

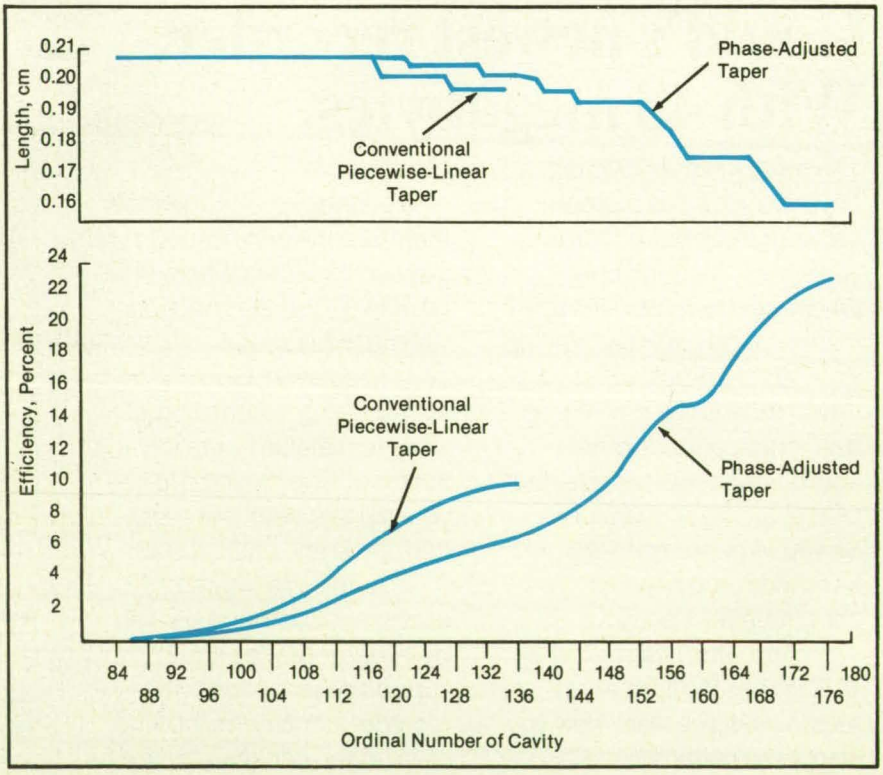

Figure 2. The **Cavity Lengths** and the corresponding computed power-conversion efficiencies for a traveling-wave tube with a conventional piecewise-linear velocity taper and a phase-adjusted taper.

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electron beam is divided into a series of disks, each of which is divided further into four concentric rings. The trajectories of the rings and the amplitude and phase of the microwave field are determined from the calculated axial and radial electrical and magnetic forces arising from the distributions and motions of charge in the rings and the interactions between these charges and circuitry as the rings pass along the sequence of cavities. The magnitudes and the phases of the bunches in the electron beam are taken to be those of the calculated fundamental Fourier components of current.

Solutions are obtained by iteratively making integration passes of the equations of motion along the sequence of cavities until convergence of the microwave phase and amplitude is obtained. Typically, this requires about as many iterations as there are cavities.

A ground-station satellite communications coupled-cavity traveling-wave tube, operating in the uplink frequency band of the NASA Advanced Communications Technology Satellite (ACTS) and built according to the phase-adjusted taper design of Figure 2, achieved more than twice the peak-power conversion efficiency of a baseline tube with a conventional piecewise-linear taper. The efficiency increased from 9.6 percent to 22.6 percent, a record value for a traveling-wave tube at a frequency above 20 GHz. The corresponding peak output power increased from 420 to 1,000 W.

The main importance of the development of the phase-adjusted taper is that it very significantly increases the power capability of microwave transmission, thus enabling satellite-communication systems to have much higher data-transmission rates. This is especially important for the new high-frequency communications systems because of the rapid increase of atmospheric attenuation with increasing frequency. The efficiency enhancement capability of the phase-adjusted taper will be especially valuable for communications coupled-cavity traveling-wave tubes used in satellites where power can cost up to $1,000,000 per watt.

This work was done by Jeffrey D. Wilson of **Lewis Research Center**. *For further information, Circle 33 on the TSP Request Card.*

Further information may also be found in NASA TP-2675 [N87-22923], "Revised NASA Axially Symmetric Ring Model for Coupled-Cavity Traveling-Wave Tubes."

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. LEW-14989

CCD With Back-Side Illumination and Charge Steering

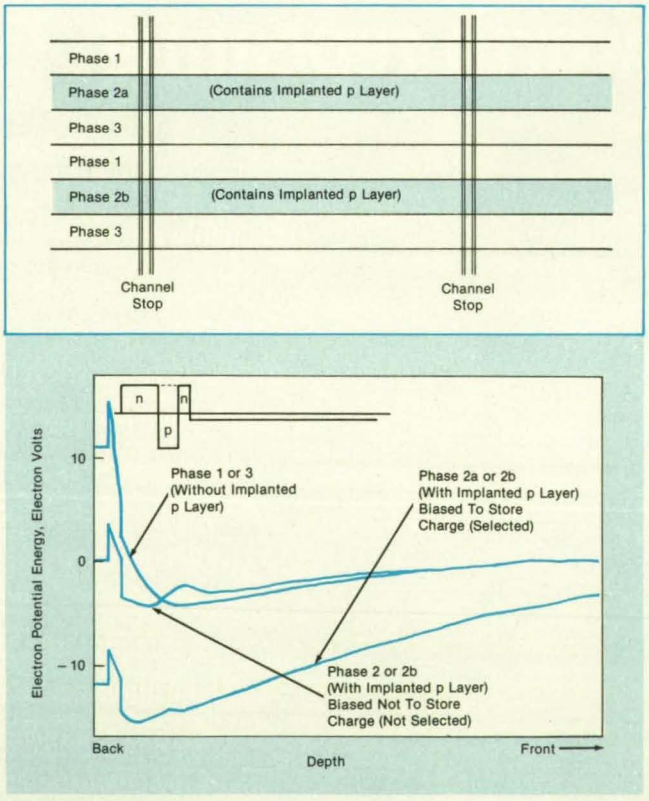
Multiple frames could be recorded in rapid succession, without sacrifice of efficiency.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed charge-coupled device (CCD) imaging array of photodetectors would have features of both a back-side-illuminated CCD and an interline-transfer CCD. The photoelectrons generated in each picture element of the array could be steered, by use of electrical control signals, to one of several nearby storage regions, without reduction of the part of the back-surface area available for collection of charge. Thus, by suitable timing of the control signals, charges from multiple image frames could be stored in rapid succession. Such a CCD could be particularly useful in imaging such rapid transient phenomena as chemically reacting flows, with interframe intervals of the order of microseconds.

As in a conventional back-side-illuminated CCD, the photoelectrons would be generated near the back surface and swept by electric fields toward the front surface into collecting potential wells, which would constitute the storage regions. As in a conventional interline-transfer CCD and unlike in a conventional back-side-illuminated CCD, the electric fields would include components parallel to the surfaces, so that the photoelectrons from each back-side location could be directed alternately to nearby storage regions that would not be directly opposite that location.

The figure illustrates a three-phase version of the proposed CCD of the buried-n-channel type, in which the ability to steer electrons to two different storage regions in phase 2 would be imparted by the addition of an internal p layer. The control signals would be bias voltages applied to overlying gate electrodes; by appropriate choice of these voltages, one could select either of the two storage regions (2a or 2b) in phase 2. The sites without p layers in phases 1 and 3 would act as isolation regions that would prevent the flow of charge from selected storage regions (e.g., 2a) to the nearest nonselected storage regions (in this case, 2b).



The **Implantation of an Additional p Layer** in phase 2, combined with appropriate biasing, would enable the application of electric fields that would steer electrons to storage sites in phase 2a or 2b.

In the first frame of a typical operating cycle, phase 2a would be selected as the storage region, while phase 2b would be deselected, causing photoelectrons generated under six adjacent electrodes in phases 1, 2, and 3 to be collected in phase 2a. In the second frame, the biases on phases 2a and 2b would be interchanged, so that all subsequent photoelectrons would be collected in phase 2b. After integration of the second frame, the CCD would be operated normally, albeit with shifted biases, to transfer out the two frames of image

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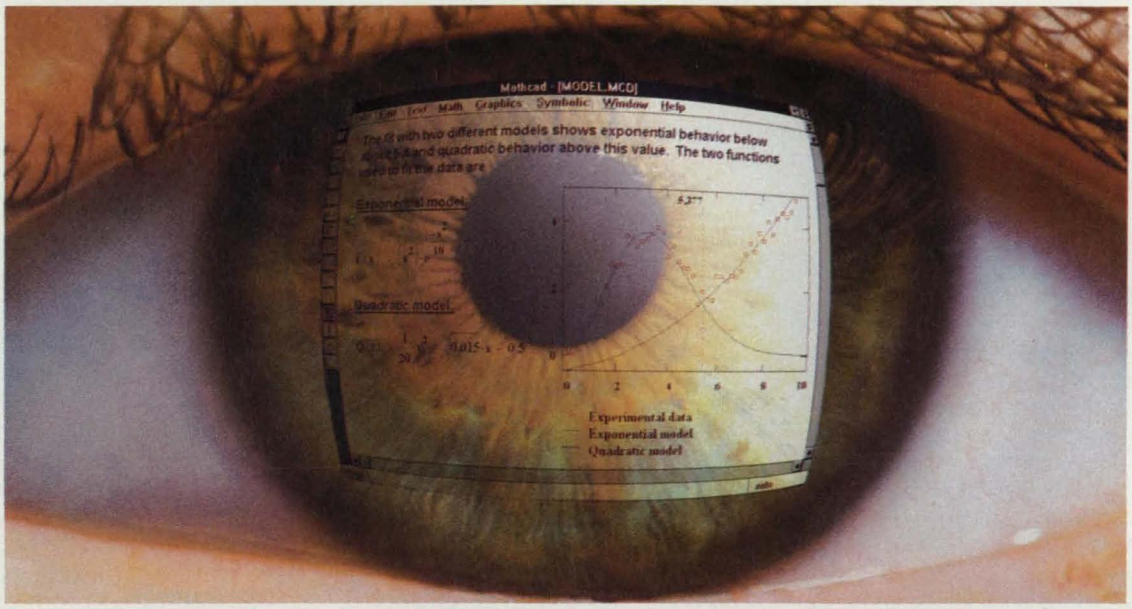

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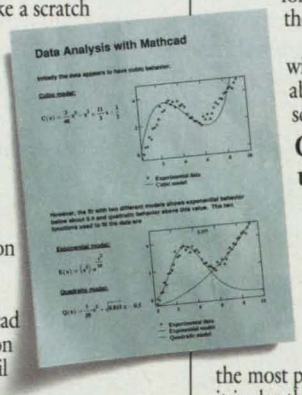

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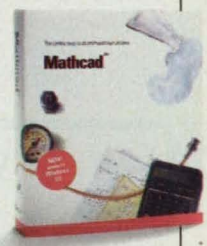

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charges, which would appear in adjacent picture elements. In this way, two images, separated in time by a few microseconds, could be collected without loss of collection efficiency.

This work was done by Eric R. Fossum of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 43 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 24]. Refer to NPO-18387.

Almond-Shaped Test Body

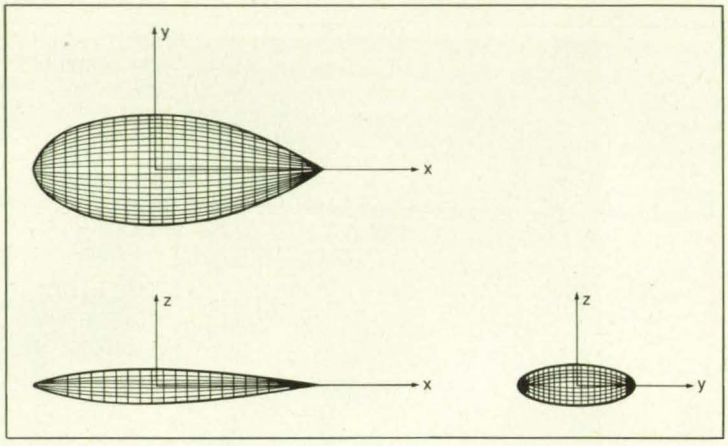
A unique shape results in a low radar cross section.

Langley Research Center, Hampton, Virginia

A test body has been developed for use in an electromagnetic anechoic chamber for purposes of evaluation of range and measurement of components. A microwave anechoic chamber should have the capability to measure the electromagnetic fields scattered from an object over a very large dynamic range — especially fields of very low amplitude. The chamber should be evaluated before any measurements can be trusted.

In the past, a sphere, which has good bistatic scattering characteristics, has been used, but the return is very large and some other means are required to test the performance for low-level signals. Another canonical shape has been the ogive, which has a very low backscattered return for very-near-axial incidence. However, there is a desire for another canonical shape that has a very low return over a very broad angular region to verify the performance of the chamber. The almond-shaped test body (see figure) was designed to have all the desirable characteristics for producing a scattered field of large dynamic range over large angular regions (see figure).

The almond-shaped test body provides a low radar cross section. The surface of the body is a composite formed by joining properly scaled ellipsoidal surfaces together. The scattering performance of the body is controlled by three main factors. First, the low backscatter return (< -55 dB/m^2 above 6 GHz) is obtained by having a sharp tip with a small cone angle to eliminate any specular return over a large angular region. The only returns are due to tip and creeping-wave diffractions, which are low-level returns. Secondly, the end opposite the tip is a smoothly curved termination that gently sheds energy. Shedding the energy in this manner, unlike in the manner of an ogive surface, which has sharp tips at both ends and from which energy scatters strongly off the rear tip, gives the desired performance. Thirdly, up to second derivative, the surface is continuous and smooth over the whole body, except at the tip. This factor eliminates any large diffraction centers that would raise the whole-body return.



The **Almond-Shaped Test Body** has a radar cross section that varies with angle over a large dynamic range.

The almond-shaped test body can also be used to mount components, the radar cross sections of which are to be measured. The advantage is that the almond-shaped test body has a very low return that does not perturb the measurement of the desired response significantly. This test body can also simulate backscatter characteristics of the component as though the component were over an infinite ground plane. The basic almond design has been improved through the addition of a planar surface, which was blended into the existing surface for mounting of components. In addition, a rigid metal mount has been incorporated in the almond-shaped test body to facilitate measurements.

Therefore, there are two applications for this design. One is as a test body to examine the measurement performance of a microwave anechoic chamber. The other is to support components so their radar cross sections can be measured in a microwave anechoic chamber. This development should be of considerable interest to a sizable group of people — in industry, universities, and research agencies — who make scattering measurements in anechoic chambers.

This work was done by Allen Dominek of Ohio State University and Richard Wood and Mel Gilreath of **Langley Research Center**. *For further information, Circle 23 on the TSP Request Card.*

LAR-13747

Faraday Cage Protects Against Lightning

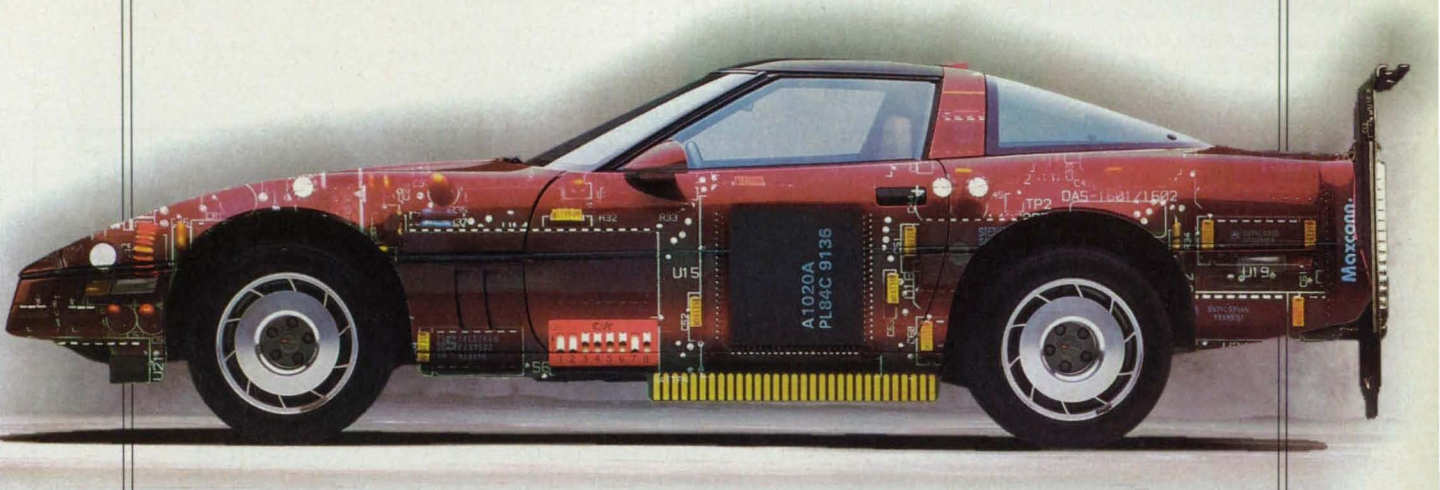
High transient currents are diverted from equipment inside.

John F. Kennedy Space Center, Florida

A Faraday cage has been designed to protect electronic and electronically actuated equipment inside it from direct and nearby strikes by lightning. The specific design is intended to prevent accidental detonation of, or damage to, explosive devices about to be tested. However, the general concept is applicable to the protection of other equipment; for example, scientific instruments, computers, radio transmitters and receivers, and power-switching equipment.

The design follows standard lightning-protection principles, so that whether lightning strikes the cage or the cables running to equipment in the cage, the lightning current is canceled or minimized in the equipment and is discharged safely into the ground. In principle, a completely closed metal surface surrounding the equipment could provide nearly complete protection; in practice, it is necessary to make holes to admit the cables (see figure), and this unavoidably makes paths along which transient currents and electromagnetic fields can enter.

The problem is to minimize penetration by the lightning transients. One protective measure is to use only coaxial and shielded multiconductor cables, and to terminate the shields of these cables with 360° backshell connectors that mate with feedthrough connectors mounted on the cage.



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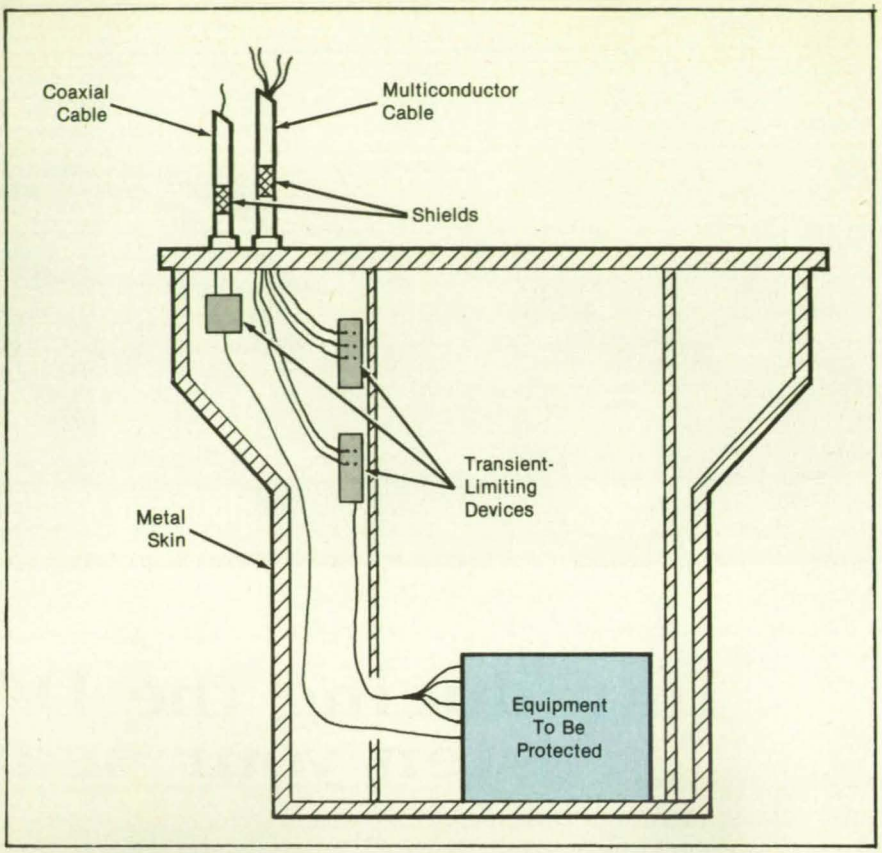
Thus, when the cables are struck by lightning, the current divides among the shields and is conducted to ground along the path of lowest impedance. For example, if the strike is close to the cage and the cage is close to the ground, a major portion of the current flows along the shields of the cables, through the backshell connectors, onto and over the surface of the cage, and through an arc to the nearest grounded object.

Small portions of the lightning current can be carried by the inner conductors of the cables, which provide paths to ground via the equipment inside the cage. Therefore, transient-limiting devices are placed in these current paths to divert most of the remaining lightning currents to ground through the cage. The electrical requirements for each piece of equipment to be protected determine whether the transient-limiting device on the conductor connected to it is a gas-filled spark gap, a metal-oxide varistor, or a hybrid consisting of a spark gap, a series impedance, and a silicon avalanche diode.

This work was done by W. Jafferis of **Kennedy Space Center**, *R. T. Hasbrouck of Lawrence Livermore Laboratory, and J. P. Johnson of Sandia National Laboratory. For further information, Circle 82 on the TSP Request Card.*
KSC-11437



This **Simplified Diagram of the Faraday Cage** shows the essential protective and protected equipment. Metallic shields protect the conductors in the cables, and the equipment inside is protected further by transient-limiting devices.

Generating Far-Infrared Radiation by Two-Wave Mixing

Proposed devices would exploit the nonlinear dielectric susceptibilities of asymmetric multiple quantum wells.

NASA's Jet Propulsion Laboratory, Pasadena, California

Far-infrared radiation in the frequency range of about 1 to 6 GHz would be generated by two-wave mixing in asymmetrically grown $GaAs/Al_xGa_{1-x}As$ multiple-quantum-well devices, according to a proposal. Experiments in which second harmonics of the 10.6-μm-wavelength radiation from CO_2 lasers were generated in such devices showed that the second-order nonlinear dielectric susceptibilities of the devices exceed those of well-known nonlinear materials (e.g., $LiNbO_3$) by factors of the order of 10^4. The proposal would exploit this large second-order susceptibility, which gives rise not only to radiation at the sum of the frequencies of two input waves (or double the frequency of one input wave as in the generation of second harmonics) but also to radiation at the difference between the frequencies of two input waves.

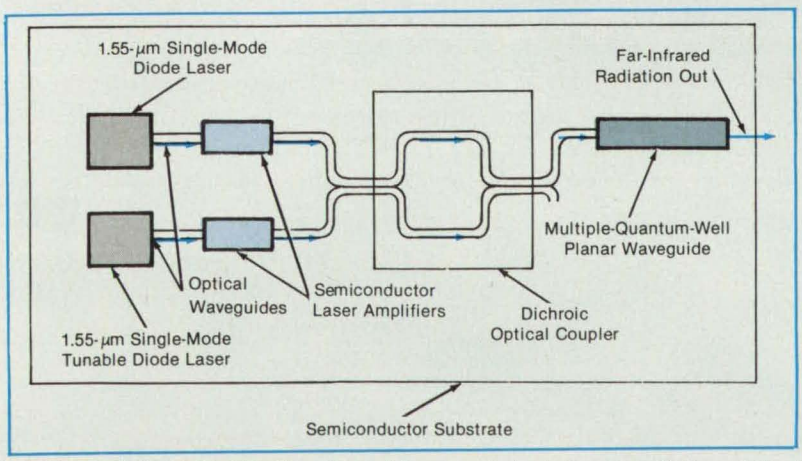
Devices of the proposed type could be used as tunable local oscillators in heterodyne-detection radiometers. The figure illustrates such an oscillator. Two near-infrared semiconductor diode lasers would be phase-locked, and one of them would be tunable. The outputs of these lasers would be amplified, then combined in a semiconductor nonlinear multiple-quantum-well planar waveguide. A dichroic coupler may be necessary for efficient coupling of the two laser beams. All components would be integrated on one circuit chip.

To maximize the amount of radiation generated at the difference between the frequencies of the two lasers, it is necessary to optimize the design of the device with respect to three factors: (1) a high degree of confinement of the electromagnetic field in the nonlinear medium to maximize the power density, (2) phase matching to extend the length of the zone of interaction between the two laser beams in the nonlinear medium, and (3) the nonlinear susceptibility. The device would be optimized with respect to the first two factors by designing and building it according to the techniques of integrated optics. For this purpose, the thin $GaAs/Al_xGa_{1-x}As$ multiple-quantum-well film would be considered a nonlinear dielectric transmission line with transverse dimensions comparable to the wavelengths of the signals to be mixed. The transmission line would support transverse magnetic, transverse electric, and transverse electric and magnetic modes, and the structure would control the dispersion of the various modes in such a way as to select preferentially the specific sets of modes, at the related mixing frequencies, that satisfy the phase-match condition.

Optimization with respect to the third factor would be based on exploitation of absorption resonances in the multiple-quantum-well structure in such a way as to obtain a large second-order dielectric susceptibility. This, in turn, requires an asymmetric multiple-quantum-well medium, which can be fabricated by suitably varying such parameters as the thicknesses of quantum wells and barriers and the aluminum contents of the barriers.

This work was done by Shmuel Borenstain of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 45 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, NASA Resident Office – JPL [see page 24]. Refer to NPO-18344.



This **Integrated Optoelectric Circuit** would generate far-infrared radiation at the beat frequency of the two diode lasers.

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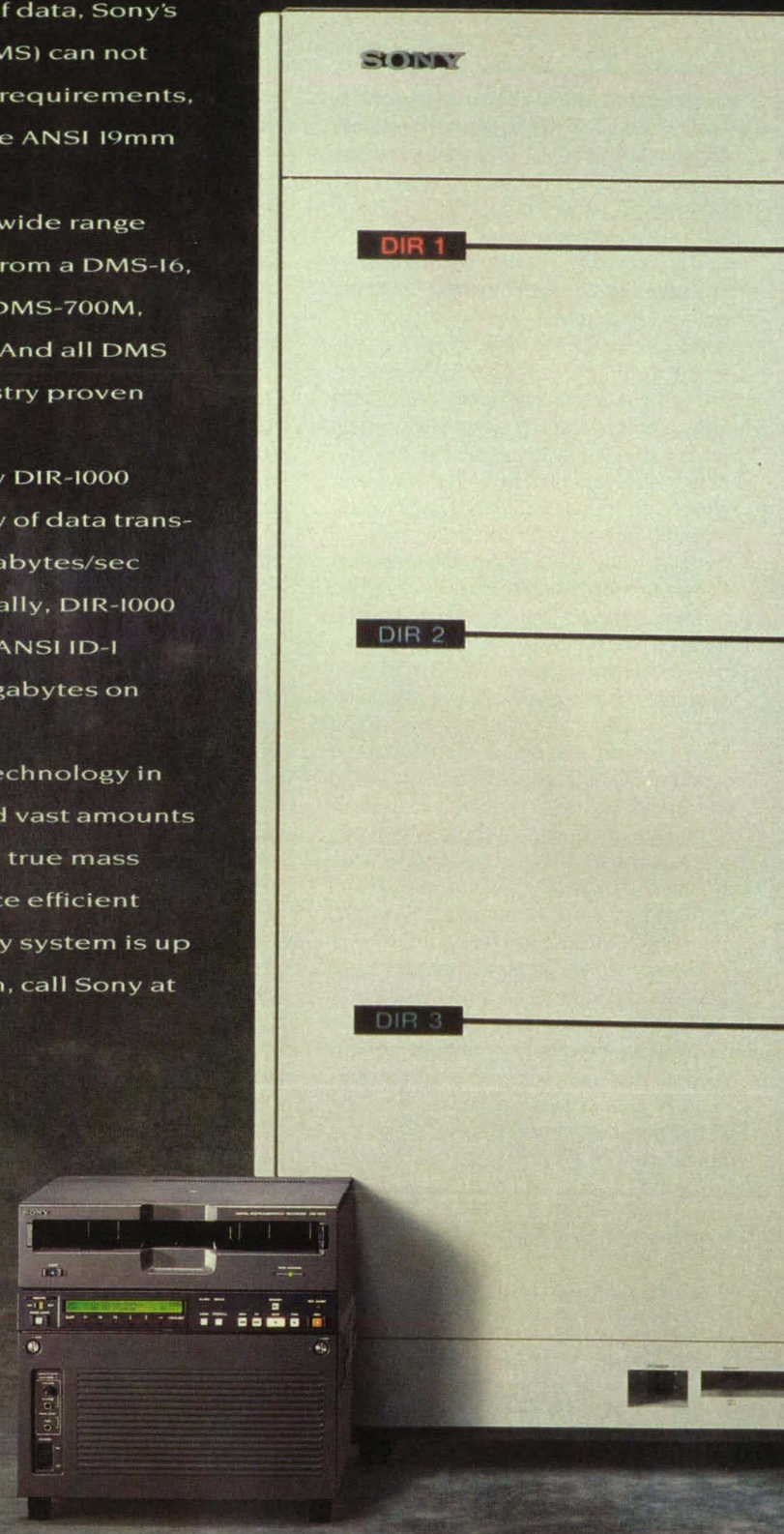

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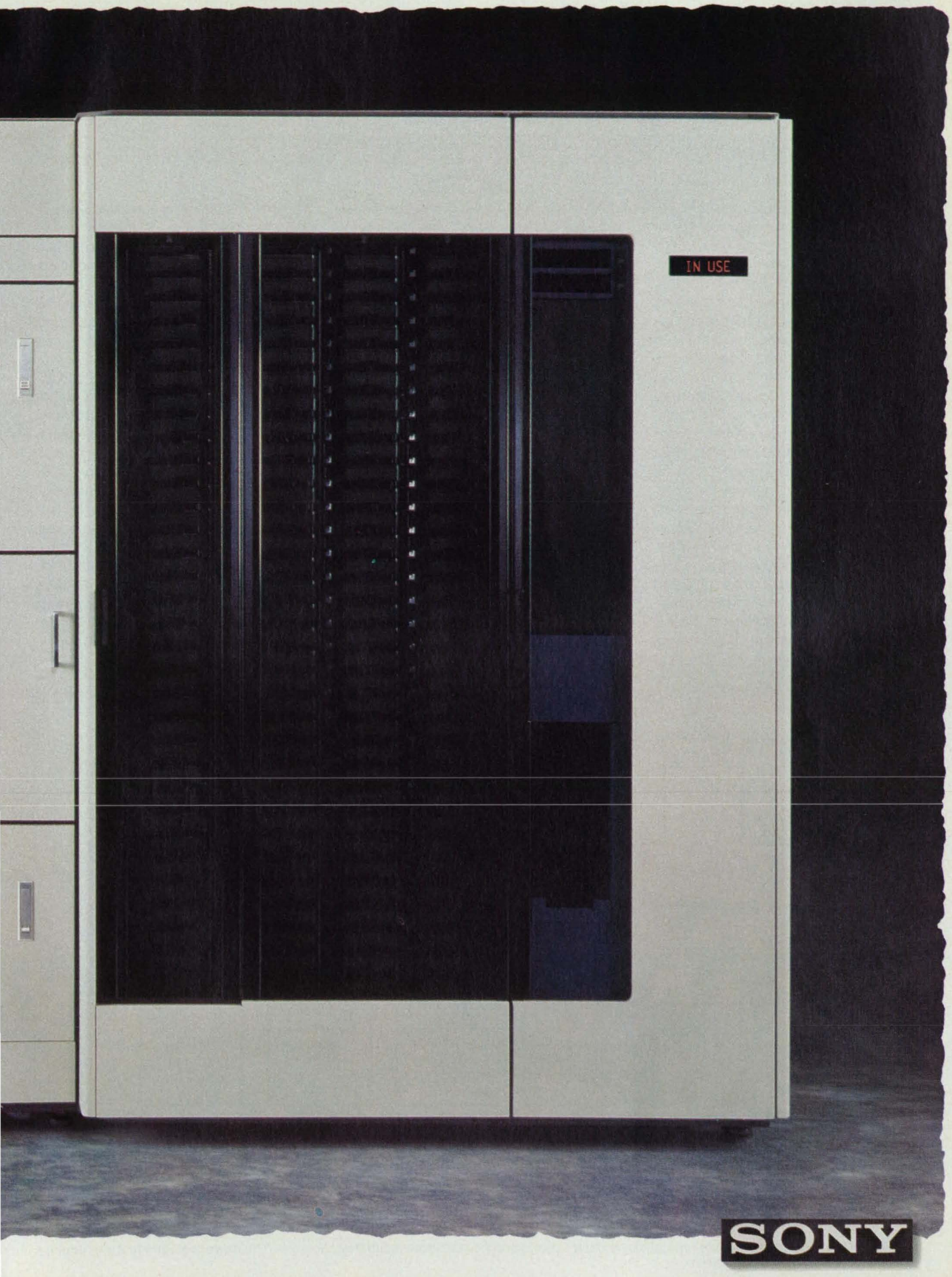


SONY

Improved Zero-Crossing Detector

Jitter is reduced substantially, and crosstalk is practically eliminated.

NASA's Jet Propulsion Laboratory, Pasadena, California

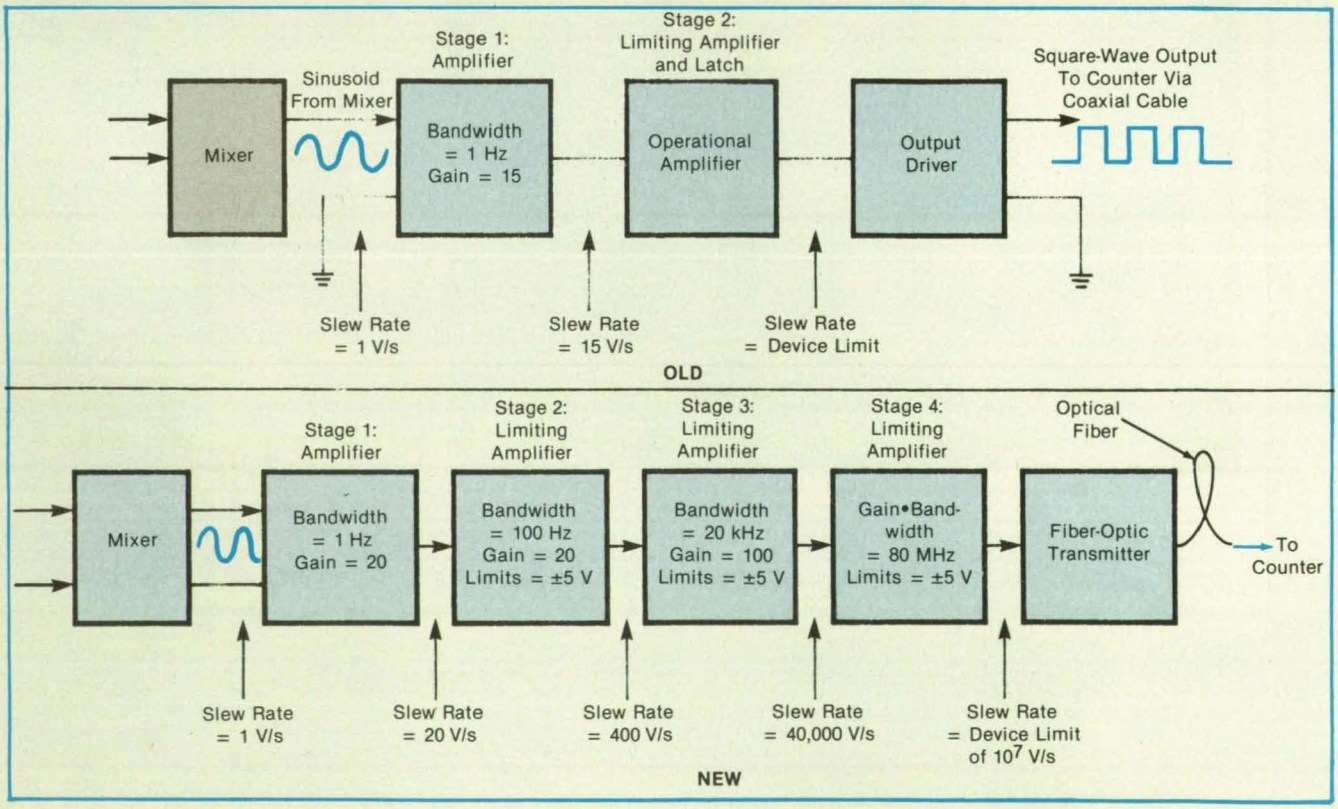
An improved zero-crossing-detector circuit is designed for precisely measuring the small difference (typically about 1 Hz) between the frequencies of two frequency-standard signal sources. The zero-crossing detectors of the best prior design exhibit a jitter of about 1 μs, which is large enough to impose a fundamental limitation upon the accuracy with which the frequencies of the latest ultra-high-stability sources can be characterized. Furthermore, the crosstalk between the prior zero-crossing detectors is so severe that the output of one such unit can induce a time offset of as much as 10^{-4} s in an adjacent unit. In the improved zero-crossing detector, crosstalk is eliminated for all practical purposes, and jitter is reduced to about 10^{-7} μs — the level required for state-of-the-art frequency-standard measurements.

The two source signals to be compared are fed to a mixer, which puts out a sinusoidal signal at the beat frequency. A zero-crossing detector transforms this sinusoidal signal to a square wave or to a train of pulses, which are sent to a conventional time-interval-measurement circuit. In a zero-crossing circuit of the older variety, shown at the top of the figure, the signal is first processed through a low-noise, low-bandwidth amplifier that increases its amplitude as much as possible without clipping. The signal is then sent to a broadband, limiting amplifier that "squares" the signal, producing leading and trailing edges that have short rise and fall times, respectively. The output of this amplifier is latched and sent to a driver, which feeds the final squared signal to the counter through a coaxial cable. The jitter in this circuit is caused by amplitude noise, and it depends on levels of noise, bandwidths of amplifiers, and instantaneous rates of change of signal voltages. Crosstalk is a parasitic effect of output ground currents.

An improved zero-crossing detector, shown at the bottom of the figure, contains a low-bandwidth first-stage amplifier and three limiting amplifiers, each succeeding one of which "squares" the signal a little bit more. The design is optimized, with respect to minimization of jitter, by use of modern low-noise operational amplifiers and by suitable choice of gain and bandwidth for each stage. Crosstalk among zero-crossing-detector units is eliminated by eliminating ground loops: input ground loops are eliminated by mounting each mixer in the chassis of the zero-crossing detector that it feeds; output ground loops are eliminated by replacing the output coaxial-cable feeds with fiber-optic transmitters. Even though the fiber-optic transmitter in each unit requires substantial current, these currents do not cause crosstalk because they do not flow among zero-crossing-detector units, but instead are contained within the chassis and power supply of each unit.

This work was done by G. John Dick and Paul F. Kuhnle of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 2 on the TSP Request Card.*

NPO-18415



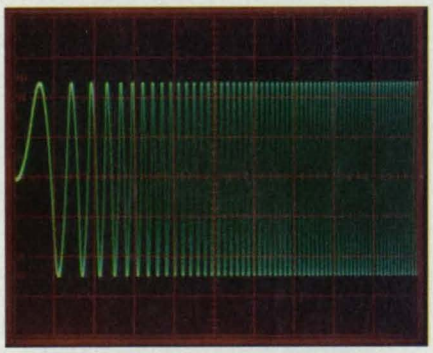
These **Zero-Crossing Detectors** are typical of the older (above) and newer, improved (below) designs. The newer designs feature reduced jitter and essentially zero crosstalk.

Synthesized Function Generators

Something New

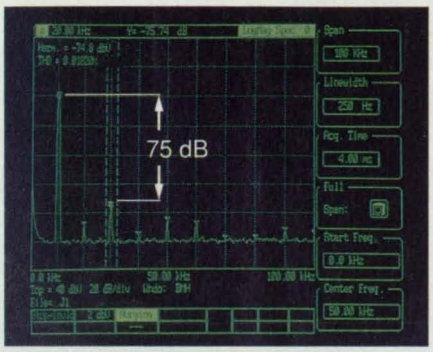
Every so often a powerful concept changes the way things are done. For a long time, function generators have been a jumble of analog circuits – ramp generators, VCOs, mixers, limiters and shapers. The new concept is Direct Digital Synthesis, and function generators will never be the same.

The performance and features of these instruments is unrivaled. Each model provides synthesizer accuracy and resolution, seamless sweeps over their entire frequency range, clean standard waveforms (sine, square, ramp, triangle), and a dirty one too (wideband gaussian noise). Distortion stays low even when driving 10 Vp-p into a 50 Ω load.



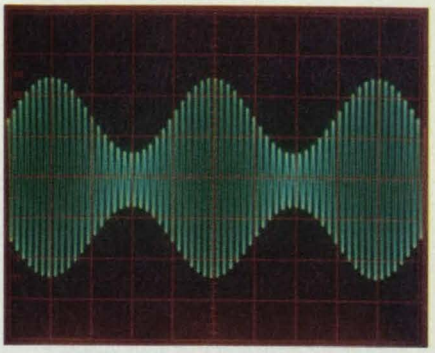
Seamless linear or log sweeps

The DS335's 3.1 MHz frequency range, 1 μHz resolution, and its clean (0.05% THD) and flat (±0.1dB) outputs, establish it as an outstanding value at $995. An optional GPIB/RS-232 interface allows integration into automatic test applications.



DS335's clean output spectra

The DS340 is similar to the DS335, with a frequency range which extends to 15.1 MHz, and arbitrary waveforms. Arbs may be programmed with 12 bits of vertical resolution, record lengths to 16k points, and sample rates to 40 MHz. A linear phase filter provides smooth outputs with a 10 MHz bandwidth.



DS345 offers AM, FM, PM and Burst modulation

The DS345 has all of the features of the DS340 with frequencies up to 30.2 MHz, and a rich set of modulation capabilities. Any of the standard waveforms may be amplitude, frequency, or phase modulated by sines, squares, ramps, triangles or arbitrary modulation patterns. Several DS345's may be slaved together via an external clock input, and the phases between their outputs may be adjusted with millidegree resolution.

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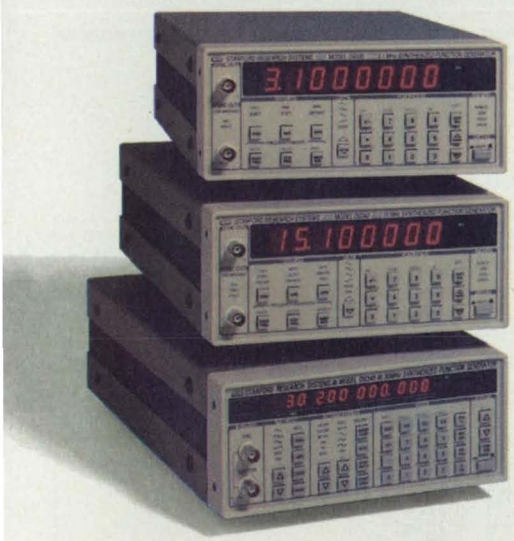

	DS335	DS340	DS345
Max Freq (Sine/Sq)	3.1 MHz	15.1 MHz	30.2 MHz
Freq Resolution	1μHz	1μHz	1μHz
Standard Timebase	±5 ppm	±5 ppm	±5 ppm
THD (f_o=10 kHz)	< 0.05%	< 0.05%	< 0.10%
Spurs (f_o=1 MHz)	<-65 dBc	<-65 dBc	<-55 dBc
Level Accuracy	±0.1dB	±0.1dB	±0.2dB
Modulation	FSK	FSK	AM,FM,PM, FSK,Burst
Arbitrary Waveforms	none	12 bits to 16k points and 40 Msamples/s	
GPIB/RS232	$395	$495	$495
Price	**$995**	**$1595**	**$2195**

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For More Information Circle No. 445

Open-Loop Acquisition of Frequency in BPSK

Precise symbol timing would not be necessary.

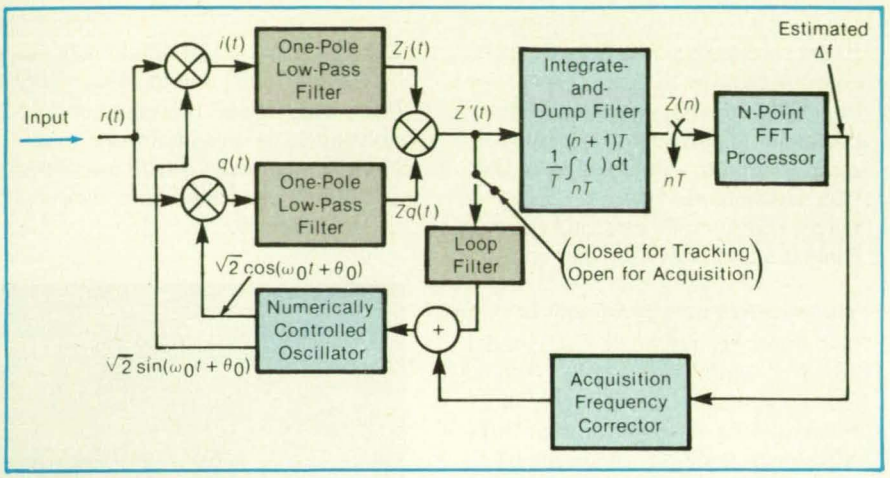
NASA's Jet Propulsion Laboratory, Pasadena, California

The figure illustrates a proposed open-loop analog/digital signal-processing system, part of which would produce an initial estimate of ("acquire") the carrier frequency of a received binary-phase-shift-keyed (BPSK) signal modulated by non-return-to-zero pulses. The system would be a Costas-loop error detector that would function in a closed-loop manner overall; the term "open-loop" refers only to the frequency-acquisition function, in which neither phase feedback nor frequency feedback would be used. The initial estimate could then be used to initiate the closure of the frequency-control loop in that it would be used to adjust a numerically controlled oscillator to a frequency sufficiently close to the true carrier frequency that it would lie within the pull-in range of the Costas loop.

Initially, the numerically controlled oscillator would be set at a frequency offset by a specified amount from the nominal carrier frequency. The incoming signal would be mixed with direct and 90°-phase-shifted outputs of the numerically controlled oscillator, yielding an in-phase signal $i(t)$ and a quadrature signal $q(t)$ (where t = time). Each of these signals would be passed through a one-pole low-pass filter, yielding $Z_i(t)$ and $Z_q(t)$, respectively. $Z_i(t)$ and $Z_q(t)$ would be mixed, yielding $Z'(t)$, which would include noise plus a sinusoidal component at twice the difference between the carrier and oscillator frequencies.

The magnitude, but not the sign, of the frequency difference would be found by searching through the magnitude spectrum of $Z'(t)$. This would be done by use of a T-second integrate-and-dump filter (where T = the symbol period of the modulation) followed by a fast Fourier transform (FFT). Because the amplitude of the double-frequency-difference sinusoid would not depend on symbol timing, the performance of the system would not be adversely affected by errors in integration periods, and synchronization with symbols would not be necessary. The ambiguity in the estimated frequency could be resolved by specifying that the frequency offset be large enough to ensure that the difference, Δf, between the oscillator and carrier frequencies would always be of the same sign under worst-case conditions.

Theoretical analysis shows that the probability of detection (the principal measure of performance) would depend on the 3-dB bandwidth of the low-pass filters and on the symbol signal-to-noise ratio. The anticipated performance of this system would be slightly better than that of other systems that effect open-loop acquisition by use of integrators instead of low-pass filters in the arms of Costas loops and in which performance varies with symbol timing.



This Costas-Loop Error Detector, when starting to operate in the acquisition mode, would estimate the difference between the frequency of the input signal and that of an internal reference oscillator. The estimate could then be used to close the frequency-control loop.

This work was done by Biren N. Shah and Jack K. Holmes of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 34 on the TSP Request Card.*

NPO-18436

Aircraft Engine-Monitoring System and Display

Safety would be increased as the pilot's workload is reduced.

Langley Research Center, Hampton, Virginia

The proposed Engine Health Monitoring System and Display (EHMSD) was designed to provide an enhanced means for a pilot to control and monitor the performances of engines. At present, the majority of engine-system instruments provide data based solely on the single sensors to which they are connected. The designs of modern, electronically generated displays of engine-sensor readouts in current and planned aircraft follow this same approach, except that multiple instruments are portrayed on a single display. The deficiency of this approach is that raw sen-

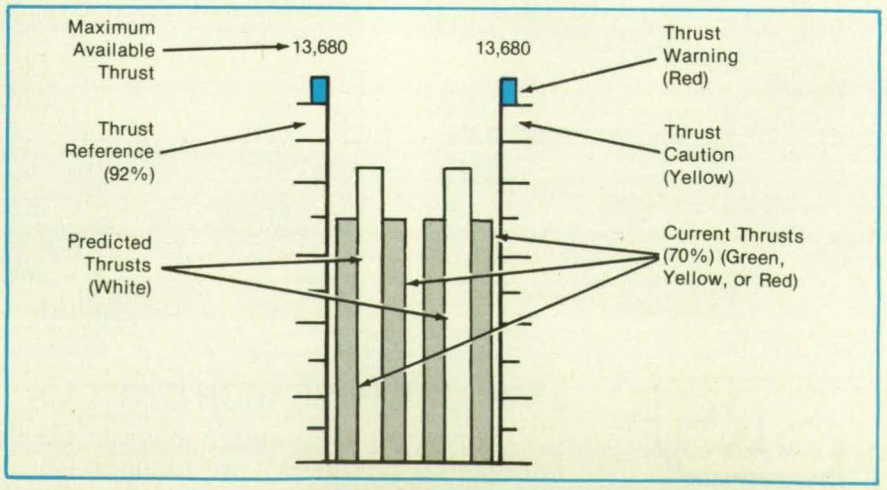


Figure 1. **Thrust Indicators for a Two-Engine System** show a representative situation.

sor data from single sensors are not the best data to provide to the pilot. They contribute to the pilot's workload and associated pilot errors.

The EHMSD would process the raw sensor data into information that is more meaningful to the pilot and present the information in a manner that is easier to understand and use. It would provide graphical information about performance capabilities, current performance, and the operational conditions (relative to nominal conditions) in components or subsystems of engines.

Information for the proposed EHMSD would be generated by a simplified mathematical model of the functions of the monitored engines and presented to the pilot on electronic displays on the cockpit instrument panel. The model would provide data on how the "ideal" engine would be performing under the current conditions; i.e., altitude, temperature, speed, and control position.

Under the present convention, to control the power of the engine, the pilot uses either an EPR (Engine Pressure Ratio: a ratio between pressures in the front and rear of the engine) gauge or an N_1 (rotational speed of the low-pressure compressor) gauge. The pilot should not have to control engine power through EPR or N_1. The pilot should be provided a means to control the thrust produced by the engine directly on the basis of EPR, N_1, EGT (exhaust-gas temperature), and other limitations of the engine. The EHMSD would provide this capability.

The display elements for control would be the thrust indicators (Figure 1), with 100 percent defined as the maximum available thrust (MAT) without exceeding any engine limit. The MAT would be a value computed from the mathematical model of the engine. This approach would offer several advantages. First, the position on the MAT indicators would always remain the same, providing the pilot with a fixed, visual reference location and reducing visual scan time. Second, because of the use of a scale normalized by the MAT for the current conditions, the takeoff-power-setting charts would no longer be required. The takeoff-power setting under this concept, a percentage of MAT, would remain constant. Third, the thrust predictor would provide an independent check between commanded thrust (where the engine-control lever would be set) and actual engine thrust.

To monitor the components or subsystems of the engine (e.g., oil pressure, oil temperature, fuel flow), current displays usually provide information via such fixed-scale and moving-pointer indicators as dial or moving-column indicators. In the EHMSD, the indicators for this purpose would be deviation-column indicators (Figure 2). The range of these indicators is equally divided into normal, caution, and warning subranges for both above- and below-nominal operational conditions.

Typically, each of these indicators would show a difference between the actual value and the nominal (model) value of the readout of the subsystem sensor for each affected engine parameter. In addition, the conventional limitations of subsystems would be merged with the deviations as

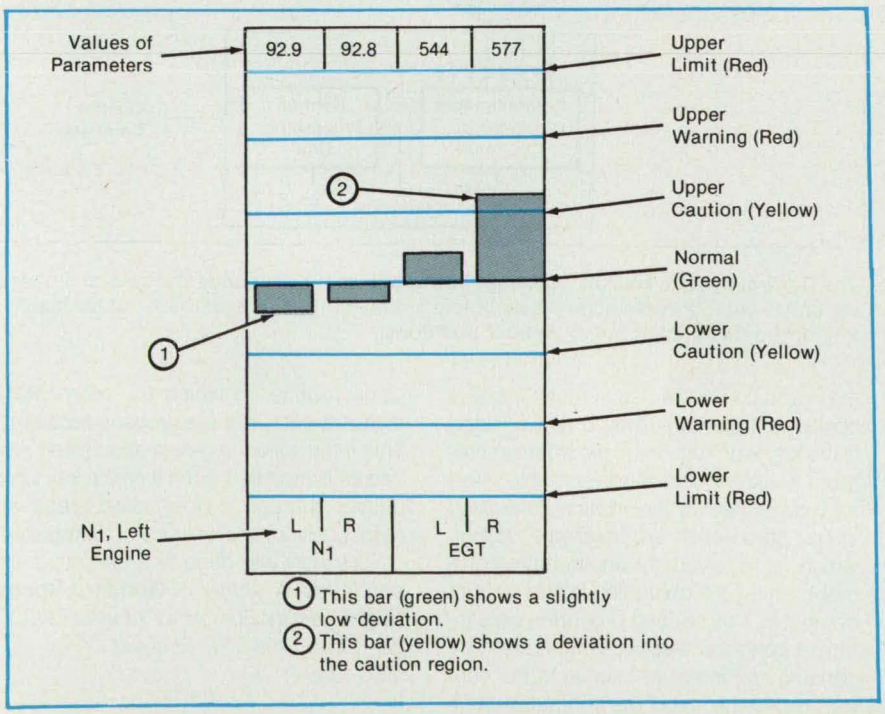


Figure 2. **Deviation-Column Indicators** for a two-engine system show normal, caution, and warning subranges.

the parameters approached their respective limits, thereby presenting the worst situation. Because these indicators would present the differences between actual and nominal (or limit) conditions, the size of each column would be a direct indication of the severity of the problem. Studies have shown that deviation-column indicators in general provide faster means for presenting multiple-element data. These indicators should enable the pilot to determine the statuses of all the subsystems of engines at a single glance.

The primary advantage of the EHMSD would be twofold. First, the simplified mathematical model of the functions of the monitored engines would provide a basis to compare the performances of the engines and systems related to the engines. The comparative data from this model would be valuable in themselves in that they would provide the pilot a means to identify degraded operational conditions. Second, the display would provide a means for the pilot to control the engine thrust directly and an innovative means for the pilot to monitor the performance of the engine system rapidly and reliably. These features lend themselves to reduced pilot workload and increased operational safety. The potential applications of the EHMSD are primarily in aircraft, but adaptation to spacecraft and other piloted, propelled vehicles should also be feasible.

This work was done by Terence S. Abbott and Lee H. Person, Jr., of **Langley Research Center**. *Further information may be found in NASA TP-2960 [N90-18393], "A Simulation Evaluation of the Engine Monitoring and Control System Display."*

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

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 24]. Refer to LAR-14049.

Scanning System Acquires Data at Designated Coordinates

Data are acquired "on the fly" as the scanner passes through the designated positions.

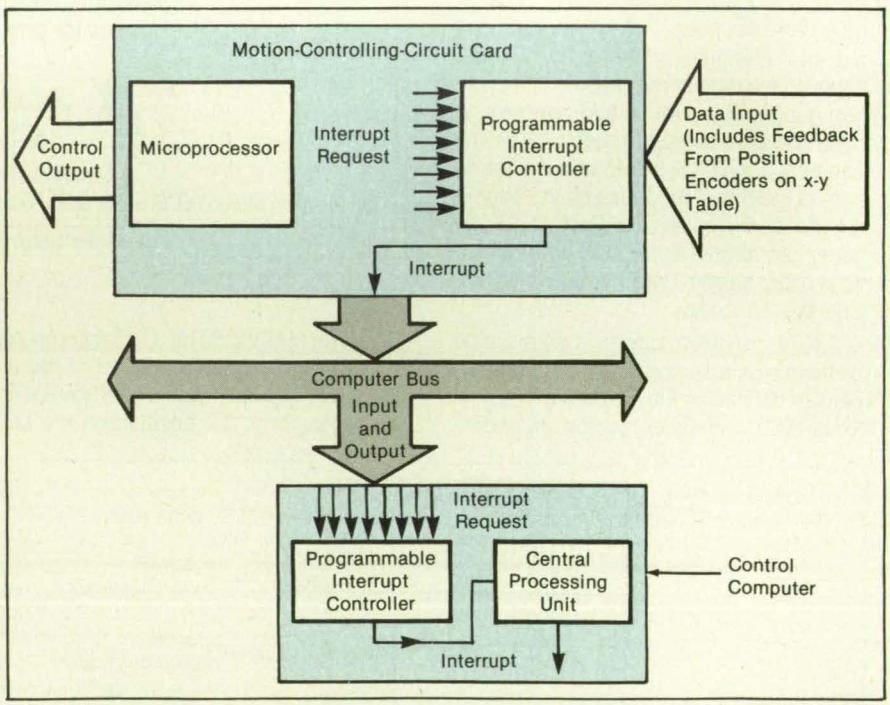
Goddard Space Flight Center, Greenbelt, Maryland

Firmware in a computer-controlled electromechanical scanning apparatus enables the acquisition of data "on the fly" — as the scanning head passes through designated positions on a plane. The firmware and scanning apparatus were designed as part of a nondestructive eddy-current inspection system and could be adapted easily to other systems that are required to take data (e.g., by use of an ultrasonic probe), perform machining operations (e.g., drill holes), or perform other functions at designated positions.

In some pointwise-data-acquisition systems of prior design, stop-and-go motion of the scanning mechanism ensures positional accuracy but entails relatively long scan time and wears out the mechanism more rapidly than steady scanning does. Other systems of prior design scan in steady motion and acquire data at fixed sampling rates but offer less positional accuracy. The present design combines the advantages and eliminates the disadvantages of both prior designs: The scanning motion is steady (except, of course, at the ends of scan lines), and there is no sacrifice of positional accuracy.

The scanning apparatus is an *x–y* translational-actuator table equipped with position encoders. The object to be inspected is mounted on the table and moved in a raster pattern under the eddy-current or other probe. The motion of the table is controlled by a circuit card that includes a microprocessor and a programmable interrupt controller (see figure), which are programmed with the parameters of the scan and with the positions at which the probe is to take measurements.

As the *x–y* table scans, position feedback from the encoders is sent to the microprocessor, which constantly compares the position with the preset measurement positions. Whenever the current position is the same as one of the preset measurement positions, the programmable interrupt controller on the motion-controlling circuit card sends an "interrupt" signal, which is received by another programmable interrupt controller in the control computer. This second programmable interrupt controller responds immediately by sending an "interrupt" signal to the central processing unit of the computer, causing the computer to enter the data-acquisition routine, in which the momentary digitized output of the probe is recorded. This interruption-and-data-acquisition procedure is repeated, each time the *x–y* table passes through a designated measurement position, until the scan is completed.



The Control System Has an "Interrupt" Structure that commands the central processing unit to enter the data-acquisition routine momentarily whenever the *x–y* table reaches any of the designated measurement positions.

This work was done by E. James Chern and David W. Butler of **Goddard Space Flight Center**. *For further information, Circle 106 on the TSP Request Card.*
GSC-13497

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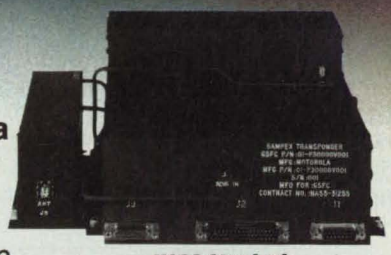

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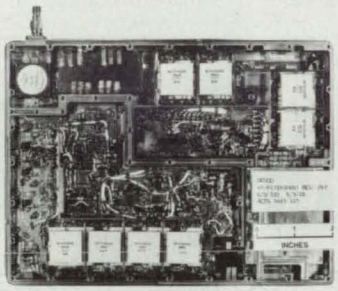

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For More Information Circle No. 397

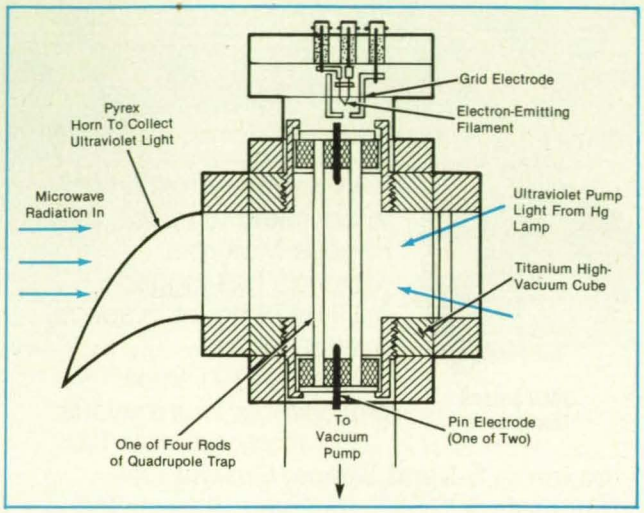
Atomic Clock Based on Linear Ion Trap

Preliminary tests indicate progress toward a goal of high stability.

NASA's Jet Propulsion Laboratory, Pasadena, California

A highly stable atomic clock is based on the excitation and measurement of a hyperfine transition in $^{199}Hg^{+}$ ions confined in a linear quadrupole trap by radio-frequency and static electric fields. The clock was built and tested as a prototype of portable frequency standards for use in astrophysics and radio science.

The linear quadrupole configuration increases the stability of the clock by enabling the use of enough ions to obtain an adequate signal while reducing the non-thermal component of the motion of the ions in the trapping field, thereby reducing the second-order Doppler shift of the hyperfine transition. This and other features of the linear quadrupole trap are described in more detail in "Linear Ion Trap for Atomic Clock," *NASA Tech Briefs* Vol. 14, No. 9 (September 1990), page 44. The principle of operation of a frequency standard based on the particular hyperfine transition was described in "Trapped-Mercury-Ion Frequency Standard," *NASA Tech Brief* Vol. 15, No. 6 (June 1991), page 55. This atomic clock operates according to the same basic principle, but differs in some of the details.



Ultraviolet and Microwave Beams probe $^{199}Hg^{+}$ ions in the linear quadrupole trap. Ultraviolet fluorescence from the ions indicates resonance between the microwave beam and a hyperfine transition in the ions.

The figure shows the quadrupole linear trap and some of the ancillary equipment. The confining radio-frequency field is generated by applying a 500-kHz signal at an amplitude of about 100 V to the four quadrupole rods. The rods are 75 mm long. A total of 15 V dc is applied to the end pins to confine the ions axially. The ions are created in the trap by a pulse of electrons that ionizes a neutral vapor of ^{199}Hg. Resonance radiation from a ^{202}Hg lamp optically pumps the ions into the $F = 0$ hyperfine level of the ground state. Microwave radiation of a frequency close to the frequency to be determined (about 40.5 GHz) propagates through the trap in the direction opposite that of the ultraviolet light.

The electron, microwave, and ultraviolet pulses are of various durations of the order of 1 s and are applied in a 6.3-s measurement cycle in a sequence such that the resonance between the microwave frequency and the hyperfine transition in question manifests itself as fluorescence (scattering) of ultraviolet light. The microwave signal is derived from a hydrogen-maser source and is adjusted in small increments (typically, 10 mHz) while measuring the fluorescence to obtain the resonance peaks.

The goal in developing this clock as a frequency standard is to attain a measure of stability of $1\times10^{-13}/\sqrt{\tau}$ over an averaging time $\tau > 1\times10^{4}$ s (where the measure of stability as used here is an upper limit on instability, as expressed in units of the root-mean-square fractional deviation of the frequency from the nominal value). In preliminary measurements, this clock has exhibited stabilities of $1.6\times10^{-13}/\sqrt{\tau}$ for $50\text{ s} < \tau < 800$ s with an atomic resonance peak 160 mHz wide and a signal-to-noise ratio of 40 for each measurement cycle. Further analysis indicates that the suppression of instabilities contributed by various known sources could yield a stability measure of about 10^{-16} for $\tau \geq 10^{6}$ s.

This work was done by John D. Prestage and G. John Dick of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 80 on the TSP Request Card.* *NPO-18382*

CyberResearch PC Products for Scientists & Engineers

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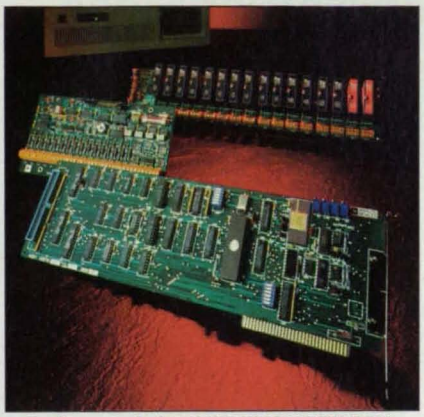

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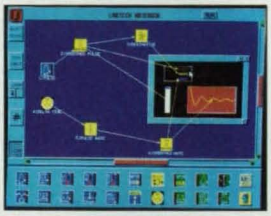

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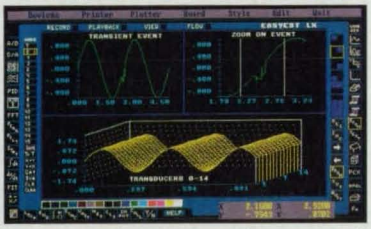

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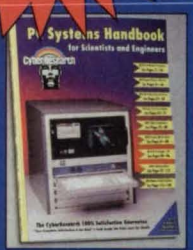
For More Information Circle No. 370

FREE PC Systems Handbook for Scientists & Engineers



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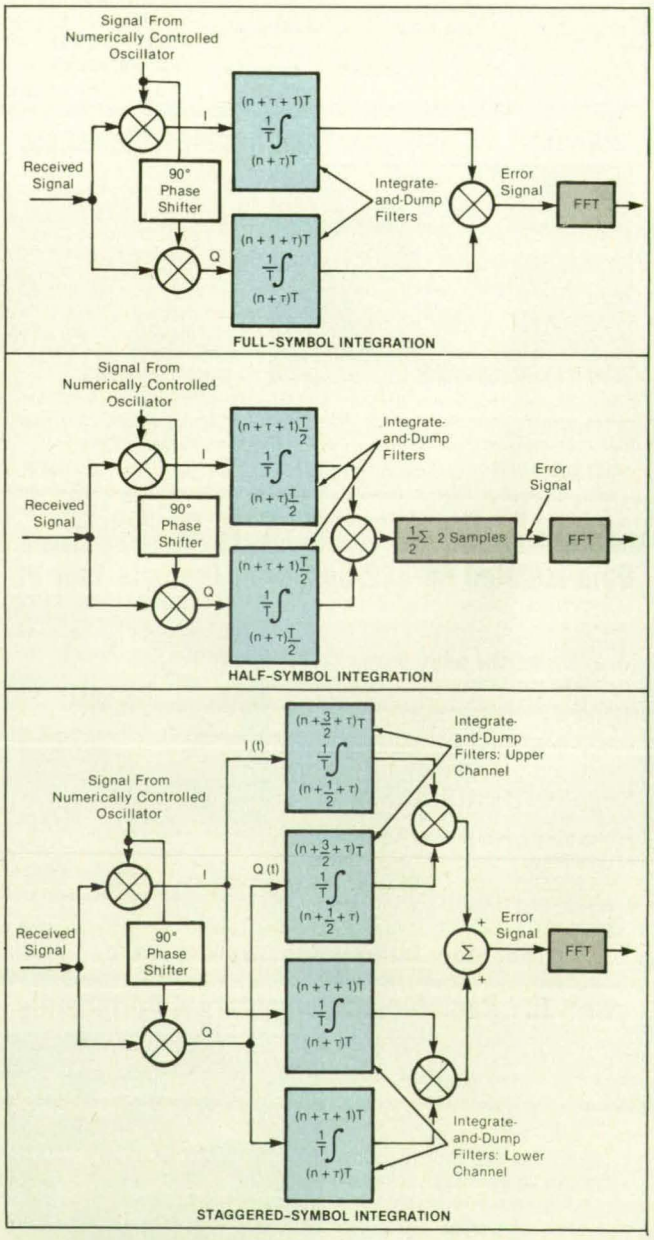
For More Information Circle No. 366

Open-Loop Acquisition of Suppressed Carrier Signals

It is not necessary to synchronize with NRZ, BPSK symbols.

NASA's Jet Propulsion Laboratory, Pasadena, California

Three digital techniques for the open-loop acquisition of suppressed carrier signals in the presence of binary-phase-shift-keyed (BPSK) modulation representing non-return-to-zero (NRZ) data symbols have been proposed. The techniques are intended mainly for use in the case of low signal-to-noise ratio, in which the offset, Δf, of the carrier frequency from the frequency of a numerically controlled oscillator in



Three **Techniques for Open-Loop Acquisition** of a suppressed carrier signal involve the use of FFT's to find a tone at twice the offset (error) frequency.

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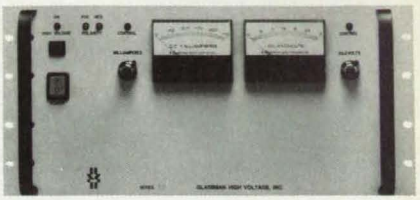

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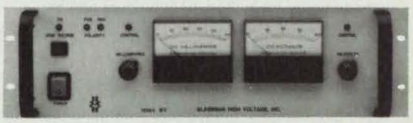
Glassman High Voltage



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Glassman High Voltage

the receiver must be found without the benefit of prior synchronization of any of the functions of the receiver with the symbols.

All three techniques are based on the assumption that the offset, τ, between the timing of the symbols and that of a clock in the receiver is an unknown but fixed fraction of the symbol period, T. In all three techniques, fast Fourier transforms (FFT's) are performed on the outputs of integrate-and-dump filters that are parts of Costas-type loops that are used to demodulate the BPSK signals (see figure).

In each case, the timing of the integrate-and-dump filters is kept constant at the assumed symbol rate. The outputs of the integrate-and-dump filters are mixed to obtain an error signal. Theoretical analysis shows that the magnitude spectrum of the error signal is a function of many variables, including τ, and that this signal contains noise plus a tone at a frequency of $2\Delta f$. Accordingly, the carrier frequency is detected by using the FFT to search the spectrum for a tone, the frequency of which is then presumed to be $2\Delta f$.

The first technique, called "full-symbol integration," is easiest to implement. The integrations are performed simultaneously during periods of T in the in-phase (I) and quadrature (Q) channels. One disadvantage of full-symbol integration is that when $\tau \approx T/2$, the integrations cross the temporal boundaries of symbols, with the result that the error signal contains noise alone about half the time. This motivates the second technique, called "half-symbol integration," in which integrations across the temporal boundaries of symbols occur only half as often as in the full-symbol case, and consequently the error signal is noise alone only a quarter of the time. However, when $\tau \ll T$, the error signal in half-symbol integration is degraded by 3 dB because the opportunity to integrate over the full symbol period is not exploited.

The third technique, called "staggered-symbol integration," represents a compromise between the first two techniques. In this case, the I and Q channels are cross-coupled into a "top" channel and a "bottom" channel, each of which contains full-symbol integrators; the timing of the integrations in the bottom channel is delayed by $T/2$ with respect to that in the top channel. The error signal in this case never consists of noise alone because when the integrations in one channel cross the temporal boundaries of symbols, those in the other channel do not. Instead, the error signal is a composite — a sum of delayed and undelayed error signals — and contains both signal and noise. Theoretical analysis shows that staggered-symbol integration offers the best performance at low signal-to-noise ratios.

This work was done by Biren N. Shah and Sami M. Hinedi of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 107 on the TSP Request Card.*

NPO-18364

Eliminating Bias in Acousto-Optical Spectrum Analysis

Digital processing includes a real-time correction for a signal-dependent bias.

NASA's Jet Propulsion Laboratory, Pasadena, California

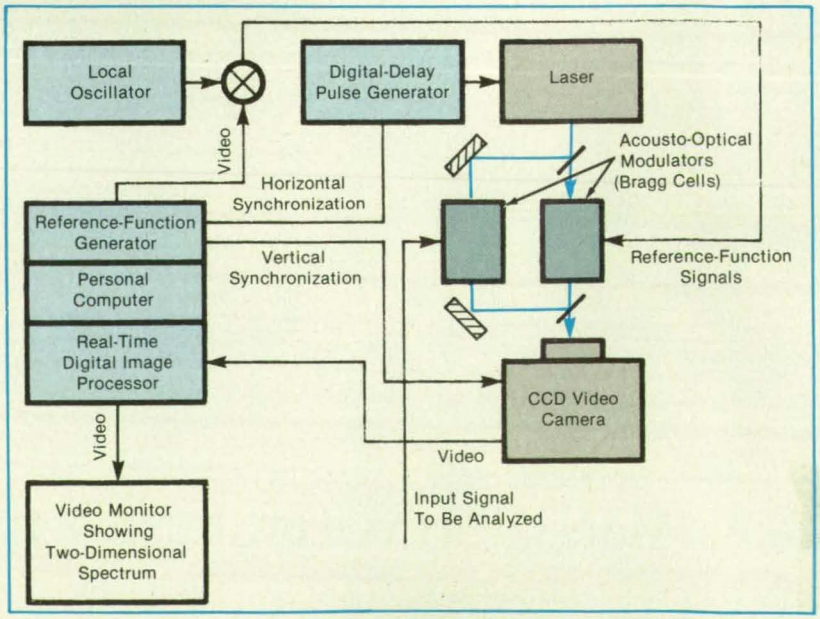
A scheme for the digital processing of video signals in an acousto-optical spectrum analyzer provides real-time correction for a signal-dependent spectral bias. The spectrum analyzer in question is the one described in "Two-Dimensional Acousto-Optical Spectrum Analyzer" (NPO-18092), *NASA Tech Briefs*, Vol. 15, No. 9 (September 1991), page 72, and a related apparatus is described in "Three-Dimensional Acousto-Optical Spectrum Analyzer" (NPO-18122) on page 62 of the same issue. The signal-dependent spectral bias is formed on a charge-coupled-device (CCD) video camera into which the optically processed spectral image is projected. The figure illustrates schematically those relationships among electronic and optical subsystems that are relevant to the method of correction for the signal-dependent spectral bias.

As explained in more detail in the noted prior articles, the input signal to be analyzed is processed electro-optically along with a set of reference-function signals in such a manner as to form a two-dimensional spectral image in the CCD camera, where the position of a bright spot along one axis of the focal plane represents the frequency of the input signal with coarse resolution, while the position of the spot along the perpendicular axis represents finer frequency resolution within the local coarse-resolution cell.

A signal-dependent spectral bias is generated because of the interferometric combination and square-law detection of the input signal and the reference-function signals on the CCD camera. The signal-dependent spectral bias is constant along the fine-resolution axis. However, the magnitude and phase of the spectrum varies randomly from pixel to pixel along the fine-resolution axis. Thus, averaging the pixel values along the fine-resolution axis in each coarse-resolution channel results in an accurate estimate of the signal-dependent spectral bias in that coarse-resolution channel. The essence of the correction is to average over the digitized outputs of all the pixels in each CCD row, which is along the fine-resolution axis, and to subtract this average from the digitized output of each pixel in that row. The overall time delay of the above process corresponds to the readout time of about 60 microseconds for one CCD row, which is negligible compared to the CCD frame-readout time of about 30 milliseconds.

This work was done by Homayoon Ansari and James R. Lesh of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 58 on the TSP Request Card.*

NPO-18275



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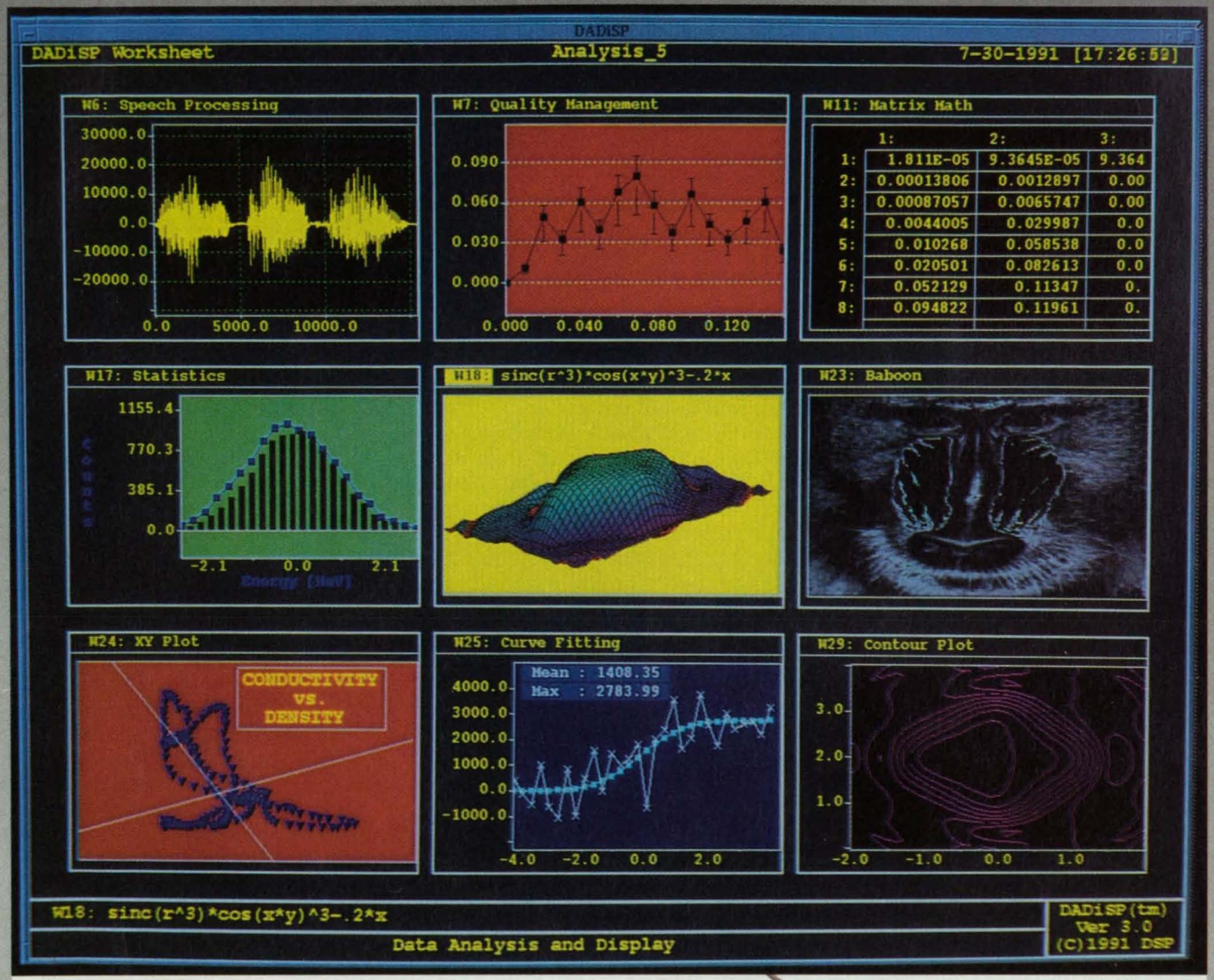

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Projected-Fringe, Phase-Stepping Profilometer

This system makes a topographical map of an object within minutes.

Lewis Research Center, Cleveland, Ohio

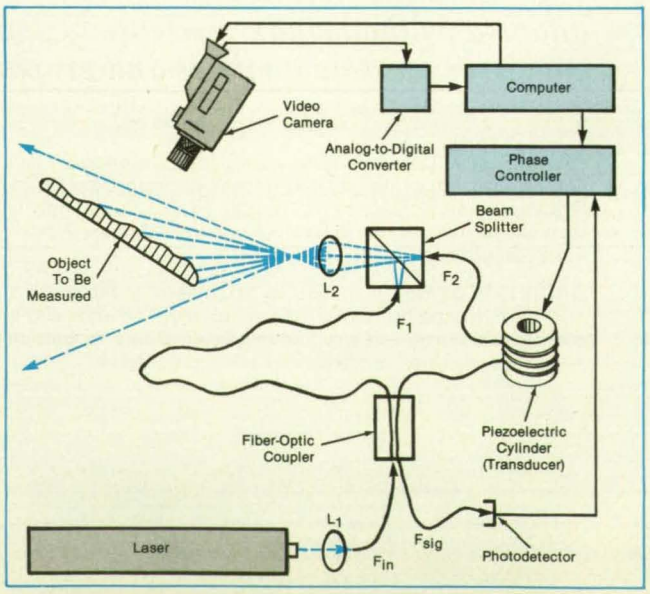
The projected-fringe, phase-stepping profilometer is a system of optical, electronic, optoelectronic, and electro-optical equipment that measures the surface profiles of a variety of objects. It projects an optical interference pattern onto an object of interest and steps the phase of the pattern to extract the phases of the interfering beams where they intersect the object. The resultant full-field phase map is a measure of the surface profile of the object, and the data can be obtained within seconds.

The system (see figure) includes a closed-loop phase controller that provides accurate, stable phase steps, a compact, rugged optical system that is flexible and efficient, a video camera that rapidly acquires data on the full field, and a computer that processes the data. The system can measure the surface of almost any object that reflects enough light to be recorded by the camera and that remains stationary during the time it takes to acquire four images. The resolution of the system is easily changed from less than a millimeter to several tenths of a meter, and the measured area is likewise variable by means of a zoom lens on the camera.

Laser light is coupled through lens L_1 into one leg (F_{in}) of a single-mode fiber-optic coupler. The coupler splits this light into two beams, which are emitted from output optical fibers F_1 and F_2. These beams are combined in a beam splitter and projected through lens L_2 onto the surface of the object to be measured. There, they form an interference pattern, which is recorded by the video camera, digitized, and stored on a computer. The relative phase of the two beams is stepped by $\pi/2$ radians, causing the projected fringe pattern to shift by one-quarter of a cycle. This shifted pattern is recorded and stored. This process is repeated to obtain two more images, each after the fringe pattern has been shifted by an additional quarter cycle.

The resulting four images are digitally manipulated to compute the relative phase of the interfering beams at each point on the surface of the object. This phase map is related to the surface profile of the object according to a function that depends on the spacing of the projected fringes, the angle at which the fringes intersect the surface of the object, the viewing angle of the camera, and the angle of divergence of the beams that form the projected fringe pattern. The sensitivity of the measurement can be easily changed by repositioning the end of one of the fibers F_1 or F_2 and/or by moving lens L_2 along the optical axis. The common-path design and active phase stabilization produce an optical configuration that is relatively insensitive to environmental disturbances.

The accuracy of the measurement is dependent on the accuracy of the phase steps. The closed-loop phase controller in this system provides an order of magnitude more accuracy than previous phase-stepping techniques have provided. The relative phase of the two beams is sensed by a photodetector, which detects the light reflected from the ends of fibers F_1 and



The **Projected-Fringe, Phase-Stepping Surface Profilometer** is a noncontact, full-field surface profilometer that has many potential industrial applications, including the inspection of machined and ceramic parts, printed circuit boards, and optical components. The system is rugged and compact and can measure surfaces that have a wide variety of sizes and finishes.

WHICH WOULD YOU RATHER WRITE?

```
/*
  C_EXAMPLE.C
    This program reads 100 values from channel 2 of the AXV11-C then
    displays the data in a graph on the screen.

    This is a simple application using the DECRTI libraries.

    This program can be compiled, linked, and run as follows:
          $CC C_EXAMPLE
          $LINK C_EXAMPLE, SYS$INPUT/OPT
          Sys$Library:VAXCRTL.EXE/share
          <CTRL-Z>
          $RUN C_EXAMPLE
*/

#include <lioset.h>                 /* LIO set parameter definitions */
#include <decrti.h>                 /* DECRTI routine definitions */
#include descrip                   /* string descriptor definitions */
#include stsdef                    /* STATUS value bit definitions */

main()
{
/* Declare local variables */
        int STATUS              /* STATUS returned by LIO routine calls */
          ,axv_id               /* LIO-assigned device ID */
          ,data_length  /* number of data bytes to read */
          ;

/* Declare the string descriptors for the string constants */
        $DESCRIPTOR (dev_type, "AXA0:");    /* AXV11-C device type */
        $DESCRIPTOR (mode_string, "IXSY");  /* LGP$PLOT mode string value */
        $DESCRIPTOR (xlabel, "Time");       /* LGP$PLOT x-axis label */
        $DESCRIPTOR (ylabel, "Voltage");    /* LGP$PLOT y-axis label */
        $DESCRIPTOR (title, "C_EXAMPLE");   /* LGP$PLOT graph title */

/*
Declare data buffer for raw data in LSP$FORMAT_TRANSLATE_ADC. This
is a word (16-bit) array containing 100 elements.
*/
    short int raw_data[100];
/*
Declare data buffer for voltages in LSP$FORMAT_TRANSLATE_ADC and
LGP$PLOT routines. This is a single-precision, floating-point
array containing 100 elements.
*/
     float voltages[100];

/* Program execution */

/* Set up the AXV11-C */

      printf("C_EXAMPLE, Read data, convert it, plot it\n\n");

/*
Attach the AXV11-C and set up for mapped (polled) I/O. This routine
call returns an LIO-assigned device ID for the device.
*/
          STATUS = LIO$ATTACH (&axv_id, &dev_type, &LIO$K_MAP);
                   if(!(STATUS & STS$M_SUCCESS)) LIB$SIGNAL(STATUS);

/* Set up the AXV11-C to use the synchronous I/O interface. */

          STATUS = LIO$SET_I (&axv_id, &LIO$K_SYNCH, &0);
                   if(!(STATUS & STS$M_SUCCESS)) LIB$SIGNAL(STATUS);

/* Set up AXV11-C channel 2 for input. */

          STATUS = LIO$SET_I (&axv_id, &LIO$K_AD_CHAN, &1, &2);
                   if(!(STATUS & STS$M_SUCCESS)) LIB$SIGNAL(STATUS);

/* Set up a channel gain of 1. */

          STATUS = LIO$SET_I (&axv_id, &LIO$K_AD_GAIN, &1, &1);
                   if(!(STATUS & STS$M_SUCCESS)) LIB$SIGNAL(STATUS);

/* Trigger on LIO$READ and fill buffer as fast as possible. */
          STATUS = LIO$SET_I (&axv_id, &LIO$K_TRIG, &1, &LIO$K_IMM_BURST);
                   if(!(STATUS & STS$M_SUCCESS)) LIB$SIGNAL(STATUS);
```

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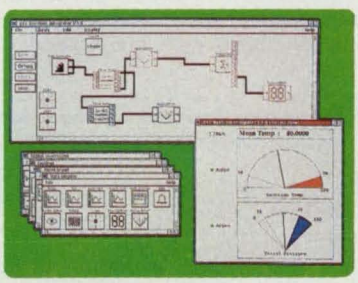

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For More Information Circle No. 668

F_2. The output from the photodetector generates a signal that compensates for any drifts in phase by driving a piezoelectric cylinder around which fiber F_2 is tightly wrapped. The controller steps the relative phase of the two beams in increments of $\pi/2$ radians by coarsely setting the phase to the desired value, alternating the polarity of the signal from the photodetector, and then locking onto the new phase.

This work was done by Carolyn Mercer and Glenn Beheim of **Lewis Research Center**. *Further information may be found in NASA TM-103252 [N90-28033], "Phase-Stepping Fiber-Optic Projected-Fringe System for Surface Topography Measurements."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.
LEW-14996

Simplified Digital Spectrum Analyzer

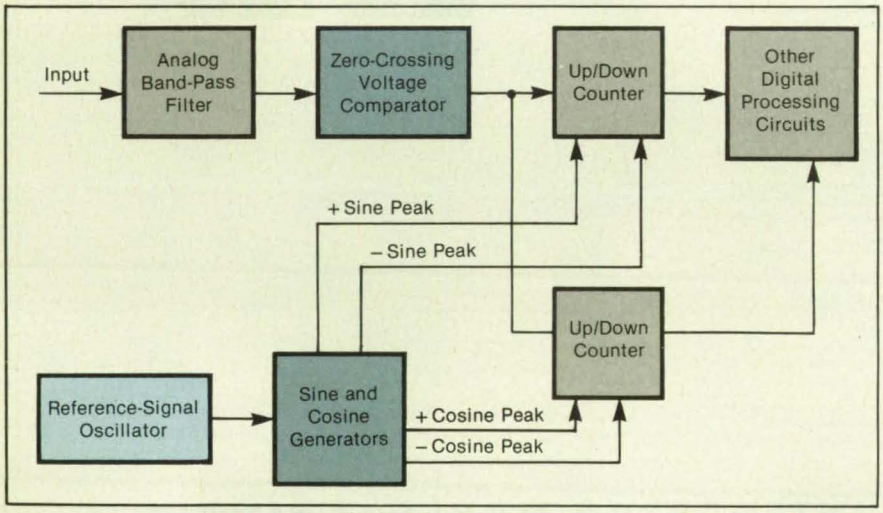
Complexity and power consumed are less than those of other digital spectrum analyzers.

NASA's Jet Propulsion Laboratory, Pasadena, California

A spectrum analyzer (see figure) that consists mostly of digital circuitry computes approximate cross-correlations between a noisy input signal and a reference signal of known frequency, yielding a measure of the amplitude of the sinusoidal component of the input at that frequency. A sequence of such correlations can be computed at different frequencies to obtain an approximate amplitude-vs.-frequency spectrum of the input.

The input signal is first passed through an analog band-pass filter to reduce aliasing (because the subsequent digital processing stages are susceptible to aliasing of input components at ⅓ and 3 times the reference frequency). The filtered signal is fed to a zero-crossing voltage comparator, which acts as a 1-bit analog-to-digital converter in that it puts out a square-wave-like signal that is high if the input is positive or low if the input is negative.

The squared signal is fed into two up/down counters. One of the counters is clocked at the positive and negative sine peaks of the reference signal. It counts up if the input signal is positive at the positive peak or negative at the negative peak; it counts down if the input signal is negative at the positive peak or positive at the negative peak. The other counter operates similarly, except that it is clocked at the positive and negative cosine peaks of the reference signal. If a sinusoid at the reference frequency is present in the input, then a large count accumulates in one or both of the up/down counters if the sampling is continued during a large number of cycles of the reference signal.



This **Spectrum Analyzer** can be regarded variously as performing sampling, 1-bit cross-correlation, and filtering functions, all implemented by digital means. This block diagram is a simplified version: the spectrum analyzer as originally designed is more complicated and is part of an acoustic-signal processor.

The magnitudes and signs of the counts indicate the approximate phase of the input sinusoid with respect to that of the reference signal. The counts can be squared and summed to obtain an approximate measure of the power of the input sinusoid. At the end of a sampling period, the counters are reset to zero.

This digital sampling scheme can be regarded either as the accumulation of 1-bit cross correlations (the computation of which does not require multiplications, as multiple-bit correlations do) between the input and reference signals or as a digital filter. The bandwidth of the filter is inversely proportional to the number of cycles in the sampling period.

In comparison with such other digital spectrum analyzers as those that compute fast Fourier transforms (FFT's), this one is simpler, consumes less power, and operates faster. An FFT analyzer must perform many time-consuming complex multiplications, using data from the entire spectrum to obtain any part of the spectrum. In contrast, this spectrum analyzer performs no mulltiplications and, because it processes the data on each frequency independently, can focus upon a narrow spectral range of interest without having to process data on the rest of the spectrum.

This work was done by Steven W. Cole of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 49 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 24]. Refer to NPO-17759.

Acquisition Performances of QPSK Carrier-Tracking Loops

Times to, and probabilities of, acquisition are computed and compared.

A report presents a comparative study of the acquisition performances of several types of carrier-signal-tracking loops for the reception of quadrature phase-shift keying (QPSK) signals. In this study, acquisition times and probabilities of acquisition as functions of both the loop signal-to-noise ratio and the ratio between the frequency offset and the bandwidth for each loop were obtained by computer simulation.

The loops are classified primarily into three types: the maximum a-posteriori, (MAP) estimation loop, the Costas crossover loop (also known as the polarity-type Costas loop), and the generalized Costas loop (sometimes denoted the conventional Costas loop). Each loop is classified further as being of type II or type III, depending on whether a certain parameter that appears in the z-domain transfer function of a low-pass filter in the loop is or is not zero, respectively.

Loops of the three primary types can be represented by a common block diagram, and differ in the processing of the in-phase and quadrature signals (Z_c and Z_s, respectively). The MAP estimation loop produces an error signal, Z_o, given by $Z_o = Z_c\tanh(RZ_s) - Z_s\tanh(RZ_c)$ where R is the symbol signal-to-noise ratio. The MAP estimation loop requires a-priori knowledge of R and is best implemented with digital technology, but at the price of complexity.

To reduce the complexity of the MAP estimation loop at high R, one can approximate $\tanh(Z)$ with $\mathrm{sgn}(Z)$ (where $\mathrm{sgn}(Z) = 1, 0$, or -1 when $Z > 0, = 0$, or < 0, respectively). This yields the Costas crossover loop with error signal given by $Z_o = Z_c\mathrm{sgn}(Z_s) - Z_s\mathrm{sgn}(Z_c)$. To reduce the complexity of the MAP estimation loop at low R, one can approximate $\tanh(Z)$ with the first two terms in its Taylor-series expansion to obtain $Z_o = Z_cZ_s(Z_c^2 - Z_s^2)$. This yields the generalized Costas loops. Both of these approximate loops can be implemented in a straightforward manner and do not require a-priori estimation of R. However, all three loops require an estimate of the amplitude of the incoming signal to be able to operate at the desired bandwidth.

In this study, a mathematical model of the signals in the various loops is developed. In-phase and quadrature signals are generated numerically and processed according to the various loop algorithms. Each simulation point is obtained by use of 5,000 runs for each combination of loop signal-to-noise ratio and frequency offset. The results of the simulation show that even though the MAP loop produces the smallest squaring loss at all signal-to-noise ratios, the other two loops sometimes exhibit shorter acquisition time and greater probability of acquisition.

This work was done by Sami M. Hinedi and Biren N. Shah of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Acquisition Performance of Various QPSK Carrier Tracking Loops," Circle 60 on the TSP Request Card.*

NPO-18166

Performance of Digital Data-Transition-Tracking Loop

Coherent and incoherent sampling at various sampling and symbol rates are considered.

A report presents a theoretical study of the performance of an all-digital data-transition-tracking loop (DTTL). DTTL's are used in those modern digital communication receivers in which the modulation consists of nominally rectangular waves that represent binary symbols, and the changes in polarity, called "transition boundaries" between symbols, occur at the beginnings and ends of symbol periods. A DTTL is a subsystem that estimates the times of the transition boundaries in the effort to synchronize the functions of other subsystems of a receiver with the symbols.

The DTTL can be designed to sample coherently (with its sampling clock controlled by the symbol-synchronization loop) or incoherently (with its sampling clock running freely at a rate that can differ from an integer multiple of the sample rate). In both cases, the DTTL can also be designed to sample either instantaneously or by the integrate-and-dump technique, which should be used when the number of samples per symbol period is small. The theory presented in this study is valid for both instantaneous and integrate-and-dump sampling.

For both coherent and incoherent sampling, equations are derived to analyze the effects of few samples per symbol period and of noncommensurate sampling and symbol rates. The effects of noise and the frequency response of the DTTL are taken into account. The effects upon the variance of the phase error of the DTTL and on the mean time to lose lock are quantified through computer simulations.

One of the conclusions drawn from the numerical results is that because of the phase ambiguity attributable to the period between successive samples, the digital DTTL performs poorly when the number of samples per symbol period is a small integer. This deficiency can be alleviated when the number of samples per symbol period is not an integer and the low-pass filter through which the phase-error signal in the loop is processed into a control signal for the sampling oscillator has the appropriate bandwidth.

Another product of the study is a closed-form expression for the *S*-curve. This is the curve that shows the expectation value of the error signal as a function of the phase error for a given signal-to-noise ratio and for a given offset of the first sample time mark in a received symbol from the transition boundary. The *S*-curve is so named because it can take on any of a variety of shapes that resemble a sinusoid or the letter "*S*" lying on its side. The closed-form expression for the *S*-curve is valid for any number of samples per symbol period. Yet another product of the study is a demonstration of the interplay between the bandwidth of the loop and the number of samples per symbol period in the reduction of the phase ambiguity and of the self-noise, which is a component of noise that arises from the sampling process and is caused by a combination of timing and the finite number of samples.

This work was done by Sami M. Hinedi and Unjeng Cheng of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Performance of the All-Digital Data Transition Tracking Loop," Circle 42 on the TSP Request Card. NPO-18176*

Behavior of Costas Loop in Reception of Telemetry

The modulation index, bit rate, subcarrier waveform, and subcarrier frequency affect performance.

A report presents a study of the behavior of a Costas loop in the reception of a binary non-return-to-zero telemetry signal phase-shift-modulated onto a sinusoidal or square-wave subcarrier signal that is, in turn, phase-modulated onto a carrier signal. The analysis applies to the case in which the received signal includes additive white Gaussian noise and may be Doppler-shifted and in which the carrier signal is not completely suppressed.

This study extends a prior study that did not take account of phase-shift subcarrier modulation and the Doppler effect. Furthermore, whereas the phase error of the Costas loop was assumed to approach zero at high signal-to-noise ratio (SNR) in the prior study, it is not assumed to do so in this study. Only the linear approximation, which is valid for small errors, is invoked in this study.

Equations that describe the degradation of performance of the Costas loop in terms of phase jitter, conditions that cause loss of lock, and other effects are derived, and it is shown that the Costas loop can be used to track the telemetry signal with residual carrier in the presence of Doppler shift. It is found that the mean-squared tracking jitter increases when a residual carrier is present. The principal parameters that affect the degradation of performance of the Costas loop are found to be the telemetry modulation index, the telemetry bit rate, and the waveform and frequency of the subcarrier. It is shown that the performance can be optimized by a suitable choice of the bit rate, the waveform and frequency of the subcarrier, and

the noise bandwidth of the filters in the arms of the Costas loop.

Degradations of performance are computed in numerical examples that involve single-pole Butterworth arm filters and both sinusoidal and square-wave subcarriers. For these examples, optimum values of the ratio between the noise bandwidth of the arm filters and the bit rate at a given integer ratio between the frequency of the subcarrier and the bit rate are determined. (These values are optimum in the sense that they result in a specified mean-squared tracking jitter under a specified operating condition.)

This work was done by Tien Manh Nguyen of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "The Behavior of a Costas Loop in the Presence of Space Telemetry Signals," Circle 11 on the TSP Request Card.*
NPO-18290

Effect of Phase Unbalance in Product Modulator

The performance of the carrier-tracking loop in a telemetry system is degraded.

A paper presents a theoretical study of the effect of phase unbalance in the product modulator of the phase-modulation transmitter in a deep-space telemetry system upon the performance of the system. The purpose of the study is to determine the important parameters necessary for the design of a balanced product modulator. Items of particular interest are the relationship between the undesired residual carrier signal and the phase unbalance, the behavior of the carrier-tracking loop in the receiver under the influence of the phase unbalance of the product modulator in the transmitter, and the degradation of performance (in terms of the increase in the bit-error rate) caused by the phase unbalance.

The product modulator is mathematically modeled as two amplitude modulators excited in opposition, plus a subtractor, operating on a carrier signal. When the two amplitude modulators are perfectly balanced against each other, the output is the product of the carrier signal and the modulation; the carrier is fully suppressed. In practice, perfect balance is not attainable. The phase unbalance — the inequality between the phases of the outputs of the two amplitude modulators — gives rise to a residual carrier signal in the output of the subtractor.

The mathematical model of the product modulator is used in this study to derive equations for the relative strengths of the desired suppressed-carrier component and the undesired residual-carrier component of the transmitted signal. A computer simulation to determine the degree of suppression of the carrier is described, and its results are compared with the values given by the equations at values of phase imbalance from 1° to 12° in 1° increments. The simulation and the equations agree within 2 to 3 dB in all cases. It should be mentioned that the computer simulation gave results different from those of the equations derived in the paper for carrier suppression because the FFT algorithm employed in the simulation did not include the "zero-padding procedure for imporved frequency resolution. As a result, the location of the unsuppressed carrier component does not fall exactly on the carrier frequency and this gives rise to the error.

Next, the study addresses the effect of the unsuppressed-carrier component on the carrier-tracking phase-locked loop in the receiver. A stochastic differential equation that describes the dynamic behavior of this second-order phase-locked loop in the presence of the unsuppressed-carrier component is derived. Because this equation is nonlinear and very difficult to solve, a computer simulation is performed, using representative parameters of a receiver in the Deep Space Network. It is shown that if the phase unbalance is sufficiently large, the carrier-tracking loop can lose lock on the suppressed-carrier component and lock onto the unsuppressed-carrier component. Next, the study addresses the effects of the unsuppressed-carrier component on the bit detector in the receiver: equations for the bit-error rate as a function of the phase unbalance are derived.

The study concludes by presenting the following recommendations:

- The phase unbalance should not lie outside the range of ± 2°.
- The minimum suppression of the carrier should be 35 dB.

This work was done by Tien M. Nguyen of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "The Impact of the Phase Unbalanced Product Modulator on the Performance of the Space Telemetry System," Circle 39 on the TSP Request Card.*
NPO-18293

Multilayer Monochromator for Hard X Rays and γ Rays

Advantages include compactness, high spectral resolution, and relatively low cost.

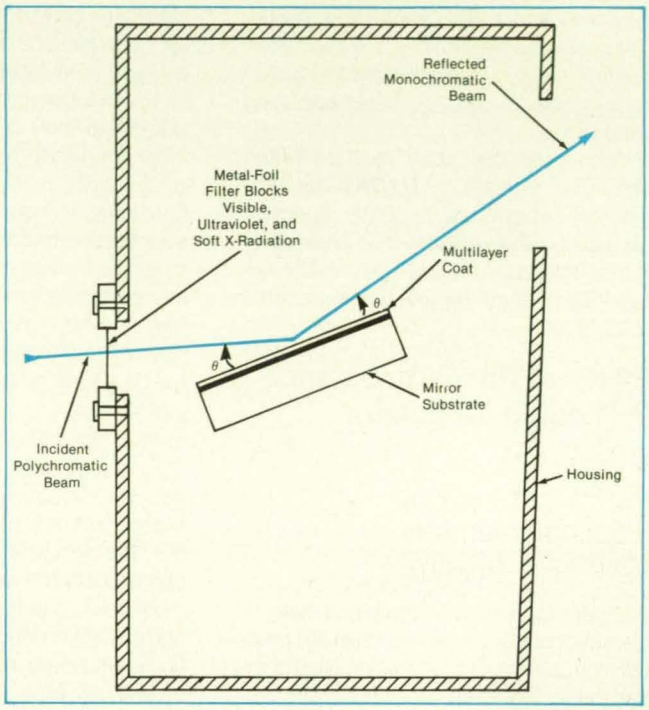
Marshall Space Flight Center, Alabama

A compact monochromator for hard x rays and γ rays provides high spectral resolution with high throughput. This instrument can be fabricated with relative ease and at relatively low cost. It is easily maintained in alignment and capable of operating at any photon energy from about 8 to about 140 keV. The hard-x-ray/γ-ray monochromator could be used in nuclear, astronomical, and biomedical research, x-ray crystallography, research on the processing and properties of materials, research in x-ray lasers, and x-ray lithography.

This monochromator (see figure) resembles the instruments described in "Compact X-Ray and Extreme-Ultraviolet Monochromator" (MFS-28499), "Scanning X-Ray or Extreme-Ultraviolet Monochromator" (MFS-28492), "Ultra-High-Spectral-Resolution X-Ray/EUV Monochromator" (MFS-28500), and "Four-Mirror X-Ray and Extreme-Ultraviolet Monochromator" (MFS-28498), *NASA Tech Briefs*, Vol. 15 No. 6 (1991), page 44. Like the monochromators of the previous articles, this one operates on the principle of the multilayer Bragg reflector. To restate the principle briefly: Alternating layers of high- and low-atomic-number material in a multilayer coat constitute a synthetic Bragg crystal, which reflects radiation in a narrow spectral band about a peak-reflection wavelength, λ, given by $N\lambda = 2D \sin\theta$, where N is the order of the Bragg diffraction (usually 1), D is the effective thickness (corrected for refraction) of a high-atomic-number/low-atomic-number pair of layers, and θ is the angle between the incident beam of radiation and the surface of the multilayer mirror.

For operation in the spectral range from 8 to 140 keV, it is necessary to use a multilayer coat with $D \approx 15$ Å and glancing angles, θ, ranging from 3° down to 10 arc minutes. The mirror substrate on which the multilayer coat is to be deposited must be long and flat enough for use at the low glancing angles, must be sufficiently rigid to maintain its flatness to within 1/100 wavelength of visible light, must have a low coefficient of thermal expansion, and must be polished smooth to a fraction of an angstrom. For these purposes, the substrate can be made of sapphire or silicon carbide slabs, typically 1 cm wide, 12 cm long, and 4 cm thick. By use of advanced flow-polishing methods, it can be polished to a smoothness of 0.2 to 0.5 Å root mean square.

A metal-foil filter is placed in the input aperture of the monochromator housing to block visible, ultraviolet, and soft x-ray photons, which may also be produced by the source of hard x-rays and γ rays. It is especially important to select foil materials and thicknesses to block soft x rays because the small angles of incidence can be less than their critical angles, causing these rays to be reflected along with the desired hard x rays or γ rays.



This **Reflecting Monochromator** contains a multilayer Bragg reflector that acts as a wavelength-selective mirror for soft x rays and γ rays. For operation in the photon-energy range of 8 to 140 keV, multilayer spacings are of the order of 15 Å, and θ typically ranges between 3° and 10 arc seconds.

This work was done by Richard B. Hoover of **Marshall Space Flight Center**. *For further information, Circle 13 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 24]. Refer to MFS-28497.

Charge-Carrier-Scattering Spectroscopy With BEEM

Scattering of electrons and holes can be measured with spatial and energy resolution.

NASA's Jet Propulsion Laboratory, Pasadena, California

Ballistic-electron-emission microscopy (BEEM) constitutes the basis of a new spectroscopy of the scattering of electrons and holes. This spectroscopy provides measurements that characterize the scattering process with both energy and spatial resolution. It has been used to investigate transport phenomena, scattering phenomena, and the creation of hot charge carriers in Au/Si and Au/GaAs metal/semiconductor microstructures.

In BEEM, a sharply pointed tip electrode scans near the surface of a coat of metal about 100 Å thick on a semiconductor. The principle of operation is similar to that of a scanning tunneling microscope, except that the metal coat acts as a third electrode.

The figure shows energy diagrams for operation in the BEEM mode for both p-doped and n-doped semiconductor substrates coated with thin layers of metal. The tip electrode injects ballistic charge carriers into the metal via quantum-me-

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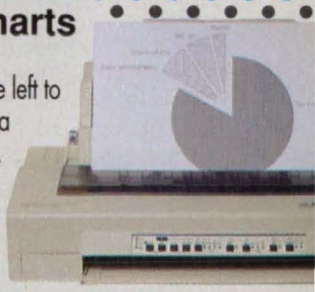

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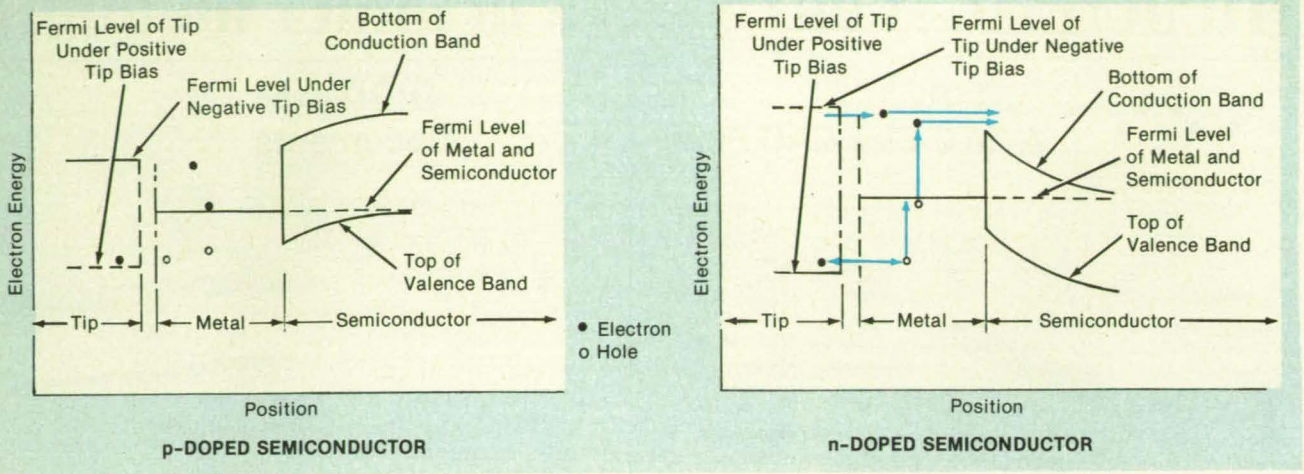

In the **Usual BEEM Mode**, the tip is biased positive to inject holes (in the case of a p-doped semiconductor) or negative to inject electrons (in the case of an n-doped semiconductor). In the new spectroscopic mode, the bias is reversed to obtain measurements indicative of scattering in the metal/semiconductor microstructure.

chanical tunneling. Some of these carriers can propagate, without scattering, to the Schottky barrier at the interface between the metal and the semiconductor, where they can be collected as majority carriers in the semiconductor. In this respect the metal is analogous to the base of a transistor. Therefore, an n-doped semiconductor can serve as a collector for electrons, while a p-doped semiconductor can collect holes. In each case, if the polarity of the bias voltage on the tip is reversed, ballistic current of carriers of the opposite type does not flow because the built-in Schottky-barrier potential opposes the ballistic motion of the carriers and does not block leakage of minority carriers back into the metal.

Now the principle of the new spectroscopy will be explained for the case of the p-doped semiconductor. Although ballistic electrons would not ordinarily be collected, scattering could create holes for collection, even under reverse tip bias. As shown in the left half of the figure, negative bias on the tip causes the injection of hot electrons into the metal. While some of these electrons reach the Schottky barrier without scattering, others lose energy in scattering on conduction electrons in the conduction energy band in the metal. The scattering excites the conduction-band electrons to energies above the Fermi level, creating hot holes in the metal. Some of these holes cross the Schottky barrier and are collected in the valence band of the semiconductor.

When the tip is biased positive as in the usual BEEM mode, hot holes are injected into the metal directly by quantum-mechanical tunneling. Like the hot holes created by scattering, some reach the Schottky barrier and are collected. Analogous processes of injection of holes and electrons, scattering, and collection of holes occur in the case of an n-doped semiconductor.

This work was done by Michael H. Hecht, Lloyd D. Bell, and William J. Kaiser of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 93 on the TSP Request Card.*
NPO-18411

High-Temperature Tribometer and Data-Acquisition System

Data on friction and wear can be acquired and processed quickly.

Lewis Research Center, Cleveland, Ohio

A new friction-and-wear test rig (tribometer) at NASA Lewis Research Center, Cleveland, Ohio, tests the friction and wear properties of ceramic and metal materials at temperatures up to 1,200 °C in controlled atmospheres. The tribometer was designed to help develop high-temperature lubricants and self-lubricating composite materials for such advanced applications as Stirling engines, advanced gas turbines, seals and bearings in hypersonic vehicles, and low-heat-rejection engines.

The tribometer can be set up in a pin-on-disk or pin-on-ring configuration (see Figure 1). It can rub materials in unidirectional sliding at speeds that range from 0.025 to 22 m/s and in oscillatory sliding at frequencies up to 4.5 Hz at amplitudes up to ±60° (±13.3 cm). The test atmosphere is established by flow of a purge gas at a controlled rate. All components within the test chamber are compatible with oxidizing, inert, or reducing gases. Test loads can vary from 0.1 to 100 kg.

The tribometer is connected to a data-acquisition system that uses computer programs developed specifically to enhance the productivity and convenience of the testing facility. The data-acquisition system is based on a personal computer (PC) with an IEEE 488 interface. Specialized programs were written in an expanded form of BASIC. The programs record average values of data that would normally be read from meters and chart recorders. The data are automatically stored in usable form and can be easily manipulated and plotted after each test (see Figure 2).

The programs automatically compensate for minor runout (misalignments or geometric nonuniformities) of specimens and for thermal gradients in the test chamber. One program is written for unidirectional sliding and uses computer-generated timing to trigger the acquisition of data; another program written for oscillatory sliding uses an electronic position signal from the rig to trigger the acquisition of data. The programs are easy to use. Input parameters like the duration and frequency of acquisition of data are selected by the user.

With this new tribometer and its data-acquisition system, the friction and wear properties of many new materials and lubricants can be ascertained accurately and conveniently. This type of information is needed in the development of materials for advanced aerospace and terrestrial applications.

This work was done by Harold E. Sliney and Christopher Dellacorte of **Lewis Research Center**. *Further information may*

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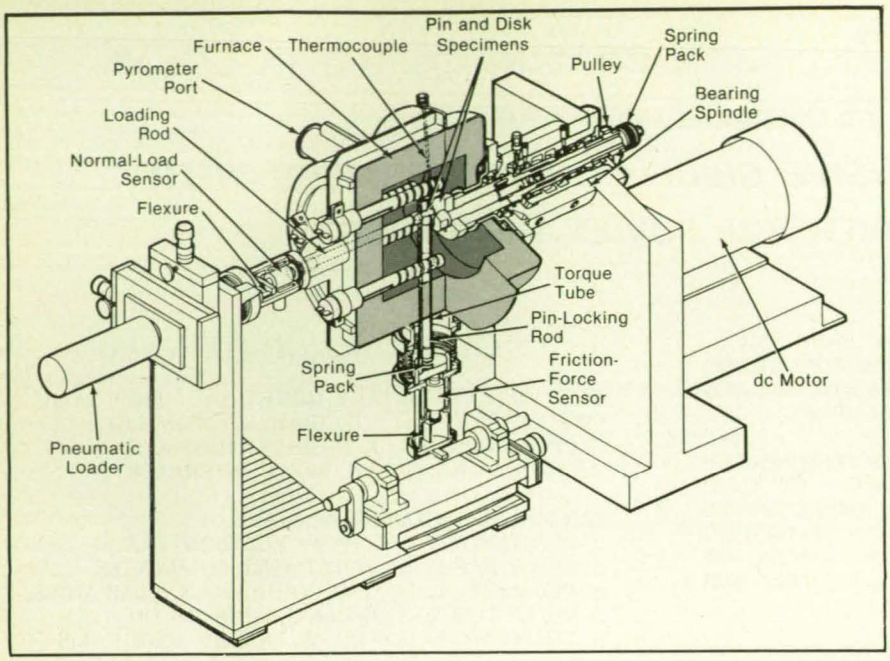

Figure 1. The **The High-Temperature Tribometer** is shown here in the pin-on-disk configuration.

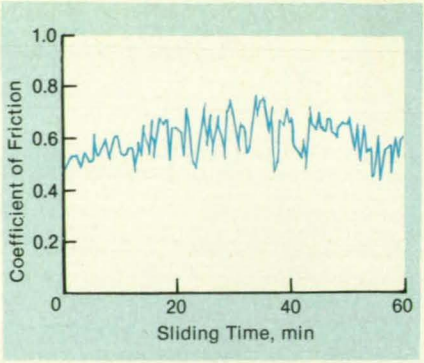

Figure 2. The **Computer Generated This Plot** from data taken in a test of oscillatory sliding of carbon/carbon composite specimens at a temperature of 1,200 °C.

be found in: NASA TM-102405 [N-90-12670], "A New Test Machine for Measuring Friction and Wear in Controlled Atmospheres to 1,200 °C," and NASA TM-102508 [N-90-17811], "The Application of a Computer Data Acquisition System for a New High Temperature Tribometer."

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LEW-15362

Measurement of Residual Stress in Ferromagnetic Materials

MAC and MAE techniques are combined to characterize stresses completely.

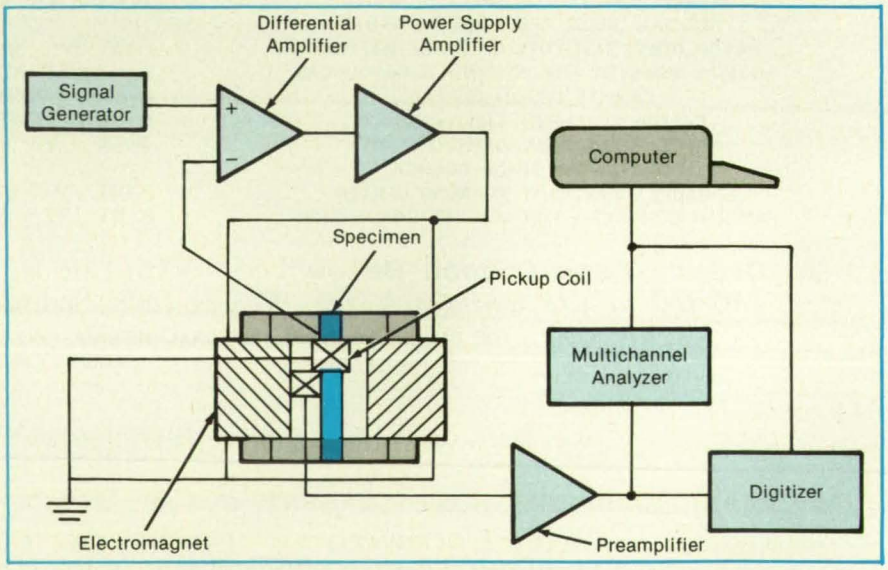
Langley Research Center, Hampton, Virginia

Complete and accurate characterization of residual stress is one of the most troublesome problems in the field of nondestructive evaluation. A technique developed by NASA, called the "magnetoacoustic" (MAC) technique, can be used to detect residual compression in ferromagnetic materials, without having to use calibration standards. The MAC technique, however, does not enable the detection of residual tension in a ferromagnetic material.

A newer technique, called "magnetoacoustic emission" (MAE), has been clearly shown to provide a capability to detect residual tension. The MAE and MAC techniques have now been combined to provide for the complete characterization of residual stresses in ferromagnetic structural materials. The implementation of both techniques involves some unique instruments and methods developed at NASA Langley Research Center.

In the MAE technique, one uses a broadband acoustic transducer for passive detection of acoustic noise generated by the motions, induced by an external ac magnetic field, of the walls of magnetic domains. The results of experiments have shown that this effect is sensitive to the magnitude of tensile stress.

The effect of compressive stress on the generation of MAE is very small. While the insensitivity of MAE measurements to uniaxial compression is usually an advantage, it can also be a disadvantage in that a state of high compression can be mistaken as a state of a low tension. To avoid this mistake, it is necessary to know whether the object being tested is under residual compression, which condition can be detected easily by use of the MAC technique.



MAE Instrumentation is connected with a desk-top computer to determine the spectral characteristics of MAE.

In the MAC technique, one measures the changes in the natural speed of sound in the material as a function of net magnetization induced in a ferromagnet. For MAC measurements, narrow-band acoustic transducers are used. The difference between the phases of the transmitted and received acoustic waves is proportional to the transit time of the acoustic waves in the specimen, which time is directly related to the speed of sound.

The instrumentation developed at Langley Research Center (see figure), called "pulse-phase-locked-loop" (P^2L^2), is used for automated measurements of normal-

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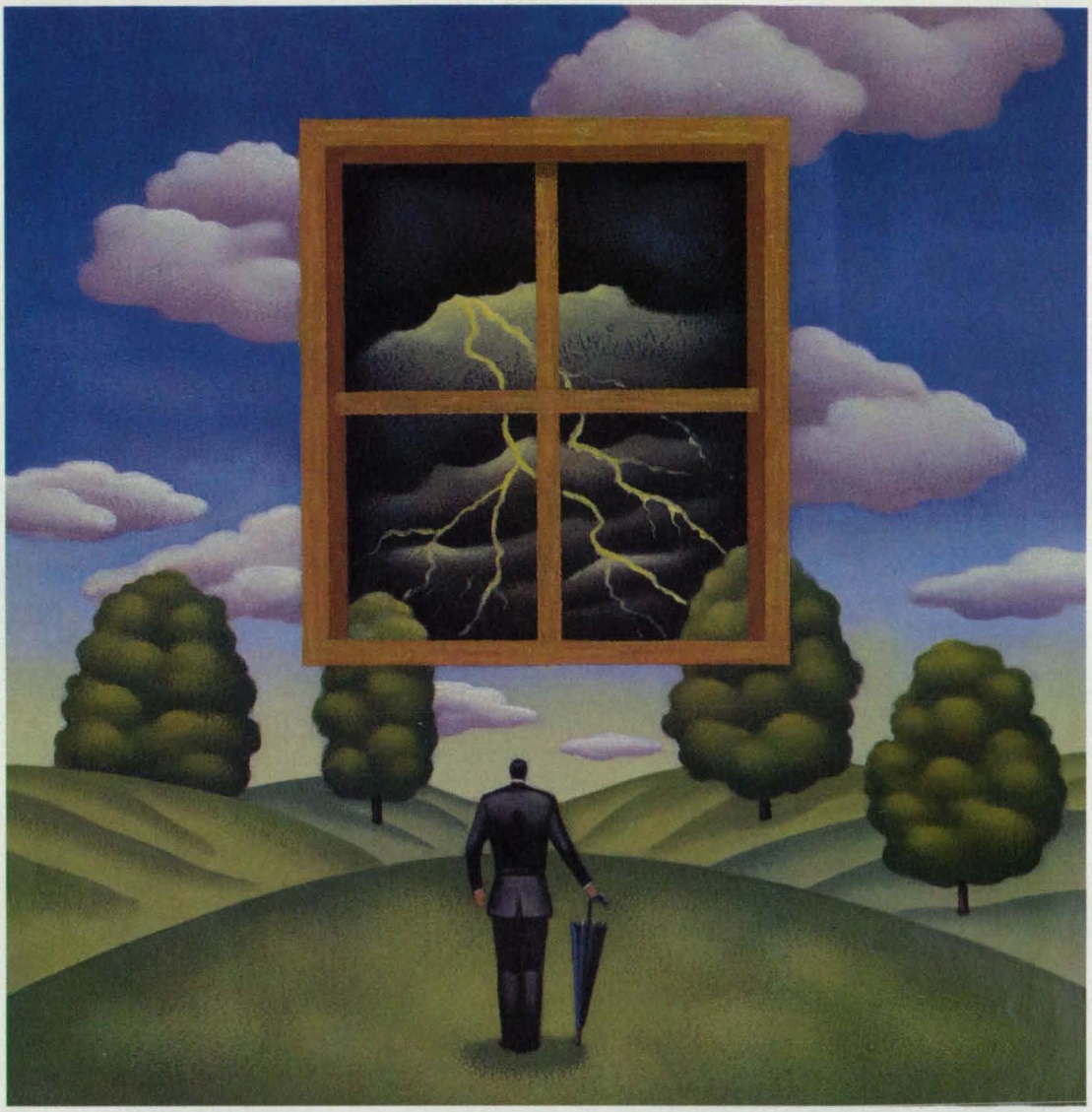

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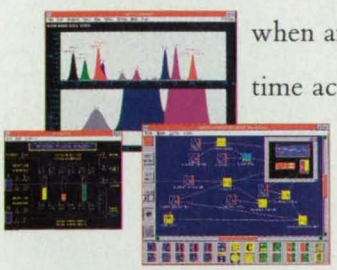

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ized changes in the speed of sound in the specimen. The parameters measured are the fractional changes in frequency necessary to maintain the constant difference between the phases of the transmitted and received waves as the speed of sound changes. The changes in frequency are measured by a frequency counter, which is connected with a desk-top computer.

The combination of the MAC and MAE techniques makes it possible to characterize residual tension and compression in structural ferromagnetic materials without being limited by surface conditions and unavailability of calibration standards. Such a development is significant in the field of characterization of materials as well as in the detection of fatigue failure.

This work was done by Min Namkung and William T. Yost of **Langley Research Center**, *Peter W. Kushnick of Lockheed Engineering and Sciences Co., and John L. Grainger of Analytical Services and Material, Inc. No further documentation is available.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 24]. Refer to LAR-14239.

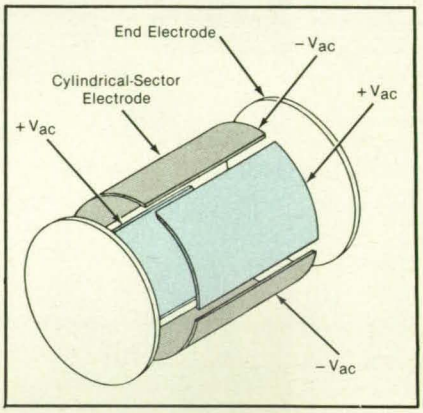
Four-Sector Cylindrical Radio-Frequency Ion Trap

Features would include relatively large ion-storage capacity and shielding against external fields.

NASA's Jet Propulsion Laboratory, Pasadena, California

A linear radio-frequency ion trap of cylindrical configuration has been proposed. Such radio-frequency traps are used principally in frequency-standard laboratories to confine $^{199}Hg^{+}$ ions electrodynamically in isolation from the external environment. The long confinement in isolation reduces fluctuations in frequency by suppressing perturbations of atomic energy levels. The device is similar to that described in "Linear Ion Trap for Atomic Clock" (NPO-17758), *NASA Tech Briefs*, Vol. 14, No. 9, (1990).

The proposed trap would consist of a closed metal cylinder partitioned into four equal cylindrical-sector electrodes and two circular end electrodes (see figure). The radio-frequency voltage would be applied to each cylindrical-sector electrode with a polarity opposite that of the adjacent cylindrical-sector electrodes. In addition, dc bias voltages could be applied to various electrodes with respect to each other or to ground. When applied to the cylin-



This **Radio-Frequency Ion Trap** would be made by dividing a hollow metal cylinder into four cylindrical electrodes with two end-electrodes. Radio-frequency voltages would be applied in alternating polarity ($\pm V_{ac}$) to the cylindrical-sector electrodes.

drical shells, the effect could be to alter the trapping-potential field (for example, a gravitational offset for macroparticles) with dc-biaed endcaps, a field would be produced, which would achieve axial confinement of the ions.

One of the principal advantages of this configuration is that the electrodes would surround the trapped ions almost completely, shielding them against fields external to the trap electric fields. Other advantages can be discerned by analysis of the trapping fields under the conventional assumptions that the trappin frequency greatly exceeds the characteristic frequencies of the secular motions of the ions and that the micromotions at the field frequency are small in comparison with the range of secular motions. If it is also assumed that the cloud of trapped ions is not dense enough to affect the electrostatic potential in the trap significantly, then one can compute all radio-frequency and dc electrostatic fields in the trap by solving Laplace's equation with the applied potentials as boundary conditions.

Conventional trapping-field theory yields an effective steady component of potential (as a function of position) that represents the time-average effect of the radio-frequency field upon the ions. Then, the dc bias potential (as a function of position) is added to obtain the total effective potential field that governs the secular motions of the ions. Such calculations have been performed for a typical $^{199}Hg^{+}$ trap (radius 9.5 mm, length 108 mm, radio-frequency potentials ± 100 V) under several different dc bias conditions. The calculations lead to the following conclusions, among others:

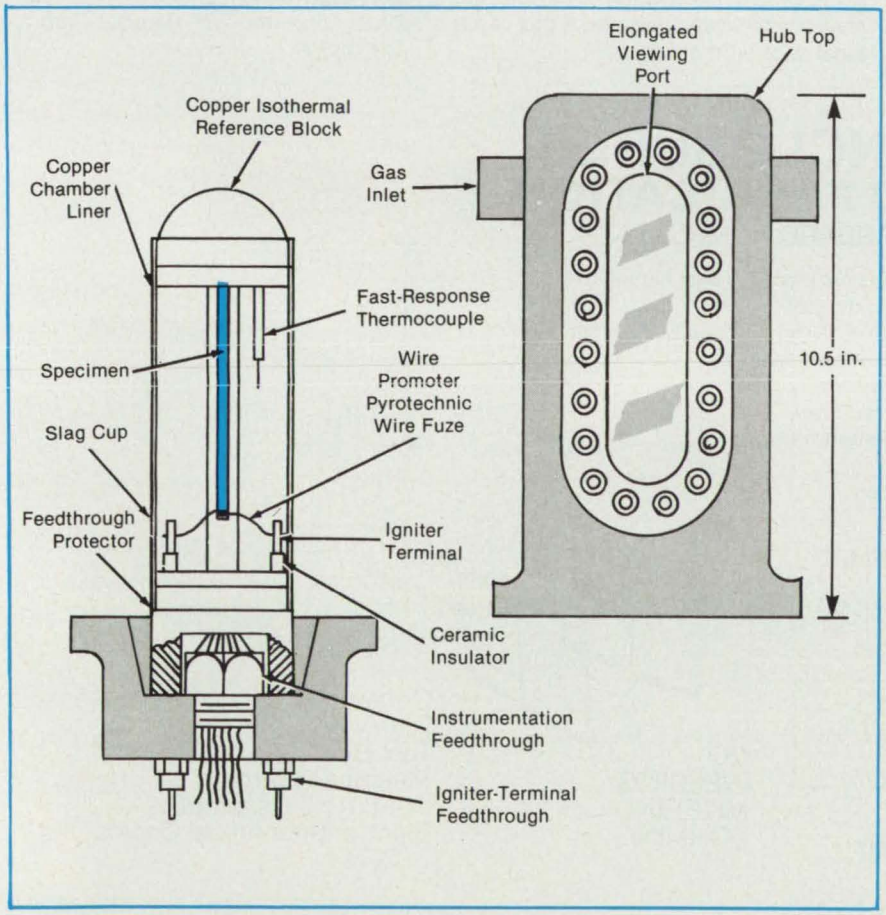
- The electric field on the electrode surface would have a minimum in the center of each cylindrical-sector electrode. Consequently, it should be possible to cut small viewing holes there without significantly disturbing the electric fields inside the trap.
- Near the ends of the trap, that component of the effective potential that arises from the radio-frequency field would tend to expel any ion from the trap, regardless of its charge.
- If dc biases were applied to the cylindrical-sector electrodes, the resulting static electric fields near the ends of the trap would tend either to expel ions from the trap or to localize them near the center of the trap, depending on the polarities of the biases. In addition, the combined effect of the radio-frequency and dc bias fields would be to create a new equilibrium position for ions, with a new nonzero equilibrium potential.
- As in all linear traps, the effective trapping volume available for the storage of ions would be greater than in conventional hyperbolic trap configurations.

This work was done by Ruthann K. Melbourne, John D. Prestage, and Lutfollah Maleki of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 96 on the TSP Request Card.*
NPO-18335

Chamber for Microgravity Combustion Experiments

A rugged unit can be used in a drop tower.

Lyndon B. Johnson Space Center, Houston, Texas



A **Hub Top With Gas Ports** encloses the combustion chamber. Instrumentation wire is fed into the chamber through its base. Combustion is initiated by a pyrotechnic wire fuse. Oxygen is supplied to the chamber to support combustion, then argon is fed to quench it.

A versatile container for microgravity combustion experiments can be used in outer space, in an airplane, or on Earth in a drop tower. The container can withstand repeated prolonged impacts.

The container is a portable test apparatus with a data-acquisition-and-control system. It incorporates a window for viewing combustion and feeds gases to the combustion chamber, including oxygen for combustion and argon and nitrogen for quenching.

A rod specimen is mounted securely from the top of a copper liner in the combustion chamber (see figure). Electrical wires at the bottom of the specimen ignite it on command from the control system. Wiring for instrumentation and control enters the combustion chamber through its base.

The pressure in the chamber can be as high as 1,440 lb/in.^{2} (10 MPa). At the high-pressure limit, a burst-disk valve releases the gases from the chamber. The entire combustion and quenching sequence can be viewed or filmed through an elongated window measuring 2 by 6 in. (5 by 15 cm).

This work was done by Theodore A. Steinberg of Lockheed Engineering and Sciences Co. for **Johnson Space Center**. *For further information, Circle 81 on the TSP Request Card.*
MSC-21777

Measuring Spatially Varying Transmittance of a Filter

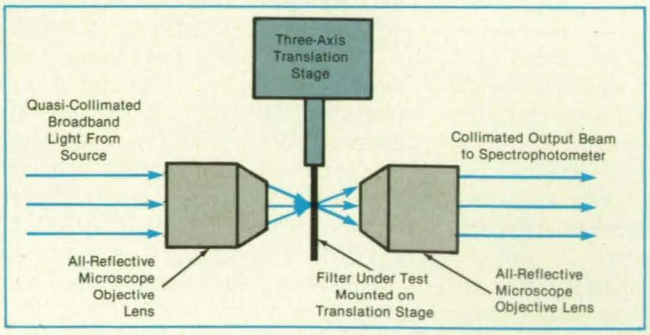
A focusing/collimating-and-scanning apparatus fits in the sample chamber of a spectrophotometer.

NASA's Jet Propulsion Laboratory, Pasadena, California

A focusing/collimating-and-scanning apparatus adapts a commercial spectrophotometer to the spectral transmittance of an optical filter as a function of position on the filter, at a spatial resolution as small as 25 μm. The apparatus is mounted in the sample chamber of the spectrophotometer.

Because the apparatus includes only reflective optics, measurements can be made in any wavelength band covered by the spectrophotometer: infrared, visible, or ultraviolet. The apparatus was used originally to measure the spatially varying spectral transmittance of a nominally linearly varying optical filter that had been fabricated for a thermal-infrared imaging spectrometer.

In the usual operation of the spectrophotometer used to test the filter, a collimated beam of light that has a relatively large cross section passes through the specimen in the sample chamber and on into a scanning monochromator and detector for analysis. However, to measure the spatial variation of the spectral transmittance of a filter, it is necessary to focus the light to a small spot on the filter. Accordingly, in the focusing/collimating-and-scanning apparatus, two all-reflective microscope objectives are used (see figure). The first objective focuses the quasi-collimated light from a source onto the desired spot. To achieve maximal resolution, one of the axes of a three-axis translation stage on which the filter is mounted provides a focus adjustment to place the plane of the filter precisely at the focal point of the first microscope objective. The second microscope objective recollimates the diverging cone of light that emerges from the filter. Thus, the beam that enters the monochromator is collimated, just as in the unmodified spectrophotometer, but the transmittance measured is that of the focal spot on the filter.



The **Focusing/Collimating-and-Scanning Apparatus** enables a spectrophotometer to measaure the spectral transmittance at many different positions on the filter.

The other two axes of the translation stage position the filter laterally with respect to the axis of the beam of light. By making measurements at a uniformly or otherwise suitably spaced lattice of points, one can measure the dependence of spectral transmittance upon position on the filter. The mechanisms of the translation stage are spring-loaded, and the adjustments along each axis are all made in the same sense each time to preclude backlash.

This work was done by Clayton C. LaBaw of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 25 on the TSP Request Card.*
NPO-18298

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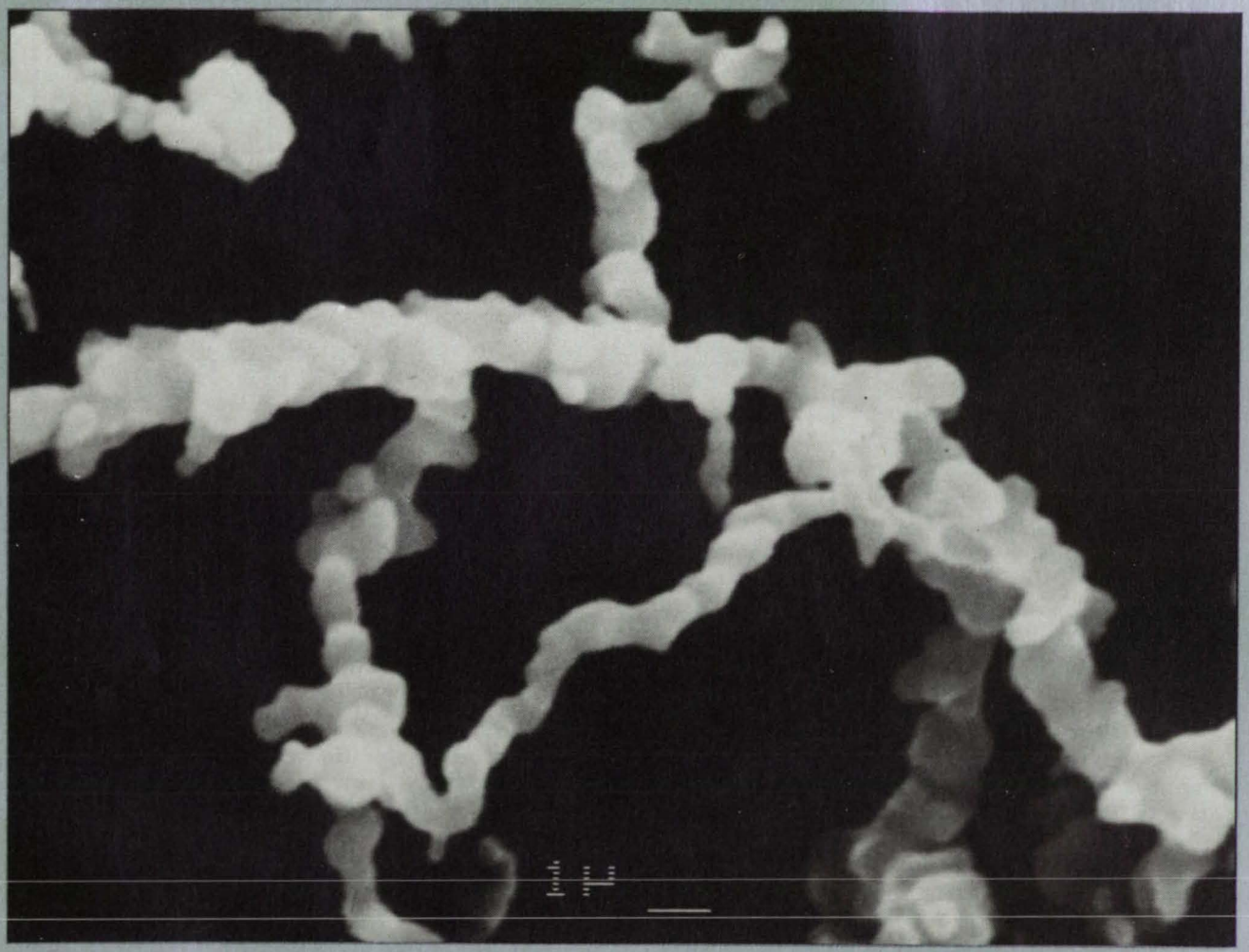

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For More Information Circle No. 652

Classification of Land Cover From Airborne MSS Data

Refinements of the basic classification method increase accuracy.

Ames Research Center, Moffett Field, California

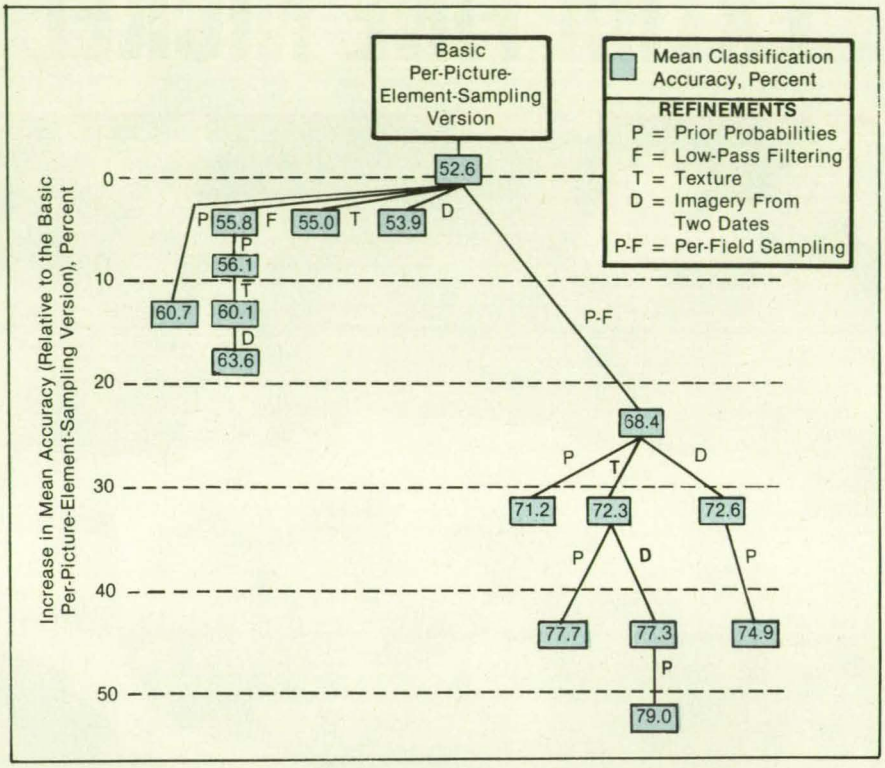
A method for the processing of images of rural uplands produced by an airborne multispectral scanner (MSS) semiautomatically classifies designated areas within each image into types of land cover (e.g., grass, woods, and buildings). The method is based on principles similar to those of other spectral-image-classification methods in that it involves the selection of wavelength bands, radiometric calibration, correction for the effects of the scan angle (away from nadir) and the atmosphere, training, and assessment of accuracy.

In this case, the images of each scanned area are produced simultaneously in four wavelength bands: 0.45 to 0.52 μm (green), 0.63 to 0.69 μm (red), 0.76 to 1.05 μm (near infrared), and 2.08 to 2.35 μm (middle infrared). These bands were selected because they are related to the biophysical characteristics of vegetation. To identify a set of training data, random numbers are used to select fields from lists of fields that are known, from previous surveys, to have land cover of the types to be studied. These data are used to train a maximum-likelihood classification algorithm.

The basic version of the method involves classification of each picture element according to its spectrum. The basic method can be augmented with one or more of the following five refinements:

1. *Per-field sampling*, in which the sampling unit is a field rather than a picture element or group of picture elements within a field (a "field" could also be, say, part of a forest). The main benefits are reduced classification time and the elimination of mixed classes within fields. The main disadvantage is the need to define the boundaries of each field prior to analysis.
2. *Low-pass filtering*, in which the radiance of each picture element is replaced by an average over that and the neighboring picture elements. It has been found that low-pass filtering may increase the accuracy of classification for land covers, the images of which have high spatial frequencies.
3. *Image texture*, which, the radiance of each picture element is replaced by the standard deviations of that and the neighboring picture elements. The main advantage is the ability to separate spatially "rough" surfaces (e.g., forest) from spatially "smooth" surfaces (e.g., glass).
4. *Prior probabilities*: The proportions of types of land cover derived from prior studies are used to weight the maximum-likelihood classification algorithm. The types of land cover that occupy the largest areas have the largest weights and tend to be classified most accurately.
5. *Imagery from two dates*: Data from two dates (e.g., one in June and one in September) yield a small increase in accuracy of classification.

The basic method with various combinations of refinements was applied to airborne airborne MSS data on eight types of land cover in upland England. The figure shows the mean accuracy of classification for each version of the method. The highest mean accuracy, 79 percent, was obtained by use of all refinements except low-pass filtering. The per-field-sampling refinement produced the largest single increase.



The **Mean Classification Accuracies** were computed for 16 different versions of the classification scheme.

This work was done by Paul J. Curran and Mike I. Pedley of the University of Sheffield while Paul J. Curran was an NRC Senior Research Associate at **Ames Research Center**. *For further information, Circle 10 on the TSP Request Card.*
ARC-12688

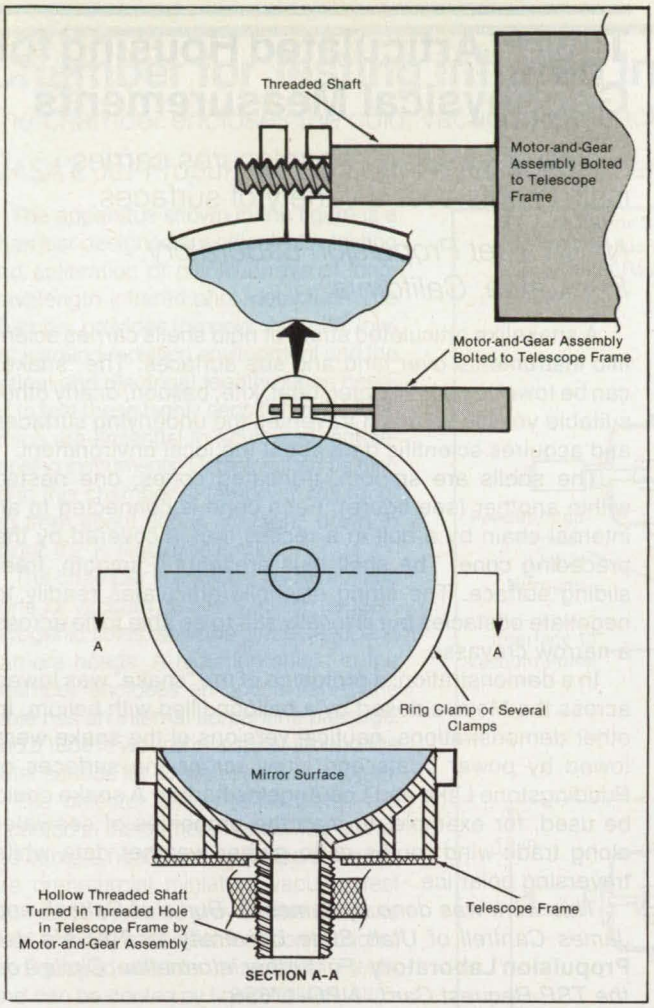
Adjusting Curvatures of Large Mirrors and Lenses

Actuators apply stresses to generate compensatory distortions.

NASA's Jet Propulsion Laboratory, Pasadena, California

In a technique for adjusting the curvature of a large focusing mirror or lens, actuators apply stresses to generate distortions that counteract undesired distortions. The technique is particularly applicable to large astronomical-telescope mirrors with diameters of the order of 60 cm or more.

The distortions to be counteracted are typically of the order of a few microns or less; they are caused by changes in temperature and changes in orientation in the gravitational field. In the case of mirrors fabricated on Earth but operated in outer space, distortions are caused by removal of the gravitational field. In addition, optical performance is affected by variations in the index of refraction of air with temperature and altitude. Although all of these



Motor-and-Gear Assemblies under remote control vary the squeeze of a ring clamp and the push or pull of a hollow shaft to make fine adjustments in the curvature of a telescope mirror.

effects and more are taken into account in the design and fabrication of large mirrors and lenses, it is still necessary to apply compensatory distortions as fine adjustments to realize the full potential of these optics to provide subarcsecond resolutions.

In the version of the technique illustrated in the figure, compensatory distortions are applied by (1) a peripheral ring clamp or several clamps that are tightened or loosened by motor-and-gear drives and (2) an inner concentric threaded hollow shaft driven by another motor-and-gear assembly. Tightening or loosening the clamps affect the curvature of the mirror mostly in the outer concentric zones, while the axial force exerted by the hollow shaft affects the curvature mostly in the inner concentric zones. In another version (not shown in the figure), many actuators could be mounted on a backing plate behind the mirror to apply a compensatory distortion independently to each of many zones. In either version, the motor-and-gear assemblies or other actuators can be adjusted remotely.

To formulate an optimum design, one must consider the actuators and mounts to be an integral part of the mirror or lens system. The mirror or lens can be made more adjustable by making it thinner. Although this makes the mirror or lens more vulnerable to some distortions, it is not necessarily a serious disadvantage: one could also design the optical figure to have a small initial distortion that can be eliminated by tightening a ring clamp to some nominal small tension.

This work was done by Morris M. Birnbaum of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 47 on the TSP Request Card. NPO-18345*

Towed Articulated Housing for Geophysical Measurements

A snakelike string of enclosures carries instruments over a variety of surfaces.

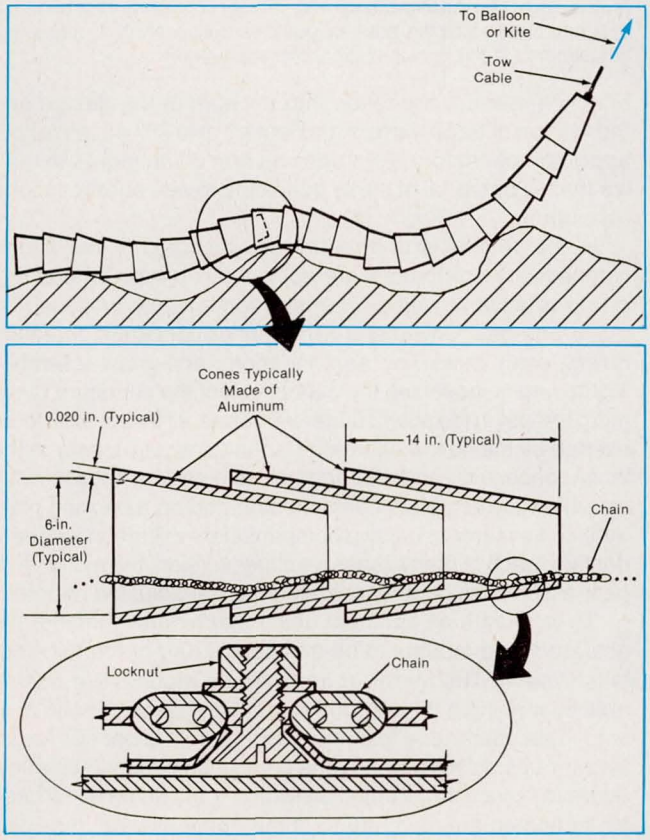
NASA's Jet Propulsion Laboratory, Pasadena, California

A snakelike articulated string of rigid shells carries scientific instruments over land and sea surfaces. The "snake" can be towed by a helicopter, boat, kite, balloon, or any other suitable vehicle so that it traverses the underlying surfaces and acquires scientific data about the local environment.

The shells are smooth, truncated cones, one nested within another (see figure). Each cone is connected to an internal chain by a bolt in a recess that is covered by the preceding cone. The shell thus presents a smooth, free-sliding surface. The string of shells articulates readily to negotiate obstacles but is locally stiff to be able to lie across a narrow crevasse.

In a demonstration, a prototype of the "snake" was towed across the Mojave desert by a balloon filled with helium. In other demonstrations, nautical versions of the snake were towed by power boats and kites across the surfaces of Puddingstone Lake and Los Angeles harbor. A snake could be used, for example, to map the properties of seawater along trade-wind routes or to gather weather data while traversing polar ice.

This work was done by James D. Burke of Caltech and James Cantrell of Utah State University for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 9 on the TSP Request Card. NPO-17656*



The **Instrument Snake** consists of overlapping cones of aluminum strung on an internal chain. In addition to housing scientific instruments, the snake serves as ballast for the kite or balloon that tows it.

Chamber for Testing Infrared Imaging Detectors

The chamber encloses the cold, vacuum, low-background-radiation environment needed for testing.

NASA's Jet Propulsion Laboratory, Pasadena, California

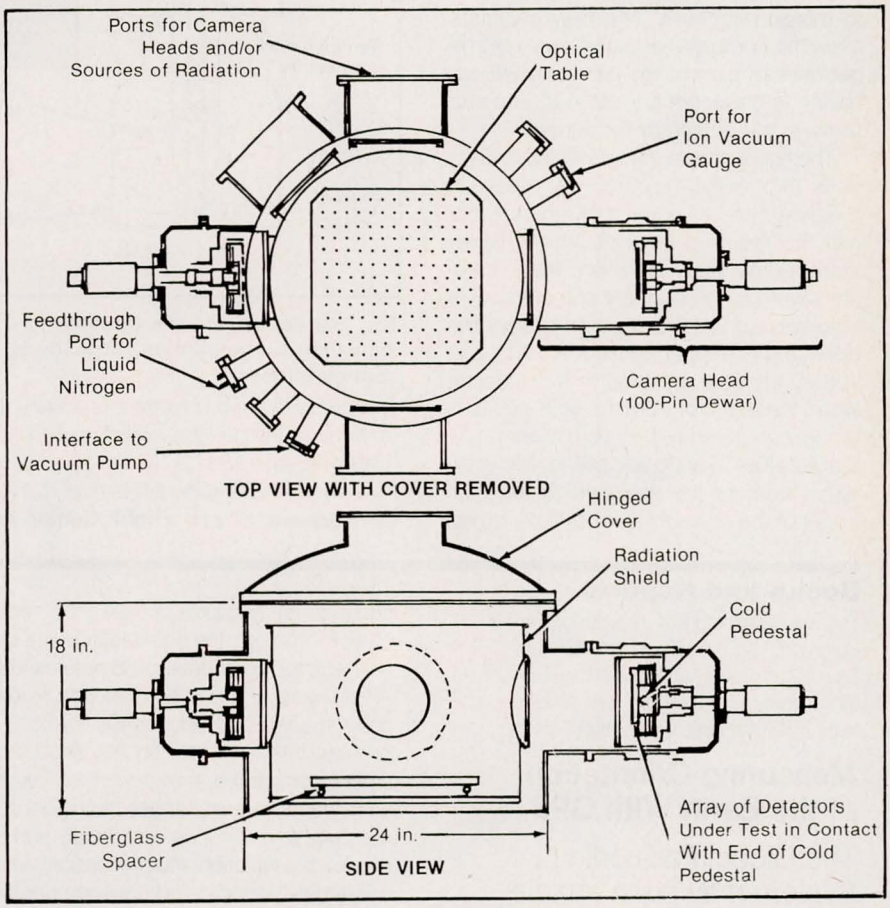
The apparatus shown in the figure is a chamber designed specifically for testing and calibration of planar arrays of long-wavelength infrared photodetectors. The chamber provides the cold, vacuum, low-background-radiation environment and the optical and electrical feedthroughs needed to test these highly sensitive detectors, which are essential to advanced remote-sensing instruments. Detectors can be tested in this chamber at temperatures ranging from about 300 K (ambient) down to about 4.2 K (liquid helium).

The chamber is equipped with multiple ports for vacuum pumps, vacuum gauges, cryogenic fluids, sources of radiation, and camera heads. A radiation shield in the chamber encloses an optical table; the table has an internal serpentine passage, and a tube is wound in a spiral around the outer surface for cooling by liquid nitrogen.

The detector arrays to be tested are mounted in the camera heads. The standard camera heads used with the chamber are commercial miniature vacuum test chambers that also provide the requisite fluid, optical, and electrical connections, are equipped with internal radiation shields, and can be cooled by liquid helium, nitrogen, or neon. These camera heads are known as 100-pin Dewars because each includes 100 triaxial 50-Ω terminals to connect the outputs of the sensors to the external test circuits.

Because infrared-transmissive optics and infrared-reflective optics that have acceptably wide passbands and acceptably low losses are difficult to fabricate, the pinhole-camera method is used to form the images on the detectors. A small plate containing a pinhole is mounted on an end cap that is bolted to the lid of the internal radiation shield in a 100-pin Dewar. Pinhole plates can be interchanged to install pinholes of different sizes as needed.

In preliminary tests, the chamber was found to consume about 6 liters of liquid nitrogen per hour during initial cooldown (which typically required about an hour). Thereafter, the chamber consumed about 2 liters per hour in maintaining the detectors at 77 K. Although the preliminary measurements of the vacuum were not complete, it appears that the pressure in the chamber falls to about 10^{-4} mtorr (about 10^{-5} Pa) after pumping for a few hours.



This **Vacuum/Cryogenic Test Chamber** accommodates a variety of infrared sources, detectors, and associated equipment for testing of the detectors at temperatures down to about 4.2 K in a low-background-radiation environment.

This work was done by Craig O. Staller and Richard W. Capps of Caltech and Douglas Butler, Nancy Moss, and Wynn Norwood of R. G. Hansen and Associates for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 92 on the TSP Request Card.*
NPO-18089

Variable-Temperature Cryostat for Radiation-Damage Testing of Germanium Detectors

Operating and annealing temperatures can be varied over wide ranges without breaking vacuum.

Goddard Space Flight Center, Greenbelt, Maryland

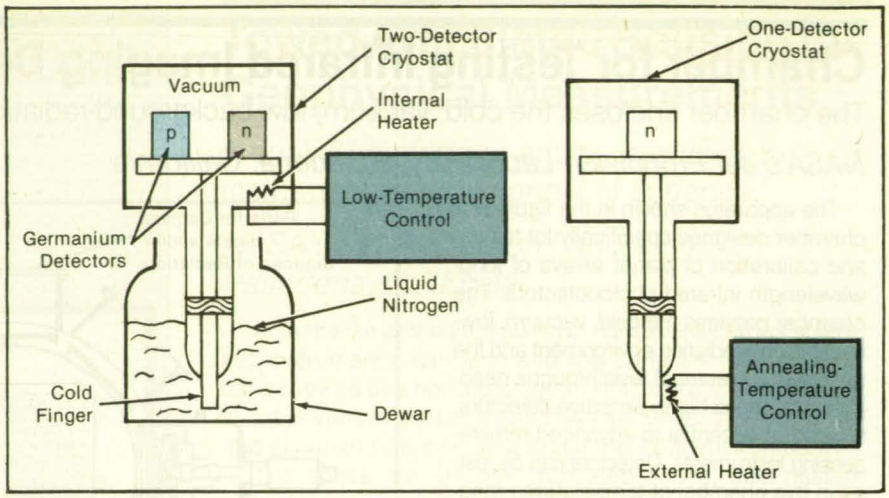
Variable-temperature cryostats were developed and used in a study of radiation damage to, and annealing of, germanium gamma-ray detectors. The cryostat design comes in two styles: one that accommodates a large (140-cm^3) single detector and one that accommodates two medium-sized (90-cm^3) detectors. Each two-detector unit in the study contained a p-type and an n-type detector.

The resolution of germanium detectors degrades when the detectors are exposed to the radiation environment of outer space. P-type degrctors degrade faster than n-type detectors, and the rates of degradation of both types are related to the operating temperature. Most of this knowledge comes from testing small planar detectors. In past studies, the refurbishment of a detector for the next test has involved removal of the detector from its cryostat and annealing at temperatures from 125 to 150 °C.

Germainum detectors will be the heart of many gamma-ray-spectrometer instruments

on future NASA missions. Gamma-ray spectroscopy will certainly be important for missions to asteroids, comets, Mercury, and the Moon. All of these missions are longer than the useful life of a new detector. Therefore, radiation-degradation knowledge and in-situ annealing capability are essential to mission success. The new cryostats allow the complete testing of large-volume germanium gamma-ray detectors without having to break the cryostat vacuum and remove the detectors for annealing.

The figure shows the two styles of cryostats. In operation, a cryostat is placed in a dewar filled with liquid nitrogen to obtain the required low operating temperature. In the study for which these cryostats were developed, the detectors were irradiated with a 1.2-GeV proton beam while operating at temperatures of 90, 100, and 120 K. Heaters installed in the cryostat warm the detector from the 90-K equilibrium temperature to the desired operating temperature. During annealing, large external heaters are strapped to the cold finger of the cryostat. Two sets of thermocouples are used to control precisely the annealing temperature, which can lie between 90 and 130 °C.



The **Two-Dector and the One-Dector Cryostat** are shown in the low-temperature and annealing configurations, respectively. Both cryostats are designed to operate in both configurations.

This work was done by Samuel R. Floyd of **Goddard Space Flight Center** *and Bernard P. Puc of Princeton Gamma Tech Inc. For further information, Circle 103 the TSP Request Card.*
GSC-13439

Books and Reports

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

Measuring Orientation of the Earth With GPS

The Global Positioning System may soon enable rapid determination of short-term variations.

A report discusses the feasibility of using the Global Positioning System (GPS) to measure the orientation of the Earth. The measurements sought would resolve short-term fluctuations (characterized by time scales of the order of days or hours) in the locations of selected points fixed on the crust of the Earth (e.g., GPS receiving stations) to within centimeters or millimeters in a moving reference frame that has a known relationship with an inertial reference frame. The measurements would be used to enhance the precision of spacecraft navigation and in geophysical and meteorological studies of the daily exchanges of angular momentum among the fluid core, crust and mantle, oceans, and atmosphere.

For the purpose of this discussion, the orientation of the Earth is considered to consist of three parts: (1) the angle of rotation (UT1) about the current axis of rotation or, equivalently, the difference between UT1 and a mean angle of rotation (UTC) about the current axis of rotation; (2) the position of the current axis of rotation with respect to a reference axis tied to the crust and mantle (the relative motion of these two axes is called the "polar motion"); and (3) the orientation of the current axis as it precesses and nutates in inertial space. UT1 and polar motion, known collectively as UTPM, are the motions of primary interest here; on the short time scales considered, they are caused by the aforementioned exchanges of angular momentum, and can thus vary rapidly and unpredictably. Nutation and precession, which are largely periodic and caused principally by interactions with other celestial bodies, are not included in the discussion.

The report describes a covariance analysis of the errors associated with GPS monitoring of the orientation of the Earth. The analysis was performed with the Orbit Analysis and Simulation Software (OASIS) computer program, using adjustable parameters that included the initial positions and velocities of the GPS satellites, parameters of a mathematical model of solar-radiation forces acting on the satellites, locations of stations, wet zenith tropospheric path delay for each GPS ground station, offsets of satellite and station clocks, biases in phases of GPS carrier signals, offset of the center of mass of the Earth from a reference center, and the orientation parameters. Each parameter was modeled either as a constant or as a stochastic-process noise variable over an observing window of a given length. The sensitivity of the estimates of orientation to errors in selected parameters were also examined.

The report concludes that when the full constellation of 18 or more GPS satellites and the associated globally distributed network of highly precise GPS ground receiving stations become active, the GPS system should be able to provide rapid (within 12 hours) determinations of variations in the orientation of the Earth. The change in UT1 over a 24-hour period should be measurable to an accuracy of better than 1 cm. It should be possible to monitor centimeter-sized variations of UTPM on time scales of a few hours.

This work was done by Adam P. Freedman of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Measuring Earth Orientation With the Global Positioning System," Circle 57 on the TSP Request Card.*
NPO-18301

Microwave Remote Sensing of Meteorological Quantities

Measurements needed to compute fluxes of heat and moisture are discussed.

A report discusses the state of the art of remote sensing of meteorological quantities by microwave radiometers in orbit around the Earth. This study is concerned mainly with measurements of the fluxes of heat and moisture that occur in the exchange of energy, via turbulence and radiation, between the ocean and the atmosphere.

The report contains seven sections. The first section summarizes the interactions among ocean currents, winds, evaporation, precipitation, and fluxes of latent and sensible heat. The second section begins by presenting the conventional bulk parameterization in which meteorological

conditions are modeled via relationships among the large-scale wind stress, τ; the flux of sensible heat, H; the flux of moisture, E; the flux, EL, of the latent heat of vaporization, L (which is carried by moisture); the speed of the wind, U; the temperature of the ocean at the surface, T_s; the temperature of the air, T; the mixing ratio, Q_s, at the surface of the ocean (generally taken to be the saturation mixing value at the temperature of the ocean at the surface); and the mixing ratio, Q, as derived aboard a ship from a measurement of the dewpoint. The discussion then turns to variations of the transfer coefficients with height, stability, and sea state.

The second section concludes by noting that spaceborne sensors cannot measure T or Q but can measure U, T_s, and W, which is the column-integrated water vapor in the atmosphere. If the relationship between Q and W were known, then one of the bulk-parameterization equations could be used to determine E. The third section discusses the method of relating Q to W.

The topic of the fourth section is the measurement of U by active microwave scatterometers and the measurement of Q_s by a scanning multichannel microwave radiometer. The fifth section describes the retrieval of EL by an indirect method and a direct method. In the indirect method, E is computed via the bulk parameterization from (1) measurements of U, W, and T_s and (2) the global relationship between Q and W. In the direct method, EL is computed directly as a weighted sum of microwave brightnesses at various wavelengths.

The sixth section discusses the retrieval of H by an indirect method that involves the bulk parameterization and the derivation of T from Q under the assumption of a certain relative humidity. The seventh section discusses the status of past, present, and expected future satellite-borne microwave sensors and the need to design future sensors for optimal synergism with respect to the determination of the vertical structures of the fluxes of moisture and heat at shorter time scales.

This work was done by Wing-Yuen T. Liu of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Remote Sensing of Surface Turbulence Heat Flux," Circle 101 on the TSP Request Card.*

NPO-18022

Polarimetric Radar Signatures of Frozen and Thawed Forests

Scattering from branches appears to be greater in the thawed condition.

A report summarizes a study of radiometrically and polarimetrically calibrated data from airborne synthetic-aperture-radar images of the same single-species forest stands in frozen and thawed conditions. C-, L-, and P-band images were acquired during the interval of March 13 to March 19, 1988, covering eight stands of white spruce, five stands of balsam poplar, and two stands of black spruce in the Bonanza Creek Experimental Forest near Fairbanks, Alaska. During this interval, temperatures ranged from +9 °C to −15 °C, and the moisture content of the snow and trees changed from liquid water to ice.

The L-band copolarization radar cross sections of some stands were found to be as much as 6 dB less in the frozen than in the thawed condition. This effect was attributed to the fact that the dielectric constants are greater in the thawed than in the frozen condition.

More-subtle differences between the polarimetric characteristics in the frozen and thawed conditions were determined by computing two features of the statistics of the Stokes matrices computed over the resolution elements of each forest stand. The first such feature was the fractional polarization, F (when $F = 0$, the average radar return is unpolarized; when $F = 1$, the average radar return is completely polarized). The second such feature was the distribution of the difference between the

phases of the horizontal and vertical co-polarization elements of the backscattering amplitudes ("polarimetric phase distribution" or "PPD" for short).

Comparisons of *F* and PPD indicate that the contributions from diffuse scatterers are greater in the thawed than in the frozen condition. This suggests that the contribution of scattering from the crown is responsible for the appreciable increase in L-band backscatter in the thawed condition.

This work was done by Ronald Kwok, Eric Rignot, JoBea Way, John Holt, and Anthony Freeman of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Polarization Signatures of Frozen and Thawed Forests of Varying Biomass," Circle 63 on the TSP Request Card. NPO-18280*

Geodetic Precession vs. Frame Dragging

Precession of a gyroscope is discussed in terms of metric theories of gravitation.

A report discusses the precession of a freely falling or orbiting gyroscope with respect to geodetic precession and frame-dragged precession, which are predicted by metric theories of gravitation. The discussion is relevant to current investigations in orbital mechanics, navigation, and general relativity.

Geodetic precession is caused by the motion of the gyroscope in the gravitational field of a massive body; frame-dragged precession is caused by the gravitomagnetic interaction, which is a magnetic-like effect caused by the motion (usually, the rotation) of the massive body. Both effects are small: for a gyroscope in a polar orbit 650 km above the Earth, the geodetic precession is 6.6 arc seconds per year, while the frame-dragged precession is only 0.042 arc second per year.

In a reference frame in which a nonrotating massive body is at rest, the predicted precession appears to be purely geodetic; in a frame in which the gyroscope is at rest, the precession appears to be purely frame-dragged. These predictions can be proved rigorously by deriving that transformation of coordinates that gives the metric in a reference frame that moves with the gyroscope. In this report, it is shown that these predictions can also be deduced directly in metric theories of gravitation from the fundamental equation for the precession of a gyroscope.

The equation for the precession of a gyroscope in a Lorentz reference frame, oriented with respect to the distant stars, the velocity of which is matched to that of the gyroscope, is given to post-Newtonian order. It is shown that three effects contribute to the precession: (1) the Thomas precession, which is caused by the nongravitational component (if any) of translational acceleration of the gyroscope; (2) frame dragging, which depends on the off-diagonal terms in the metric; and (3) the geodetic precession.

If the massive body does not rotate, then in its rest frame, the off-diagonal components of the metric vanish, in which case the equation states that the precession of the gyroscope is purely geodetic. The equation takes a different form in a nonrotating, accelerated reference frame in which the gyroscope is momentarily at rest; in this frame, the precession can be only frame-dragged. After correcting for the Thomas precession, it can be shown that in the Lorentz frame, the velocity of which is matched to that of the gyroscope, the precession is equivalent to the geodetic precession. Thus, it is shown that purely geodetic precession can be interpreted as a consequence of frame dragging.

This work was done by Timothy P. Krisher of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Geodetic Precession versus Frame-Dragging in Metric Theories of Gravity," Circle 12 on the TSP Request Card. NPO-18258*

Study of Space-Based Optical Interferometer

Calibration and operation of a proposed highly accurate instrument are discussed.

A report discusses the calibration and operation of the Focus Mission Interferometer (FMI), which is a conceptual optical interferometer to consist of component instruments mounted at widely separated locations on a large truss structure in orbit 1,400 km above the Earth. The FMI represents a new class of spaceborne astronomical instruments that would provide high-resolution images and extremely precise astrometry. When operated beyond the optically distorting influences of the atmosphere, such instruments may eventually make it possible to image planets in other solar systems and to map the heavens to a small fraction of a milliarcsecond.

The FMI would include six telescopes, each of modest aperture, in a sparse linear array along a baseline of 24-m effective length. The outputs of the telescopes would be combined in pairlike fashion in such a way that the FMI would operate as three distinct two-telescope interferometers. This study concentrates on the use of the FMI for astrometric measurements that could, in principle, be accurate to within 50 picoradians (10 microarcseconds). To attain such accuracy, it is necessary to calibrate the baseline vectors and the lengths of optical paths in the instrument to the nano-

meter level and to propagate these vectors and path lengths in real time. Furthermore, it is necessary to control path lengths to within about 5 nm, and aiming accuracies to within about 50 nanoradians.

The absolute accuracies of measurements of the angular positions of stars would depend on accurate calibration of the three interferometer baselines and of the attitude of the FMI. Once calibrated, an onboard laser metrology system would measure changes in the baselines and optical-path lengths directly. These measurements would be needed not only for postprocessing of scientific data but also to support real-time control of optical-path lengths.

The baseline-calibration process would involve a sequence of observations, with all three interferometers alternately looking together, then separately, at several known reference stars. These observations would provide updates to a Kalman calibration filter, which would continuously estimate sources of errors in the baselines. Scientific measurements of stars would also be made with the help of the calibration filter, with one interferometer observing the unknown star while the other two observed known reference stars to provide continuous information on attitude.

The line of sight of each interferometer would be controlled to keep stars in its field of view and to keep the tilt of the wave front below 50 nanoradians. Tilt would be sensed by an imaging photon camera and controlled by use of fast steering mirrors. The pointing control system would be calibrated, immediately after the initial deployment of the spacecraft, in a process separate from the calibration of baselines.

Observations of reference stars via the photon camera would be used to establish static correction factors for tilt misalignments of the optical elements in each interferometer. These factors would then be used to enable the interferometers to acquire views of stars under open-loop control to submilliradian accuracy. Once the views of stars were acquired, closed-loop control would be used to provide nanoradian pointing accuracies during measurements of baselines.

Representative calibrations have been analyzed by computer simulation. The results suggest that the FMI would be accurate enough for submilliarcsecond astrometry.

This work was done by David C. Redding, Robert A. Laskin, William G. Breckenridge, and Michael Shao of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Calibration and Operation of a Large Space-Based Optical Interferometer," Circle 5 on the TSP Request Card.*
NPO-18193

Fabrication of Metal Chloride Cathodes by Sintering

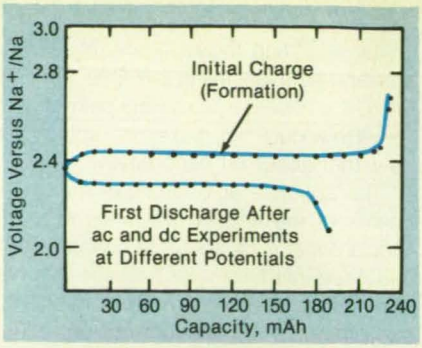
The need for a difficult and dangerous chlorination process is eliminated.

NASA's Jet Propulsion Laboratory, Pasadena, California

Transition-metal chloride cathodes for use in high-temperature rechargeable sodium batteries have been prepared by sintering transition-metal powders mixed with sodium chloride. The compositions and the sintering conditions for making mechanically strong, efficient electrodes have been optimized. Previously, the optimal way to fabricate such a cathode has involved treating the metal with chlorine gas, which is hazardous and difficult to handle.

Cathodes consisting of chlorides of transition metals are integral to sodium/metal-chloride batteries, which have potential advantages over sodium/sulfur batteries; these advantages include high energy densities that are comparable to those of sodium/sulfur batteries, increased safety, reduced material and thermal-management problems, and ease of operation and assembly. The transition-metal chloride cathodes are being evaluated for such high-energy-density applications as supplying electrical power during intervals of peak demand and electric propulsion of vehicles.

In preparation for fabrication of a transition-metal chloride electrode by the sintering technique, finely powdered sodium chloride is preheated to remove moisture. Then a fine powder of the desired transition metal (usually iron or nickel) is mixed in the appropriate proportion with the sodium chloride. The sizes of the particles in the powders are critical to the adequate bonding of the particles into an adequately porous electrode: typically, the particles are smaller than 100 μm. The porosity of the electrode can be adjusted by changing the sizes of the particles or, more effectively, by the addition of an elastomeric binder to the powders before pressing them into an electrode. The organic binder is decomposed and expelled during the subsequent sintering, leaving the porous structure behind.



These **Charge/Discharge Curves** were obtained from a 230-mAh $FeCl_2$ sintered electrode at a current density of 2 mA/cm^2 and a temperature of 230 °C.

The proportions of the transition metal and sodium chloride in the mixture of powders can be adjusted to suit the specific requirements: the higher the proportion of sodium chloride, the higher the current efficiency, but the lower the mechanical strength and porosity of the resulting electrode. The optimum composition of the electrode is 1 equivalent of sodium chloride per 3 equivalents of transition metal: on charging, ⅓ of the transition metal can be oxidized (corresponding to a current efficiency of 33 percent), and the rest of the metal then acts as the current collector.

The thoroughly mixed powders (and optional organic binder, if any) are pressed together to form an electrode at a pressure exceeding 10,000 psi (69 MPa) by use of a mold and die, with an expanded metal screen as a grid, and without any binder. The grid material must be at least as noble as the transition metal is. For example, the nickel Exmet (or equivalent) can be used as the grid for both ferrous chloride and nickel chloride electrodes.

The pressed electrodes are then sintered in an inert crucible (e.g., of graphite) at temperatures around 750 °C for a minimum of 6 to 8 h in an inert atmosphere (e.g., argon). The sintered electrodes thus fabricated in the discharged state can be electrochemically oxidized to be brought into the charged state.

These electrodes are mechanically strong enough to withstand the dilatation stresses induced in the course of charging and discharging. The charge and discharge curves of a ferrous chloride electrode fabricated by this process are shown in the figure.

This work was done by Ratnakumar V. Bugga, Salvador Di Stefano, and C. Perry Bankston of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 4 on the TSP Request Card.*
NPO-18118

Pd/Cr Strain Gauges for High Temperatures

Operating temperatures range up to 600 °C.

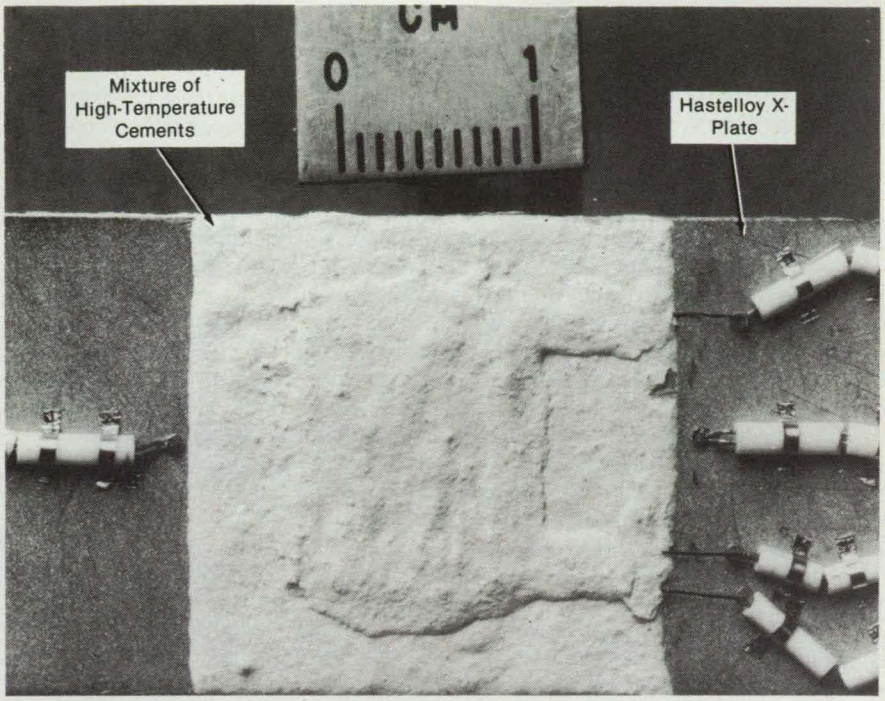
Lewis Research Center, Cleveland, Ohio

Temperature-compensated Pd/Cr electrical-resistance strain gauges have been developed for measuring static strains in the combustors, blades, and vanes of gas turbine engines. These gauges give highly repeatable readings with low drift at temperatures from ambient to 600 °C.

The gauge wire is made of an alloy of 87 weight percent Pd and 13 weight percent Cr. This alloy was chosen because, among other things, its microstructure is highly stable in the sense that it undergoes no transformation of phase between ambient temperature and 1,000 °C. An adherent, self-protective scale of Cr_2O_3 forms on the wire in air at 1,000 °C. This results in a linear, repeatable resistance-vs.-temperature relationship, which is independent of the rates of heating and cooling.

Experimental gauges were made with 45-μm-diameter Pd/Cr gauge wires. The gauges included temperature-compensating resistors in the form of 25-μm-diameter Pt wire. Each gauge was laid out in a grid 8.2 mm long and 10.6 mm wide and had a nominal resistance of 81 Ω. The compensator was laid out in a grid 4.2 mm long and 12.6 mm wide and had a nominal resistance of 10.1 Ω. The lead wires, made of the same material as that of the gauge wires, were 75 μm in diameter and were spot-welded to the gauge wires.

Two such gauges were cement-mounted, one on each face, on each of several strain-test coupons of Hastelloy X (an alloy of Ni, Cr, Mo, Fe, and Co). The cement used consisted of a mixture of 96 percent by weight alumina-base cement and 4 percent by weight zirconia-base cement. The gauges were also encapsulated with this specially developed high-temperature mixture cement since the mixture provided enhanced protection against oxidation at high temperature for these Pd/Cr fine-wire gauges. Thermocouples were also spot-welded to the metal coupons to measure temperatures during strain tests (see figure). The cemented gauges were cured at room temperature for 4 h, dried for 2 h at 93 °C, and heat cured at 121 °C for 1 h. The oven temperature was then raised to 371 °C over the course of 1 h for firing, the gauges being removed at the end of that 1-h period.



This **Strain Gauge on a Plate of Hastelloy X** is covered with a mixture of high-temperature cements. Two thermocouples are spot-welded on the plate.

The strain-gauge-and-coupon specimens were subjected to strain tests with temperature cycling between ambient and 600 °C. Some of the specimens were stabilized by presoaking them at 640 °C for 16 h before the tests. The results of the tests showed that the apparent strain-vs.-temperature relationships of the stabilized gauges were repeatable within 100 microstrain from cycle to cycle, even after an 11-h thermal "soak" at 600 °C. The Pd/Cr temperature-compensated strain gauges provide greater repeatability of apparent strain than do other gauges ordinarily used in the same temperature range.

This work was done by Jih-Fen Lei of Sverdrup Technology, Inc., for **Lewis Research Center**. *Further information may be found in NASA CR-185153 [N90-13761], "Development and Characterization of PdCr Temperature-Compensated Wire Resistance Strain Gauge."*

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

LEW-15079

Thermally Conductive Fluid Compatible With Hypergols

A special-purpose fluid would be chemically inert in its intended environment.

John F. Kennedy Space Center, Florida

A proposed thermally conductive fluid would be used to thermally couple a temperature probe to a dry well. The objective is to monitor the temperature of hypergolic fluids (nitrogen tetroxide and hydrazine or unsymmetrical dimethyl hydrazine) that flow in pipes with a dry well. Because the heat-transfer fluid would not react chemically with either hypergol, a leak that results in contact with either hypergol would not pose a hazard. Although compatibility with hypergolic fuels is normally a consideration only in rocket engines, there may be terrestrial applications in some organic-chemical synthesis processes.

The fluid would be more precisely describable as a slurry or composite of liquid and solid parts. It would consist of a perfluoroalkylether matrix (the vehicle fluid) containing suspended particles of copper oxides or other metallic oxides that do not react with the hypergols. Such a composite fluid would have a thermal conductivity greater than that of organic derivatives of petroleum.

This work was done by Gary W. Kurtz of Lockheed Space Operations Co. for **Kennedy Space Center**. *No further documentation is available.*

KSC-11389

Books and Reports

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

Biaxially Stretched Polycarbonate Film for Capacitors

Electrical properties at high temperatures are improved.

A report describes experiments on the effects of biaxial stretching on the crystal structures, dielectric properties, and selected thermal and mechanical properties of biaxially stretched polycarbonate films. This study was motivated by the need to improve the polycarbonate dielectric films used in capacitors, which have been found to be unreliable at high temperatures, especially in low-voltage, high-impedance applications.

A stretched film is said to be "oriented" in the sense that the stretching alters its crystal structure and properties in a manner related to the direction of stretch. The polycarbonate films now used in capacitors are cast from solution, then stretched along one direction (uniaxially oriented). To make biaxially oriented specimens for this study, polycarbonate films were first cast from solution, then heated to a temperature of about 170 °C and stretched in one direction to 2.27 times their original lengths followed by stretching in the perpendicular direction to various degrees (some to 2.0, some to 3.0, and some to 3.7 times their original lengths).

Uniaxially and biaxially oriented film specimens were analyzed by differential scanning calorimetry and x-ray diffraction to determine the types and degrees of crystallinity in them. Other specimens were subjected to tests of their dielectric properties, including (1) electrical breakdown strength, (2) insulation resistance vs. time at a temperature of 100 °C, (3) dissipation factor (at a frequency of 1 kHz and temperature of 25 °C) after exposure to a temperature of 100 °C for various times, and (4) coefficient of variation of capacitance with temperature (a measure of the dimensional stability of the film) after exposure to 100 °C for 1,000 hours.

The results of the tests show that biaxial stretching at the highest stretch ratios (2.27 and 3.7) produces the highest degree of crystallinity (about 37 percent), with a single crystalline phase and a distribution of crystallites more nearly isotropic than is that of uniaxially oriented film. The increased crystallinity, in turn, is correlated with greater breakdown voltage. This is consistent with the premise, stated in a previous study, that the boundaries of crystallites are sites of electrical weakness.

The life tests at 100 °C showed no significant degradation. Indeed, insulation resistances increased, possibly because of desorption of contaminants that had entered during fabrication. The dissipation factors remained constant, and the dimensional stabilities remained high.

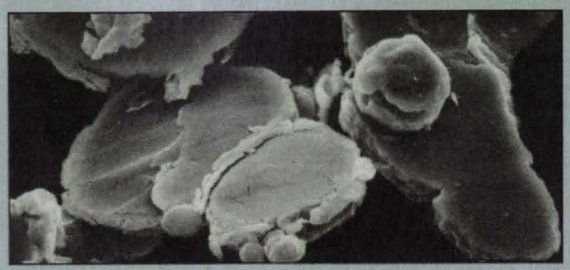
This work was done by Shaio-Ping S. Yen, Lynn E. Lowry, and Clyde P. Bankston of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Morphology and Dielectric Properties of Biaxially Oriented Polycarbonate Films for Capacitors," Circle 36 on the TSP Request Card.*

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

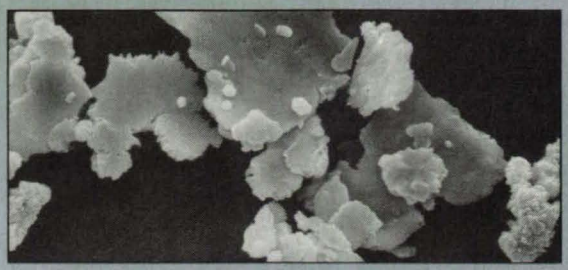
Edward Ansell
Director of Patents and Licensing
Mail Stop 305-6
California Institute of Technology
1201 East California Boulevard
Pasadena, CA 91125

Refer to NPO-18090, volume and number of this NASA Tech Briefs *issue, and the page number.*

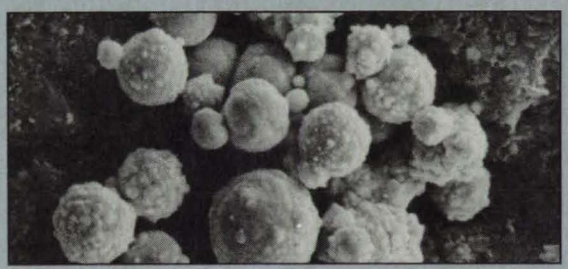
NOVAMET
CONDUCTIVE PIGMENTS



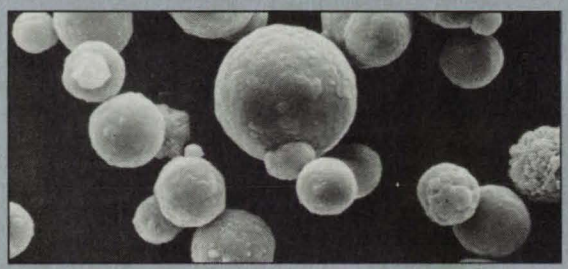
Conductive Silver Coated Nickel Flakes



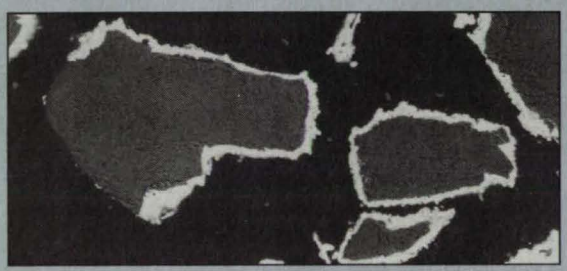
Conductive Nickel Flakes



Conductive Silver Coated Nickel Spheres



Conductive Nickel Spheres



Conductive Nickel Coated Alumina

Nickel Coated Graphite

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Computer Programs

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Computer Programs

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

Physical Sciences

Software for Processing Meteorological Data

Data can be interpolated, plotted, and otherwise generally processed into meteorologically useful forms.

GEMPAK is a package of general meteorological software developed at NASA/Goddard Space Flight Center. It includes programs to analyze and display surface, upper-air, or gridded data, including the outputs of mathematical models. There are very general programs to list, edit, and plot data on maps, to display profiles and time series, and to draw contours, streamlines, and cross sections in the case of gridded data. In addition, there are Barnes objective analysis programs to grid the data on surface and upper air.

The programs include the capabilities to derive meteorological parameters from those found in the set of data, to perform vertical interpolations to different coordinate systems, and to compute an extensive set of gridded diagnostic quantities by specifying various nested combinations of scalar and vector arithmetic, algebraic, and differential operators. A graphics/transformation software subsystem, GEMPLT, provides device-independent graphics and the capability to display output in a variety of map projections or overlaid on satellite imagery.

GEMPAK is written in FORTRAN 77 and has been implemented on VAX computers under VMS. A UNIX version, which has been verified on a SUNSparc workstation using SUNOS and on a Silicon Graphics computer using IRIX, is also available. The VMS version is delivered with the object code for the Transportable Applications Executive (TAE) program, which serves as the user interface. An alternate, built-in interface can be used with either the VMS or UNIX versions. To use the TAE (classic) with the UNIX version, a separate license for TAE PLUS must be obtained.

This program was developed in 1985. The current version, GEMPAK 5.0, was released in 1990. The package of software is delivered with source code. An extensive collection of subroutine libraries enables users to format data for use by GEMPAK, to develop new programs, and to enhance existing ones.

GEMPAK is available by license for a period of 10 years to approved licensees. The licensed program product includes the GEMPAK source code, sample data, and one set of supporting documentation. Additional documentation may be purchased separately.

VAX and VMS are trademarks of Digital Equipment Corp. UNIX is a trademark of AT&T Bell Laboratories.

This program was written by Mary L. desJardins of **Goddard Space Flight Center**. *For further information, Circle 73 on the TSP Request Card. GSC-13402*

Reformatting Data From X-Ray Photoelectron Spectroscopy

Columns of numbers in ASCII format are converted to DEC binary format.

It is often desirable to use a central, more powerful computer to analyze data captured on a local computer. ASCITOVG, a program for use on an IBM PC-series computer, creates files in binary format from columns of numbers in American National Standard Code for Information Interchange (ASCII) format. The resultant files are suitable for interactive analysis on a DEC PDP-11/73 computer under the Micro-RSX operating system running the VGS-5000 Enhanced Data Processing (EDP) software

package. EDP analyzes the data interactively with a color graphics display, speeding up the analysis considerably when compared with batch job processing. Its interactive analysis capabilities also enable the researcher to watch for spurious data that might go undetected when some form of automatic spectrum processing is used.

The incompatibility between the floating-point representations of numbers of an IBM PC and a DEC computer were resolved by a FORTRAN subroutine that correctly converts single-precision, floating-point numbers on the PC so that they can be read directly by such DEC computers as a VAX. The subroutine also can convert binary DEC files (single-precision, floating-point numbers) to IBM PC format. This may prove a more efficient method of moving data from, for instance, a VAX-cluster down to a local IBM PC for further examination, manipulation, or display.

The input data file used by ASCITOVG is simply a text file in the form of a column of ASCII numbers, with each value followed by a carriage return. These can be the output of a data-collection routine or can even be keyed in through the use of a program editor. The data-file header required by the EDP programs for an x-ray photoelectron spectrum is also written to the file. The spectrum parameters, entered by the user when the program is run, are coded into the header format used internally by all of the VGS-5000-series EDP packages. Any file-transfer protocol that provides for binary data can be used to transmit the resulting file from the PC to the DEC computer.

Each EDP data file includes at least a four-block information section ahead of the data. The header information is needed because data files from a number of different experimental techniques, as well as multi-region and depth-profile data, can be analyzed with the EDP software. This information includes general information about the data file, names of spectral regions, descriptive comments, information about the experimental technique, and information about such experimental conditions as the type of scan, the range of the scan, the source of excitation, and the analyzer mode. The files produced by ASCITOVG are in the form of a single-spectral-region, binding-energy-scan, x-ray photoelectron spectrum. Comments included in the source code should facilitate expansion of the program to some other types of data files.

This FORTRAN program was implemented on an IBM PC XT with the MS-DOS 3.1 operating system. It has a memory requirement of 53K bytes and was developed in 1989.

This program was written by P. B. Abel of **Lewis Research Center**. *For further information, Circle 52 on the TSP Request Card.*
LEW-14993

Fabrication Technology

Operating System for Numerically Controlled Milling Machine

The user can program machining operations quickly and easily.

The OPMILL computer program is an operating system for a Kearney and Trecker milling machine. It provides a fast and easy way to program the manufacture of machine parts by use of an IBM-compatible personal computer. The program gives the machinist an "equation plotter" feature, which plots any set of equations that define movements along axes (up to three axes simultaneously) and converts those equations to a milling-machine-controlling program that moves a cutter along a defined path.

Other functions supported by OPMILL include the following: drill with peck, bolt circle, tap, mill arc, quarter circle, circle, circle 2 pass, frame, frame 2 pass, rotary frame, pocket, loop and repeat, and copy

blocks. The system includes tool-manager software that can handle up to 25 tools and automatically adjusts the program to account for the length of each tool. It displays all tool information and stops the milling machine at the appropriate time.

Information for the program is entered via a series of menus and compiled to the Kearney and Trecker format. The program can then be loaded into the milling machine, the tool path graphically displayed, and tool-change information or the program in Kearney and Trecker format viewed. The program includes a complete file-handling utility that enables the user to load the program into memory from the hard disk, save the program to the disk with comments, view directories, merge a program on the disk with one in memory, save a portion of a program in memory, and change directories.

OPMILL was developed on an IBM PS/2 computer running DOS 3.3 with 1 MB of random-access memory. OPMILL was written for an IBM PC or compatible 8088 or 80286 computer connected via an RS-232 port to a Kearney and Trecker Data Mill 700/C Control milling machine. It requires a "D:" drive (fixed-disk or virtual), a "browse" or "text display" utility, and an EGA or better display. Users who wish to modify and recompile the source code will also need Turbo BASIC, Turbo C, and Crescent Software's QuickPak for Turbo BASIC.

IBM PC and IBM PS/2 are registered trademarks of International Business Machines. Turbo BASIC and Turbo C are trademarks of Borland International.

This program was written by R. B. Ray of **Goddard Space Flight Center**. *For further information, Circle 29 on the TSP Request Card.* *GSC-13366*

Mathematics and Information Sciences

Software Graphical User Interface for Analysis of Images

CAMTOOL provides an easy-to-use, mouse-driven interface.

The CAMTOOL software package provides a graphical user interface between a Sun Microsystems workstation and the Eikonix Model 1412 digitizing camera system (Ektron Applied Imaging, Bedford, MA). The Eikonix camera system can scan and digitize monochrome or color images, halftones, reflectives (e.g., black and white photographs), transmissives (e.g., negatives, x rays), rigid or flexible flat material, or three-dimensional objects.

CAMTOOL facilitates use of the camera system through an easy-to-use, mouse-driven interface. Users can digitize images and select from three destinations: workstation display screen, magnetic-tape drive, or hard disk. These three options make image data portable to a wide range of devices and software for further processing and analysis, and for immediate viewing of the initial digitized product. The application program also enables users to modify parameters that affect the digitization process and to initiate such system support options as calibration of the camera.

CAMTOOL is written in C language and has been implemented on Sun3 and Sun4 workstations running SunOS. This package runs under SunView on a color monitor. The program is available on a 0.25-in. (6.35-mm) streaming-magnetic-tape cartridge in UNIX tar format. CAMTOOL requires 101K of main memory. This package was developed in 1990.

Sun is a trademark of Sun Microsystems, Inc. Eikonix is a trademark of Ektron Applied Imaging, Inc.

This program was written by Desiree M. Leonard, Scott R. Nolf, and Elizabeth L. Avis of Computer Sciences Corp. and Kathryn Stacy of **Langley Research Center**. *For further information, Circle 89 on the TSP Request Card.*
LAR-14371

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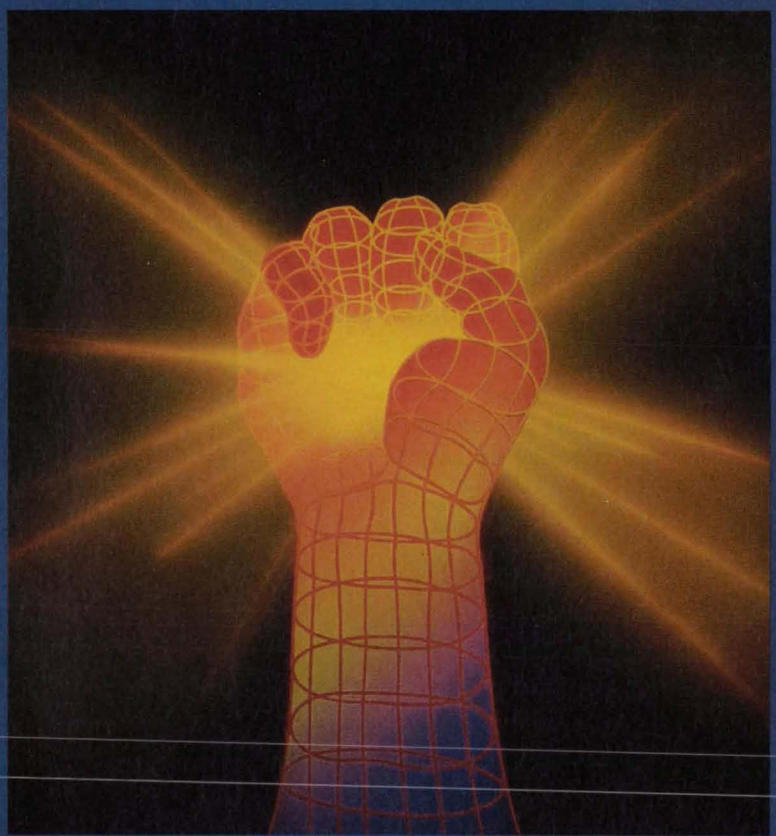

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Amtec Engineering Inc.
Arthur D. Little Inc.

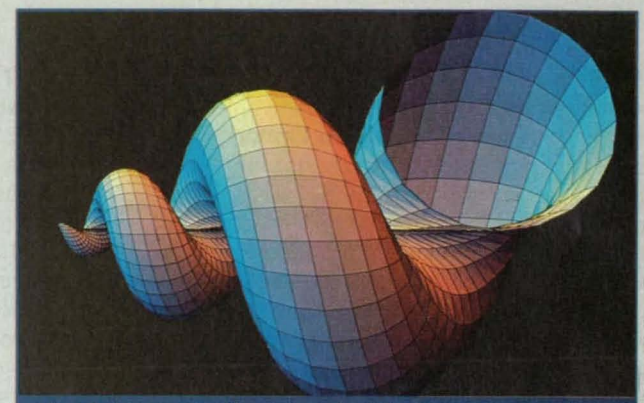


Photo: Wolfram Research

New Software For Numerical And Graphical Computation

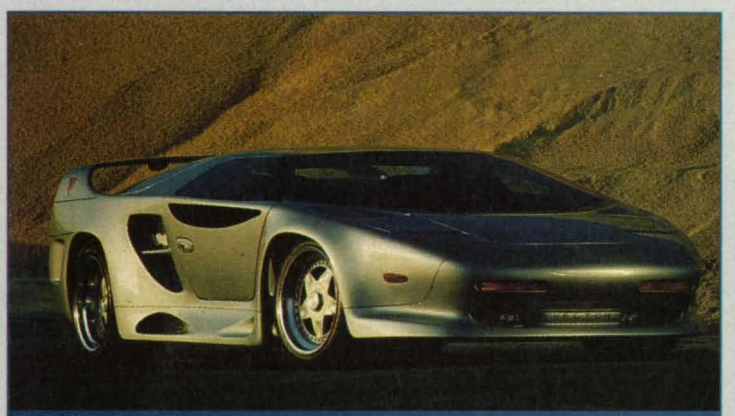


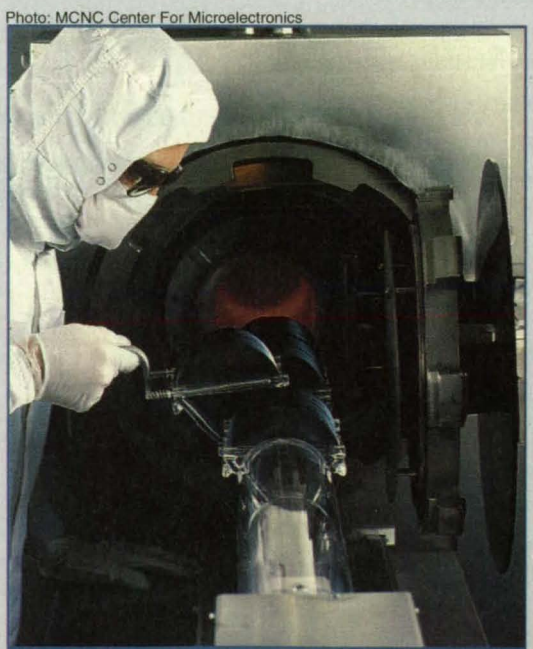
Photo: Vector Aeromotive

View The Vector Supercar - An Amazing Aerospace Spinoff

COSMIC/University Of Georgia
County Of Loudoun, Virginia
CTA Inc.
Cybernet Systems Inc.
Daedalus Enterprises Inc.
Datatape Inc.
Defense Programs Technology Transfer
Diamonex Inc.
Digiray Corp.
Digital Equipment Corporation
Dual Inc.
Edison Sensor Technology Center
Electronic Imagery Inc.
Evans & Sutherland
Federal Highway Administration
Federal Laboratory Consortium
Fermi National Accelerator Lab
Ferrofluidics Corp.
FLIR Systems Inc.
Fluid Dynamics International
General Pneumatics Corp.
Goddard Space Flight Center
Hemco Corp.
High Technology Systems Inc.
Idaho National Engineering Lab
Impra Inc.
Information Handling Services
Inframetrics Inc.
Infrared Information Analysis Center/ERIM
INPEX/INTROMARK
Institute Of Environmental Sciences
Integrated Engineering Software
Integrated Sensors Inc.

Association Of American Railroads
ASTM
Astro-Med Inc.
Aviation Week Group
Bergen Cable Technologies
BF Goodrich Aerospace
Biophysics Research Foundation
Biotronics Technologies
Birch, Stewart, Kolasch, & Birch
Boeing Company
Brookhaven National Laboratory
Caltech Supercomputer
Cannon Communications
Center For Aerospace Information
CI Systems Inc.
C. Itoh Technology Inc.
Concurrent Technologies Corp.
Control Systems Analysis
Corning Inc.

Photo: MCNC Center For Microelectronics



See Cutting-Edge Microelectronics Technology

International Computers And Telecommunications
International Environmental Institute
Ithaco Inc.
Jet Propulsion Laboratory
Johnson Space Center
Kennedy Space Center
Knowledge Express Data Systems
Langley Research Center
Lawrence Livermore National Lab
Lewis Research Center
Los Alamos National Lab
Machida Inc.
MacNeal Schwendler Corp.
Marshall Space Flight Center
Maryland Department Of Economic & Employment Development
McClellan Air Force Base
MCNC Center For Microelectronics
MERP Enhanced Composites
Mid-Atlantic Technology Applications Center
Millitech Corporation
Moltech Corporation
Morgantown Energy Technology Center
NASA
NASA Centers For The Commercial Development Of Space
NASA Regional Technology Transfer Centers
NASA Scientific And Technical Information Program

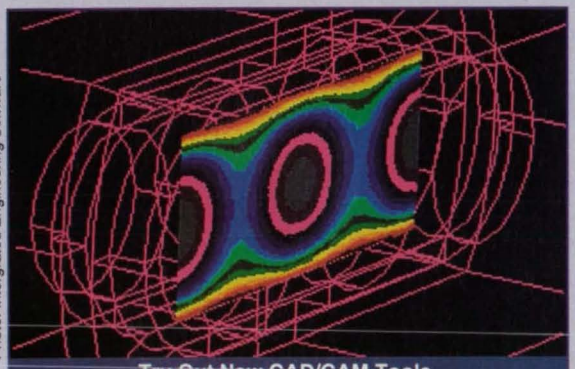


Photo: Intergrated Engineering Software

Try Out New CAD/CAM Tools

NASA Small Business Innovation Research Program
NASA Tech Briefs
National Institutes Of Health
National Institute Of Standards And Technology
National Renewable Energy Lab
National Technology Transfer Center
Naval Research Lab
Naval Surface Warfare Center
NERAC Inc.
NOAA Satellite Applications Lab
North Carolina State University
Novespace
NSI Technology Services Corp.
Numerical Algorithms Group
Nyma Inc.
Oak Ridge National Laboratory
Oklahoma Center For Design And Manufacturing
Oneida Research Services
Pacific Northwest Laboratory
Photonic Systems Inc.
Pittsburgh Energy Technology Center
Precision Filters Inc.
Princeton Plasma Physics Lab
Proto Manufacturing
Ramtek Corporation
Research Triangle Institute
RGB Spectrum
RG Hansen
Ribbon Technology
Sandia National Labs
Satellite Data Systems
Small Parts Inc.
Sonic Perceptions Inc.
Sonoscan Inc.
Southwall Technologies Inc.
Space Age Technology Products Inc.
Space News
Spire Corporation
Statistical Sciences Inc.
Stennis Space Center
Stephens Analytical Inc.
Strategic Defense Initiative Org. Office Of Technology Applications
Technical Insights Inc.
Technology Access Report
Technology Transfer Business
Technology Transfer Society
Technology Utilization Foundation
Techron, Div. Of Crown International
Tennessee Technology Foundation
Thiokol Corporation
Tiodize Company
Turbomixer Corp.
United Technologies/USBI Corp.
University Of Dayton Research Institute
Urethane 2000
U.S. Air Force, Manufacturing Technology Directorate
U.S. Army Belvoir Research, Development, & Engineering Center
U.S. Bureau Of Mines
U.S. Department Of Agriculture
U.S. Department Of Energy/Conservation & Renewable Energy
U.S. Department Of Energy/Triodyne
U.S. Environmental Protection Agency
U.S. Naval Academy
Vector Aeromotive Corp.
Vermont Research Corp.
Walter, Reed AMC
Wolfram Research Inc.

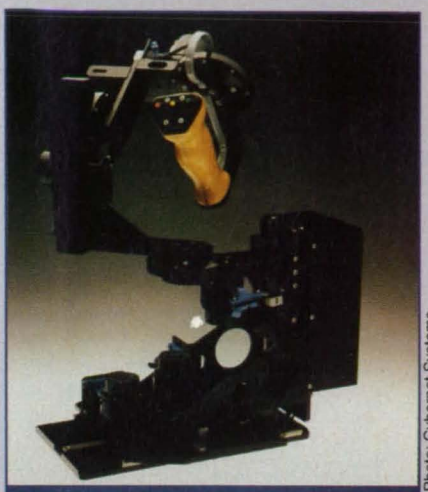


Photo: Cybernet Systems

The Latest Robotics Inventions

To find out how your company can exhibit at this important national event, call Evelyn Mars or Wendy Janiel at (800) 944-NASA.

Technology So Hot We Can't Even Show It To You!

Embargoed Until December 1, 1992

One Technology 2002 exhibitor (we promised we wouldn't reveal their name) will unveil a revolutionary new transportation technology at the show...you'll have to see it to believe it!

Technology 2002/NTI Program

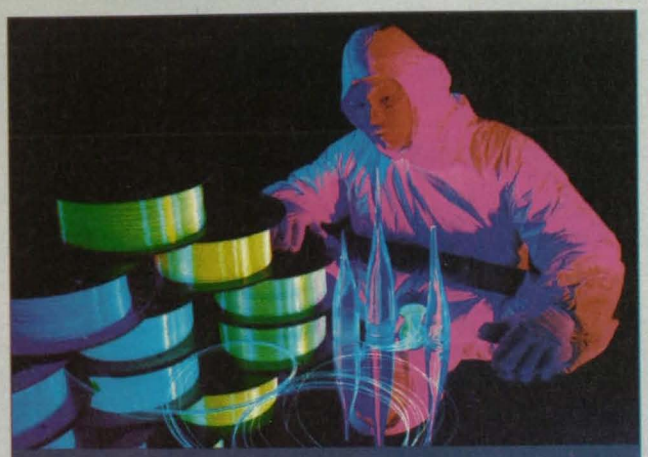
Monday, November 30

6:00 - 8:00 pm

Technology Transfer Week Opening Ceremonies & Reception

Speaker: Governor William Donald Schaefer, State of Maryland (invited)

The pre-show reception offers the chance to preview the exhibits and meet government and industry leaders in an informal atmosphere. Admission is free for **Technology 2002** full registrants and exhibitors.



On Display: The Department of Energy's Fermi Lab has produced fiber optics technology useful in the medical field for radiation monitoring.

Tuesday, December 1

8:30 - 10:00 am

Conference Opening — Federal Technology Overview

Keynote Address: *Senator Barbara Mikulski, State of Maryland*

National Technology Initiative — Opening Remarks:
Speakers at previous NTI opening sessions have included these dignitaries:
Barbara Hackman Franklin, Secretary, U.S. Department of Commerce
Daniel S. Goldin, Administrator, NASA
John W. Lyons, Director, National Institute of Standards and Technology
William K. Reilly, Administrator, U.S. Environmental Protection Agency
James D. Watkins, Secretary, U.S. Department of Energy

10:00 - 11:00 am

Plenary Theme Panels

(Panelists to be announced)

Expert panelists will explore three areas vital to the long-term health of U.S. businesses: Cooperative Research And Development; Investment And Financing; and Manufacturing Excellence.

11:00 - 11:45 am

Government-Industry Dialogue

Answers to your questions about the technology transfer process, partnering opportunities, and federal technology resources and contacts.

1:00 - 3:00 pm

National Critical Technologies Concurrent Sessions

Each presentation will last 30 minutes, including a question and answer period. Registrants may choose to attend whole sessions (four presentations) or individual presentations from a number of different sessions. Meeting rooms are situated in close proximity for easy and quick movement during sessions. Room assignments will be listed in the final program distributed at the show.

Session A101

Advanced Materials Part 1: Materials Processing

INEL Spray Forming Research
Kevin M. McHugh and James F. Kay, Senior Scientists, Idaho National Engineering Laboratory
A novel spray forming technology produces near-net-shape solids and coatings of metals, polymers, composites, and other materials. Advantages: improved product quality and major cost savings.

Film Fabrication Technologies
Robert D. McConnell, Superconductivity Program Manager, National Renewable Energy Laboratory
This presentation will spotlight an array of film fabrication techniques — including electron beam evaporation, ion beam sputtering, chemical vapor deposition, and melt coating — with commercial applications in fields ranging from superconductivity to photovoltaics.

The Effect of Hydrogen on the Optical and Scratch-Resistant Properties of Diamondlike Carbon Films
Michael T. Kussmaul, Research Engineer, Sverdrup Technology Inc.; Bruce A. Banks, Chief, Electro-Physics Branch, and Michael T. Mirtich, Engineer, Lewis Research Center
Using an innovative dual ion beam system, Lewis researchers have created extremely hard and clear thin films with applications in the military, ophthalmology, and other industries.

The Effect of Extrusion on PS-212 Self-Lubricating Materials
W.J. Waters, Materials Engineer, Sverdrup Technologies Inc.; H.E. Sliney, Materials Engineer, Lewis Research Center; and R.F. Soltis, Electrical Engineer, Cortez III
The presenters have employed extrusion processing to improve the strength and density of PS-212 ceramics, opening up a wide range of commercial uses for these unique high-temperature materials.

A102

Biotechnology and Life Sciences Part 1

Measuring the Metastatic Potential of Cancer Cells
Dr. Dennis R. Morrison, Senior Biotech Scientist, Johnson Space Center; Dr. Howard Gratzner, DNA Sciences Inc.; and Dr. M.Z. Atassi, Baylor College of Medicine
State-of-the-art digital imaging technology is providing a powerful new tool to diagnose breast, lung, and other forms of cancer, and promises more effective treatment techniques.

Immunoconjugates: Magic Bullets for Cancer Therapy?
Daniel R. Passeri, Technology Licensing Specialist, and Jack Spiegel, Patent Advisor, Office of Technology Transfer, National Institutes of Health
Discover how the exciting new technology of immunoconjugates is aiding the fight against cancer; explore current and future licensing opportunities in cancer and other therapy markets, such as arthritis, diabetes, and AIDS.

Automated System for Early Breast Cancer Detection
Isaac N. Bankman, Senior Research Scientist, Johns Hopkins University Applied Physics Laboratory
A new computerized system promises to improve the speed and accuracy of mammogram interpretation, enabling physicians to spot tumors at an earlier stage and accelerate treatment, thereby increasing the patient's chances of survival.

Design of Mechanically Compatible Fasteners for Human Mandible Reconstruction
Jack C. Roberts, John A. Ecker, and Paul J. Biermann, Senior Professional Staff, Johns Hopkins University Applied Physics Laboratory
The presenters will illustrate a design approach that overcomes many of the problems encountered in attaching disease-weakened sections of bone to one another, or a replacement material, during reconstructive surgery.

A103

Energy and Environment Part 1: Environmental Technologies

Cone Penetrometer Measures Spectral Characteristics of Soils *In Situ*
Philip G. Malone and Stafford S. Cooper, Geophysicists, U.S. Army Engineer Waterways Experiment Station
Army researchers have invented a fiber optic device that measures contamination in soils from fuels or other hazardous wastes. In field tests, it has detected diesel fuel contamination in concentrations as low as a few hundred parts per million.

Soil Reclamation and Recovery of Radionuclides and Toxic Metals
Dr. A.J. Francis, Microbiologist, Brookhaven National Laboratory
A new process for removing metals and radionuclides from contaminated soils, sediments, and sludges holds tremendous commercial potential because it can be applied to a variety of waste forms, generates no secondary waste streams, and causes little soil damage.

Recovery of Oil and Solids from Oily Sludges
Leonard A. Duval, Chief Executive Officer, RECOTECH Corporation
Mr. Duval will describe an energy-efficient and environmentally-safe process for converting large volumes of oily wastes to valuable raw materials and fuel oil.

Low-Cost Dewatering Waste Slurries
J.B. Peterson, Chemical Engineer, R.H. Church, Mining Engineer, and B.J. Scheiner, Supervisory Metallurgist, Tuscaloosa Research Center
The Bureau of Mines has developed a method for dewatering waste mineral slurries that could dramatically reduce the cost of waste disposal in the U.S.

At Technology 2002, you will find a wealth of materials inventions with down-to-Earth applications, such as mullite whiskers useful in composites manufacturing and thermal insulation.

A104

Information and Communications Part 1: High-Performance Computing and Networking

High-Performance Networks and Supercomputers for Real-Time Flight Simulation
Jeff I. Cleveland, Aerospace Technologist, Langley Research Center
This presentation will address commercial applications of high-speed data acquisition and computing technology in nuclear process control, power grid analysis, process monitoring, real-time simulation, radar data acquisition, and other key fields.

The SPLASH II Attached Processor System
Duncan A. Buell, Senior Researcher, Supercomputing Research Center
Designed for Sun workstations, SPLASH II achieves supercomputer performance on problems not suited for traditional architectures, such as the filtering of digital data signals.

Object-Oriented Tools for Distributed Computing
Richard M. Adler, Director of Advanced Development, Symbiotics Inc.
Mr. Adler will describe innovative software tools for developing heterogeneous distributed computing systems such as distributed databases and automated manufacturing control systems.

The Database Query Support Processor
Patrick McCabe, Computer Engineer, Rome Laboratory
The Air Force has created a time- and money-saving method for seamless access to heterogeneous databases based on extensions to data dictionary technology.

A105

Manufacturing Technology Part 1

"On Machine Tool" 3D Laser Measurement System
William L. Shade, Jr., Product Manager, Chesapeake Laser Systems
Mr. Shade will report on a major boon to manufacturing: an in-process, noncontacting sensor system that rapidly and accurately measures complex, contoured production parts.

Application of an On-Machine Gauge for Diameter Measurement
Kevin Harding, Principal Member, Industrial Technology Institute
This presentation will focus on the performance and potential commercial applications of the laser gauge described above.

On-Machine Capacitance Dimensional and Surface Profile Measurement System
Ralph Resnick, MetreX Division Manager, Extrude Hone Corporation
The subject invention, an analog probe designed to check the dimensions of complex shapes and contours on a machine tool or in an automated inspection cell, promises an advance over current inspection methods which are expensive, time-consuming, and labor-intensive.

Ultrasonic Polishing
Randy Gilmore, SoneX Division Manager, Extrude Hone Corporation
An ultrasonic polishing process developed for the Air Force offers many advantages in finishing complex parts: no specially shaped tools or complex fixturing are required; handworking can be eliminated; the process operates unattended; accuracy, uniformity and repeatability are outstanding; and the time savings over manual techniques are enormous.

For fastest registration fax the form on page "P" to (212) 986-7864

A106

Microelectronics/Optoelectronics Part 1

Two- and Three-Dimensional High-Performance, Patterned Overlay Multi-Chip Module Technology
Capt. James C. Lyke, Wafer Scale Electronics Engineer, Phillips Laboratory
A novel technique for reassembling bare integrated circuits dramatically improves performance while reducing component size and weight. The process has commercial applications ranging from desktop computers and workstations to biomedical imaging equipment and telecommunications systems.

Improved Performance and Safety for High-Energy Batteries
Terrill Atwater, Chemical Engineer, U.S. Army Electronics Technology and Devices Laboratory
A microchip-based process continuously predicts the remaining capacity in high-rate batteries and anticipates hazards — all in real time — enabling the production of reliable, safe, and efficient high-energy battery technology.

Thin Rechargeable Batteries for SRAM PC Card Memory Protection
Dennis N. Crouse, Senior Scientist, EIC Laboratories
Development of SRAM PC cards with permanently installed rechargeable cells and electrochromatic low battery voltage indicators promises to free PC users from having to "feed" their cards with coin cells and will allow a quick visual check of stored cards for their battery voltage status.

Passive Stacking for Improved Vibration Isolation
David A. Noever, Marshall Space Flight Center Space Science Laboratory
NASA research in space materials science has yielded a passive stacking scheme that eliminates a broad range of unwanted vibrations below 5 Hz in laser optics, atomic-force microscopy, and other Earth applications.

1:30 - 3:00 pm

National Technology Initiative Concurrent Workshop Series #1

(panelists to be announced)
Technology 2002 Tuesday symposia registrants are invited to attend these hands-on workshops, which will cover partnership opportunities in three major areas: **Transportation, Aerospace, and Manufacturing**.

3:30 - 5:30 pm

National Critical Technologies Concurrent Sessions

Session B201

Advanced Materials Part 2: Ceramics and Composites

A Novel Method for Detection and Characterization of Superconductors
B.F. Kim, Physicist, Johns Hopkins University Applied Physics Laboratory
Offering applications in process and quality control in superconductor production, a new technique dubbed magnetically-modulated resistance is more sensitive and convenient than conventional detection methods and can characterize the superconductor's granular state.

Production of Ultrafine, High-Purity Ceramic Powders
Jesse L. Hoyer, Ceramic Engineer, U.S. Bureau of Mines
Ms. Hoyer will describe an innovative grinding technology called turbomilling that holds tremendous potential for production of ultrafine high-temperature ceramic powders and whiskers.

Mullite Whiskers and Mullite-Whisker Felt
Dr. Inna Talmy, Senior Research Ceramist, and Debbie Haught, Materials Engineer, Naval Surface Warfare Center
The Navy has several patented processes for fabricating whiskers and whisker felt composed of mullite, a refractory oxide ceramic with high strengh and temperature resistance, low thermal expansion, and good dialectric properties. The loose whiskers can be used as a composite reinforcement, while the felt has applications as composite preforms and thermal insulation.

Graphite/Epoxy Composite Laminates with Co-Cured Interlaminar Damping Layers
J. Michael Pereira, Aerospace Engineer, Lewis Research Center
Damped composite laminates, fabricated by co-curing viscoelastic damping film with graphite/epoxy prepreg plies, have strong commercial potential in such areas as vibration and sound suppression.

B202

Artificial Intelligence Part 1

Expert System for UNIX System Reliability and Availability Enhancement
Catherine Q. Xu, Aeronautical Radio Inc.
The subject technology acts as an on-line system administrator to diagnose, report, correct, and prevent hardware and software failures in UNIX systems, which do not have any built-in intelligent fault diagnostics or correction capabilities.

The Generic Spacecraft Analyst Assistant: A Tool for Developing Graphical Expert Systems
Peter M. Hughes, GenSAA Project Manager, Goddard Space Flight Center
First developed for spacecraft monitoring, GenSAA graphical expert software can be used to automate data monitoring or fault detection for telecommunications links, computer networks, industrial control centers, and other commercial systems.

TARGET: Rapid Capture of Process Knowledge
R.T. Savely, C.J. Ortiz, and B.B. Ly, Software Technology Branch, Johnson Space Center
The Task Analysis/Rule Generation Tool represents a new breed of software that could profoundly reduce the time, difficulty, and cost of developing knowledge-based systems for the performance of procedural tasks.

Tree Classification Software
Wray L. Buntine, Computer Scientist, Research Institute for Advanced Computer Science
This presentation will spotlight the IND Tree Package, an AI software tool employing Bayesian tree algorithms that is part of a broad research effort to semi-automate the development of supervised learning algorithms.

B203

Biotechnology and Life Sciences Part 2: Medical Technology

Automatic Detection of Epileptic Seizures
Dale E. Olsen, Project Manager, Johns Hopkins University Applied Physics Laboratory
Johns Hopkins researchers have produced an algorithm for use in developing an implantable device that would give epilepsy patients early warning of oncoming seizures and could help treat the seizure with drugs or electrical stimulation.

A Fiber Optic Probe for the Detection of Cataracts
Dr. Rafat R. Ansari, Research Scientist, Lewis Research Center
A compact fiber optic probe developed for on-orbit science experiments has been reapplied to detect the onset of cataracts, a capability that could eliminate physicians' guesswork and result in new drugs to dissolve cataracts before surgery is necessary.

Heart Rate Spectral Analysis System
Hasan Rahman, Supervisor, Data Systems Engineering, General Electric Government Services
Mr. Rahman will report on a Macintosh-based system that performs real-time heart rate analysis during space and life sciences experiments.

CALMS: Contextual ALarm Management System
Karin C. Loftin, Senior Research Scientist, KRUG Life Sciences Inc.
An advanced software system developed to monitor astronauts during space flight is finding new applications here on Earth, particularly to help overcome the problem of integrating mentally fragile children into a classroom environment.

B204

Energy and Environment Part 2: Energy Innovations

Solid-State Isotopic Power Source for Computer Memory Chips
Paul Brown, Vice President R&D, American Nuclear Society
Tiny thin-film isotopic energy converters can be deposited directly onto integrated circuits to provide on-site power for computer memory chips. They are less toxic and last longer than conventional chemical batteries, and could run smart credit cards, cardiac pacemakers, or other electronics that don't require large amounts of power.

Photovoltaic Power Without Batteries for Continuous Cathodic Protection
W.W. Muehl, Sr., Department of the Navy, Coastal Systems Station
Mr. Muehl will describe a major advance in the application of photovoltaics: a cathodic protection system for ships, bridges, pipelines, and other structures that doesn't require any auxiliary/battery backup power.

High-Speed Solid-State Circuit Breaker
Thomas F. Podlesak, Electronics Engineer, U.S. Army Electronics Technology and Devices Laboratory
The Army has developed and installed solid-state circuit breakers that can interrupt 4160V three-phase power mains at no less than 300 microseconds, two orders of magnitude faster than conventional mechanical circuit breakers.

Variable-Speed Generators with Flux Weakening
A.A. Fardoun, E.F. Fuchs, and P.W. Carlin, University of Colorado at Boulder
Utilization of permanent magnets together with field weakening via stator excitation yeilds lightweight designs for low-speed, high-torque electric machines useful in variable speed applications.

B205

Information and Communications Part 2: Computer Simulation and Modeling

Industrial Applications of Computational Fluid Dynamics
Dr. R.R. Chamberlain, Chief Engineer/Senior Research Scientist, Adaptive Research Corp.
This presentation will explore potential uses of CFD technology in such diverse fields as automobile design, materials processing, oil production and recovery, electronics cooling, and environmental management.

Scientific Visualization Using the Flow Analysis Software Toolkit
Gordon V. Bancroft, Research Scientist, Sterling Software Inc.
FAST is a powerful software tool for visualizing and analyzing scientific data on high-performance graphics workstations. Its utility extends from space science to Earth ozone modeling to automotive design.

Integration of Design, Thermal, Structural, and Optical Analysis, Including Animation of Thermal Mapping
Ruth M. Amundsen, Aerospace Engineer, Langley Research Center
Discussion will center on how concurrent engineering can improve efficiency and accuracy in analytical modeling, such as through integration of CAD design with thermal and structural analysis.

Data Systems Dynamic Simulator
Christopher Rouff, Computer Engineer, Goddard Space Flight Center
Mr. Rouff will describe the importance and commercial potential of the DSDS, a discrete-event-based modeler that eases the simulation of complex, high-data-rate, end-to-end systems.

B206

Manufacturing Technology Part 2

A Novel Optical/Digital Processing System for Pattern Recognition
Bradley G. Boone, Physicist, and Oodaye B. Shukla, Engineer, Johns Hopkins University Applied Physics Laboratory
The presenters have developed algorithms that can be implemented optically for the extraction of features that are scale and rotation invariant. These features can then be used in conjunction with a digital neural network to perform pattern recognition on images obtained from machine vision systems and other sensors.

Vision-Aided Monitoring and Control of Thermal Spray, Spray Forming, and Welding Processes
John E. Agapakis, Vice President, Automatix Inc., and Jon Bolstad, President, Control Vision Inc.
An innovative vision sensing technique developed through the government's SBIR program incorporates intense pulse laser or strobe illumination and synchronized shuttered image sensing to produce a video image free of arc light or glare. This image can then be processed digitally to extract features for process monitoring and control.

Robotic Variable Polarity Plasma Arc (VPPA) Welding
Warls S. Jaffery, Senior Manufacturing Process Technology, Boeing Defense and Space Group
For space station Freedom, Boeing and NASA have achieved an industry first by establishing a production VPPA weld cell featuring eight axes of motion under automatic control. It produces highly reliable, porosity-free aluminum welds.

Firmware Development Improves System Efficiency
E. James Chern, Materials Engineer, Goddard Space Flight Center, and David W. Butler, Paramax Systems Corporation
A new eddy current imaging system designed for manufacturing processes such as materials dispensing, packing, and sorting improves positional accuracy and reduces wear and tear on the mechanical system.

3:30 - 5:00 pm

NTI Concurrent Workshop Series #2

(panelists to be announced)
Workshops will provide practical information in three key areas of interest to U.S. businesses: **Partnerships for Technology Transfer; Protecting Intellectual Property Rights and Technical Data;** and **Financing of Partnerships for Technology Commercialization**.

Wednesday, December 2

8:30 - 9:45 am

Concurrent Workshops: How To Do Business With The Government

(Panelists to be announced)
In small working groups, tech transfer experts from leading federal agencies including NASA, the DOD, and DOE will discuss with industry attendees how they can successfully tap into that

agency's R&D resources through patent licensing, partnerships, Small Business Innovation Research grants, and other proven mechanisms. They also will cover how the government acquires new technology from the private sector. Seating will be limited, so please plan to arrive early.

10:00 am - 12:00 pm

National Critical Technologies Concurrent Sessions

Session C301

Advanced Materials Part 3: Plastics, Polymers, and Rubber

Electro-Expulsive Separation System
Leonard A. Haslim, Research Scientist, Ames Research Center
A dynamic new deicer uses less power and is more compact and efficient than current systems. It can be easily retrofit to aircraft and ships to deice surfaces ranging from frost to one-inch glaze coatings, and has applications in fluid pumping lines, plastic mold releases, and robotic arms.

Improved Rubber Compound for Tracked Vehicles
Dawn Crawford, Materials Engineer, US Army Fort Belvoir Research, Development, and Engineering Center
The Army has produced a tough, temperature-resistant compound that extends the service life of tank track pads by two to three times, saving maintenance costs and time. Commercial possibilities include conveyor belts, fenders and bumpers on loading docks, gaskets and seals, and even soles and heels for shoes.

Dynamic Hardness Tester and Cure Meter
Dr. Walter M. Madigosky, Distinguished Scientist, Naval Surface Warfare Center
A prototype apparatus provides fast, accurate data on the mechanical properties of materials in an "in-situ" or manufacturing environment, and could become a standard test item in the rubber and plastics industries.

Instrumentation Measures Gas Permeability of Polymeric Membranes
Dr. Billy T. Upchurch, Instrument Research Division, Langley Research Center
Mass spectrometry is employed to measure the permeability of virtually any gas through polymeric membranes. Practical payoffs: food packaging, contact lenses, and other commercial materials where gas permeability and permselectivity are important.

C302

Artificial Intelligence Part 2

A Software Package for Neural Network Applications
Robert H. Baran, Naval Surface Warfare Center
Original Backprop is an MS-DOS package of four C-language programs that enable users to develop neural network solutions to a variety of practical problems in medicine and business.

Control of Complex Dynamic Systems by Neural Networks
James C. Spall, Principal Professional Staff, Johns Hopkins University Applied Physics Laboratory
Mr. Spall will describe how neural networks can be used to control/regulate complex systems for which it is difficult or impossible to build a reliable mathematical model, such as in manufacturing, biotechnology, and environmental control.

Adaptive Process Control with Fuzzy Logic and Genetic Algorithms
C.L. Karr, Mechanical Engineer, and D.A. Stanley, Supervisory Research Chemist, U.S. Bureau of Mines
Using two powerful AI techniques, researchers at the Bureau of Mines have devised simple and versatile adaptive process control systems that efficiently manipulate complex problem environments despite limited feedback.

A Genetic Algorithm Tool for Complex Scheduling Problems
Lui Wang, Software Technology Branch, Johnson Space Center
Splicer, a genetic-algorithm-based software package developed for scheduling of propellant resupply to space station Freedom, offers a relatively simple, modular, and portable tool for solving a variety of scheduling problems in manufacturing and production.

C303

Energy and Environment Part 3: Environmental Technologies

Development of a LIDAR Mapping Instrument
Fran L. Stetina, Technical Manager, Goddard Space Flight Center
NASA has developed a laser ranging device that provides timely and accurate data about Earth features such as topography, bathymetry, forestry, and wetlands.

Commercial Applications of a Multispectral Sensor System
R. Birk, ASDL Supervisor, Lockheed Engineering & Sciences Co.
The Airborne Thermal/visible Land Applications Sensor (ATLAS) offers a versatile test bed for the development of remote sensing applications including environmental monitoring, facilities management, Geographic Information Systems, and mineral exploration.

Interactive Forecasting with the National Weather Service River Forecast System
George F. Smith, Donna I. Page, and Thomas E. Adams, Hydrologic Research Laboratory, National Weather Service
Computational modeling techniques have been applied to create a tool for water resource forecasting, an immense and largely untapped market. One potential application: reservoir operators could use river flow forecasts to balance the competing needs of water supply, flood control, and hydroelectric power generation.

Application of Space Life Support Technology to Terrestrial Environmental Problems
Steven H. Schwartzkopf and Bill Walsh, Lockheed Missiles and Space Co.
This presentation will spotlight a series of life support technologies developed to remove trace contaminants from air, purify water, and process solid wastes, and will describe how these technologies can be applied to problems of environmental remediation and pollution prevention.

C304

Information and Communications Part 3: Computer Graphics and Display Technologies

Transportable Applications Environment (TAE) Plus
Martha R. Szczur, TAE Project Manager, Goddard Space Flight Center
TAE Plus is an advanced WYSIWYG tool for building and managing graphical user interfaces in a wide range of disciplines, including simulation, production, network management, scheduling, database management, image processing, and office automation.

Advanced Display Object Selection Methods
Glenn Osga, Scientist, Naval Command Control & Ocean Surveillance Center
Mr. Osga will demonstrate a time-saving interface technology that could dramatically improve the productivity of thousands of computer users.

Universal Index Management System
Nick Roussoppulos, Vice President, Advanced Communications Technology
R-trees software provides an easy-to-use and reliable interface to large pictorial databases; it can be used as an external add-on search capability for commercial database management systems or incorporated into other systems as a spatial access method.

A Natural Language Interface for a Geographic Information System
Bruce Davis, Geographer, Stennis Space Center
Under an SBIR contract, Netrologic Inc. is creating a user-friendly interface for GIS technology that will enable analysts to input English language statements to request information. This will make GIS software more attractive commercially and open new markets such as process control and biomedicine.

C305
Data Management, Storage, and Processing Part 1

An Application Protocol for CAD to CAD Transfer of Electronic Information
Charles C. Azu, Jr., Project Engineer, Naval Command Control and Ocean Surveillance Center
An innovative application protocol will enable computer-aided design software developers to transfer files between dissimilar CAD systems without any data loss, negating the current need to reenter parts of the design.

Methods for Programming Intelligent Searches of Technical Documents
David L. Gross, Computer Engineer, Analex Space Systems
The Centralized Document Database provides a common interface to an unlimited number of files of various sizes, with the capability to perform many diversified types and levels of data searches. Legal, medical, and other professionals who devote time to subject review and research would benefit greatly from this time-saving system.

An Integrated Information Retrieval and Document Management System
L. Stephen Coles, Group Chief Technologist, Jet Propulsion Laboratory
Mr. Coles will illustrate an improved method for communicating and storing information electronically that combines scanning, optical character recognition, magneto-optical storage, and multiplatform retrieval technologies.

Multispectral Lossy Data Compression Using Vector Quantization
S. Jaggi, Senior Scientist, Lockheed Engineering and Science Co.
This presentation will explore how a new data compression technique can benefit the handling, storage, and processing of remote sensing, medical, and industrial imaging data.

C306
Manufacturing Technology Part 3: Robotics

Development of a Dexterous, Redundant Manipulator for Space and Ground Robotics Applications
James B. Burke, Odetics Inc.
A dexterous robot with seven degrees of freedom and internal force reflection capabilities has been created to tackle jobs that are too dangerous or impractical for humans, such as handling nuclear waste materials or repairing satellites in orbit.

An Eight-Degree-of-Freedom Macro-Micro Robot for Precise Force Manipulations
Dr. Neville Marzwell, Jet Propulsion Laboratory
The development of an automated robot that can handle delicate objects will improve the nation's manufacturing capabilities for such tasks as polishing, finishing, grinding, and cleaning.

A Fault-Tolerant Intelligent Robotic Control System
Dr. Neville Marzwell, Jet Propulsion Laboratory
This presentation will spotlight a knowledge-based fault diagnostics and recovery system that can be applied in industrial robots to cope with various unexpected events occurring during the manufacturing process.

ROBOSIM: An Intelligent Simulator for Robotic Systems
Kenneth R. Fernandez, Marshall Space Flight Center, and George E. Cook, Vanderbilt University
A NASA software package aids the design and testing of robots, robot action planning, on-line control of robot manipulators, telerobotic user interface, and training and education.

1:00 - 3:00 pm
National Critical Technologies Concurrent Sessions

Session D401
Biotechnology and Life Sciences Part 3

Three-Channel Biomedical Telemetry System
Jeffery C. Lesho and Harry Eaton, Associate Engineers, Johns Hopkins University Applied Physics Laboratory
An ingestible electronic pill transmits precise measurements of body temperature, heart rate, muscle strain, and internal pressures. Potential uses include critical health care monitoring, sports medicine, and animal studies.

Implantable Stimulator System Restores Motor Function
Dr. P. Hunter Peckham, Research Biomedical Engineer, Department of Veterans Affairs Medical Center
Learn about a new technique that uses electrical stimulation to restore movement and sensation for people with central nervous system injuries such as stroke and cerebral palsy.

Automated System for Analyzing the Activity of Individual Brain Neurons
Isaac N. Bankman, Senior Research Scientist, Johns Hopkins University Applied Physics Laboratory
An instrument that reliably records neuron behavior could bring important new insights about the workings of the human brain and speed advances in speech processing, computer vision, and memory storage and retrieval.

Improved Inhalation Technology for Setting Safe Levels of Exposure to Workplace Chemicals
Dr. Bruce O. Stuart, Program Manager, Inhalation Technology Facility, Brookhaven National Laboratory
Dr. Stuart will detail an analytical tool for much more reliable risk evaluation and chemical exposure level setting for humans.

D402
Energy and Environment Part 4: Environmental Technologies

Active Hydrazine Vapor Sampler
Rebecca Young, Manager, NASA Toxic Vapor Detection Laboratory
NASA has produced a major advance in personnel safety monitoring: a lightweight, low-cost, easy-to-use, and intrinsically safe device that detects low-level toxic vapors in the air.

COP Improvement of Refrigerator/Freezers, Air-Conditioners, and Heat Pumps
Douglas G. Westra, Aerospace Engineer, Marshall Space Flight Center
A unique non-azeotropic refrigerant mixture offers an efficient, environmentally-safe alternative to ozone-damaging chlorofluorocarbon (CFC).

Novel Hot Water Recirculating Technology Conserves Energy/Water
Thomas J. Ingalz, Director, Water Control Products Inc.
PROtherm, a home water conservation unit utilizing a state-of-the-art microcontroller and fuzzy logic technology, could obviate "wait" water loss (amounting to billions of gallons annually in the U.S. alone), reduce water heating energy requirements, and yield unprecedented convenience to the morning shower and sink user.

Variable-Volume Flushing Device for Toilet Water Conservation
Louis J. Jasper Jr., Chief, RF Effects and Hardening Technology Branch, Harry Diamond Laboratories
The subject invention is more reliable (will not leak) than current flushing devices, is simple and economical, and conserves water by allowing one to choose the amount of water to use for flushing waste.

D403

Information and Communications Part 4: Computer Software

Automated Real-Time Software Development
Denise R. Jones, Research Engineer, Langley Research Center, and John J. Turkovich, Section Chief, Automation Technology, Charles Stark Draper Laboratory
A new computer-aided software engineering system provides an automated way to generate source code and hard copy documentation from application engineering specs, the goal being to reduce the cost of developing and maintaining real-time scientific and engineering software while increasing system reliability.

Constraint Checking During Error Recovery
Robyn R. Lutz, Jet Propulsion Laboratory
NASA has developed a technique that allows more accurate modeling of the constraints on process interactions. It can be applied to a wide range of control systems or used as an embedded extension to simulation and CASE tools.

Spinoff Technology: Engineering and Scientific Computer Codes
Bahman Zohuri and Robert Weinheimer, Galaxy Applied Engineering
A host of government computer codes originally developed for mainframe computers have been adapted to PCs and are available for commercial use. Learn how and where you can access this wealth of software.

Failure Environment Analysis Tool Applications
Ginger Pack, Project Manager, Johnson Space Center, and David Wadsworth, Lockheed Engineering and Sciences Co.
FEAT permits analysis of large systems with thousands of nodes so that failure modes and effects can be determined across subsystems, and has additional value as a training tool.

D404

Information and Communications Part 5: Computer Simulation, Video, and Imaging Technology

Development of Interactive Multimedia Applications
Albert Leigh, McDonnell Douglas Space Systems Co., and Lui Wang, Johnson Space Center
Several exciting computer-aided training, instructional, and simulation systems incorporating new media forms and technologies will be presented.

Visual Communication in Multimedia Cyberspaces
Dr. Joseph Psotka, Chief, Smart Technology, US Army Research Institute
This presentation will investigate how visual knowledge can be structured to take advantage of advanced computer environments for training, particularly hypertext and virtual reality (VR), and will discuss the development of images for a VR workstation that immerses the user in a 3D computer-generated world.

Micro-Video Display with Interactive Ocular Tracking and Voice Control
James E. Miller, Encapsulated HARPOON Weapon Warfare Center, Naval Undersea Warfare Center
A PC-based micro-video display system incorporating interactive eye tracking and voice command control enables hands-free computing for such applications as portable training and troubleshooting, and could prove a valuable aid for the handicapped.

Video Conferencing Made Easy
D.G. Larsen and P.R. Schwieder, EG&G Idaho
Department of Energy engineers have designed a state-of-the-art video conferencing system that combines an array of outstanding features, among which are true multipoint conferencing, user-friendly operation with no full-time operators required, and the potential for cost-effective system expansion.

D405

Manufacturing Technology Part 4: Intelligent Tools

An Expert System for Superplastic Forming in Concurrent Engineering Environments
Deepak Kohli, West Virginia University; Paul Gill and Suren Dwivedi, Marshall Space Flight Center
An object-oriented, knowledge-based system and computer-aided technologies are being developed to enable design and manufacturing engineers to simulate the metal sheet forming process, leading to improved design and quality.

Automated Fiber Placement Composite Manufacturing
John H. Vickers, Marshall Space Flight Center
The subject invention is a tremendous advance in automated composite manufacturing established at the Marshall Center's Productivity Enhancement Complex, where NASA engineers work with industry and university experts to solve materials and processing problems.

Expert System for Signal Validation and Equipment Surveillance
Kenny C. Gross and Ralph M. Singer, Managers, Argonne National Laboratory
An artificial-intelligence-based expert system has been produced for signal validation and equipment surveillance in industrial applications that require high-reliability, high-sensitivity annunciation of degraded sensors, discrepant signals, or the onset of system disturbances.

Application of Space Time Neural Networks to Detect Tether Skiprope Phenomena
James A. Villarreal, Johnson Space Center
Numerous industrial and commercial control applications could benefit by adopting a patented neural network architecture first developed to detect and predict oscillations of tethered satellites in Earth orbit.

D406

Microelectronics/Optoelectronics Part 2

Wireless Infrared Communications for Space and Terrestrial Applications
James W. Crimmons, President, Wilton Industries Inc.
For space station Freedom, NASA sponsored development of infrared (IR) systems that provide simultaneous multi-channel, multi-user communications for both voice and data. Mr. Crimmons will explore potential — and actual — "spinoffs" of this technology, including a wireless IR telephone system and wireless personnel tracking products.

Flexible High-Speed CODEC
J.V. Wernlund and G.P. Segallis, Harris GCSD
An advanced high-speed error correction decoding technique provides substantial coding gains with limited bandwidth expansion compared to the uncoded bit-error-rate performance of several common modulation methods. Commercial applications include cellular communications and high-data-rate links used to transfer video images.

Ultra-Stable Low-Phase-Noise Dielectric Resonator Stabilized Oscillator (DRO)
Muhammad Mizan, Electronics Engineer, U.S. Army Electronics Technology and Devices Laboratory
The Army has fabricated a microwave DRO with better phase noise and temperature stability performance than current models. Applications for the small, lightweight, low-cost oscillator include cellular phone systems and built-in test equipment.

Excimer Laser Processing of Backside-Illuminated CCDs
Stephen D. Russell, Scientist, Naval Command Control & Ocean Surveillance Center
Laser implantation of dopant atoms into the backside of backside-illuminated charge-coupled devices repairs defective pixels and improves the dark current and spectral response. This process is particularly useful for solid-state imaging detectors requiring a wide spectral response and low-light-level detection.

3:30 - 5:30 pm

Track #1: University Tech Transfer Opportunities

(panelists to be announced)
In this highly interactive session, technology transfer experts from MIT, Stanford, and other top schools will tell you about specific opportunities for licenses, R&D partnerships, and technology incubators.

Track #2: International Technology Forum: Foreign Inventions for U.S. Benefit

(panelists to be announced)
Leading technology managers from around the globe will show you their nation's portfolio of technologies available for transfer and discuss key contacts and resources for follow-up.

7:00 - 10:00 pm

Third Annual Technology Transfer Awards Dinner — Hyatt Regency Hotel

Keynote Speaker: Norman Augustine, Chairman and CEO, Martin Marietta Corporation
Achievement awards will be presented to federal employees and private sector companies who have made important strides in translating innovative ideas into products and processes that benefit the national economy and daily life.

Thursday, December 3

8:30 - 9:45 am

Concurrent Workshops: How To Do Business With The Government (Part 2)

(panelists to be announced)

10:00 am - 12:00 pm

National Critical Technologies Concurrent Sessions

Session E501

Advanced Materials Part 4

Applications of Phase Change Polymers in Fibrous Substrates
Tyrone L. Vigo and Joseph S. Bruno, US Department of Agriculture
A process for insolubilizing polyethylene glycols onto a variety of fibrous substrates produces materials with improved properties and fabrics exhibiting novel thermal adaptability, reduced static charge, resistance to oily soils, and smooth drying properties.

Rust Transformers/Rust Compatible Primers
Dario A. Emeric, Chemist, US Army Belvoir Research, Development, and Engineering Center
The Army has developed a compound for use on a rusted surface before application of an organic coating that obviates the need for sandblasting or removing the adherent corrosion.

Method for Predicting Properties of and Tailoring Salt Solutions for Industrial Processes
Dr. Moonis R. Ally, Oak Ridge National Laboratory
This unique method can predict a wide range of thermodynamic properties of concentrated aqueous salt solutions, both single-salt and multiple-salt, to enable determination of system pressures, boiling temperatures, and heats of mixing, dilution, evaporation, and condensation.

An X-Ray Scatter Approach for Nondestructive Analysis of Low Atomic Numbered Elements
H. Richard Ross, Sverdrup Technology Inc.
A nondestructive analysis technique based on the intensity ratio of Compton and Rayleigh scatter in x-ray fluorescence spectra is used to define light element components in alloys, plastics, and other materials.

E502

Artificial Intelligence Part 3

An Artificial Intelligence-Based Structural Health Monitoring System for Aging Aircraft
Joseph E. Grady, Aerospace Engineer, Lewis Research Center
A new system monitors vibrations of in-service parts and, using a computer-based pattern recognition algorithm, estimates the damage and structural degradation of aging airframes.

The Ground Processing Scheduling System
Michael J. Deale, Senior Engineer, Lockheed Space Operations Co.
GPSS is a general-purpose AI-based scheduling tool that aids in managing large, resource- and configuration-constrained scheduling problems. It can be applied to scheduling tasks in plant management, construction, operations, and transportation.

Reactive Control and Reasoning Assistance for Laboratory Instruments
David E. Thompson, Senior Scientist, Ames Research Center
Interactive software developed at NASA autonomously controls scientific laboratory instruments and provides data analysis of real-time data in support of dynamic refinement of experiment control. The technology has been applied to a differential thermal analyzer and a gas chromatograph.

Knowledge From Pictures
Walt Truszkowski, Head, Automation Technology Section, Goddard Space Flight Center
A new tool configures an expert system's rule base by an automated analysis of a picture — a graphical representation of some target system to be supported by the expert system's diagnostic capabilities. This rule base could be used to automate fault detection, isolation, and repair of the target system.

E503

Biotechnology and Life Sciences Part 4: Computers in Medicine

Optimal Design of Composite Hip Implants
D.A. Saravanos, Senior Research Associate, Lewis Research Center
STAT, a structural optimization code for propulsion components, has been adapted to automate and improve the design of composite orthopedic implants.

Finite Element Analysis of a Composite Artificial Ankle
Leigh Ann Perkins, Aerospace Engineer, Marshall Space Flight Center, and Blaise E. Czekalski, Software Consultant, Integraph Corp.
NASA conducted an ankle strength analysis to aid in the design of a composite artificial ankle. A 3D finite element model of the ankle was created from ANSYS layer shell elements and various analyses performed to ensure that the joint met spring, strength, and stiffness requirements.

Design of a Portable Powered Seat Lift
Bruce Weddendorf, Structural Designer, Marshall Space Flight Center
A battery-powered device assists people suffering from degenerative hip or knee joints in sitting and rising from sitting. Though the size of a thin briefcase, the seat can lift a user weighing up to 300 pounds to nearly standing.

Microcomputer-Based Software for Biodynamic Simulation
N. Rangarajan, President, GESAC Inc.
Mr. Rangarajan will describe DYNAMAN, user-friendly biodynamic simulation software that is easily installed on a PC. Based on the Articulated Total Body model previously available only on larger computer systems, the software can be used to predict occupant motion during an automobile or aircraft crash.

E504

Data Management, Storage, and Processing Part 2

The Data Egg: Single-Handed Text Entry Without Positional Constraints
Gary L. Friedman, Technical Group Leader, Jet Propulsion Laboratory
JPL researchers have devised a small, handheld unit that allows text entry with only one hand. The Data Egg can be operated in any position, either autonomously or tethered to a PC.

MIRAGE: The Data Acquisition, Analysis, and Display System
Hasan Rahman, General Electric Government Services
MIRAGE provides a portable desktop unit capable of real-time acquisition, monitoring, archival, and processing analysis. The low-cost system, which features a Macintosh user interface, can acquire either parallel data from a high-rate demultiplexor interface or packetized data from a DECnet interface.

Tunneling Magnetic Force Microscopy
Dr. Edward R. Burke, Laboratory for Physical Sciences
This invention uses a flexible magnetic probe instead of the fine-wire probe used in scanning tunneling microscopes to provide improved atomic-level resolution for imaging surface topology.

The Operator Performance Support System
Marlen Z. Conklin, System Engineer, and Eugene Walker, Program Manager, Naval Command Control, and Ocean Surveillance Center
A proposed operator station incorporates elements of video and image databases, productivity software, interactive computer-based training, text databases, expert programs, and human factors engineering to assist in complex systems operation.

E505

Manufacturing Technology Part 5

A New Technology for Manufacturing Scheduling
R.S. Hornstein, Office of Space Communications, NASA Headquarters, and J.K. Willoughby, Avyx Inc.
Derived from space systems operations, a new technology can produce finite capacity schedules for both discrete and process manufacturing environments. Systems built with the technology are easy to adapt or extend and can accommodate machine and routing alternatives and software/hardware constraints.

Three-Dimensional Laser Window Formation for Industrial Applications
Vincent G. Verhoff, Aeropropulsion Engine Components Project Engineer, Lewis Research Center
NASA has developed a unique glass molding process for forming 3D compound-curvature laser windows to extreme accuracies. Such windows are an integral component of specialized non-intrusive laser data acquisition systems employed in compressor and turbine research testing facilities, and could be used for view ports in testing devices or factory machines .

High-Performance Sapphire Windows
Stephen C. Bates, Senior Engineer, Advanced Fuel Research Inc., and Larry C. Liou, Aerospace Engineer, Lewis Research Center
A project is underway to strengthen sapphire to compare with steel and to develop mounting techniques to minimize thermal stress during its use. Sapphire windows will afford a moderately-priced glass alternative in applications where optical access must be maintained but the pressure or temperature is too high to permit the safe use of glass.

A Dual-Pressure, Ultra-Pure Gas Delivery Vessel Assembly
Isaac Maya, Director of R&D, Arral Inc.
A new gas vessel assembly delivers ultra-pure gas at exhaust pressures of 6000 psi and 100 psi, with an accuracy of 10 psi. Ideal for fast, high-pressure discharge applications, the device is extremely lightweight and offers very long storage life.

E506

Sensors and Signal Processing

On-Line Process Analysis Innovation: The New Shunting Dielectric Sensor Technology
Frank A. Waldman, President, Axiomatics Corp.
Innovative sensor technology incorporates a shunting electrode and conventional electrode pair within a dielectric sensor to greatly magnify the changes in dielectric measurements due to changes in the composition of a material in the electric field.

A Modular, Programmable Measurement System for Physiological and Spaceflight Applications
John W. Hines, Research Scientist, Ames Research Center
The NASA Ames Sensors 2000! program has produced a compact, modular, programmable sensor signal conditioning and measurement system suitable for a variety of commercial applications.

Smart Sensor Method and Apparatus
Tom Koger and Vivien Cambridge, Sverdrup Technology Inc.
A microprocessor-based software system employs a unique signal processing technique to speed sensor response time. Designed for application to hydrogen leak sensors, it reduces response time from 1.5 minutes to 8.5 seconds and could be applied to such devices as electronic medical thermometers.

ATTIRE: Analytical Tools for Thermal InfraRed Engineering
S. Jaggi, Senior Scientist, Lockheed Engineering & Science Co.
ATTIRE, a thermal sensor simulation software package, simulates the various components of a sensor system and allows each subsystem to be analyzed independently. Performance parameters can then be integrated to obtain system-level information.

1:00 - 3:00 pm

Track #1: University Tech Transfer Opportunities (Part 2)
(panelists to be announced)

Track #2: International Technology Forum: Foreign Inventions for U.S. Benefit (Part 2)
(panelists to be announced)

Preregister and Save

Complete the registration form on the next page and mail with check or money order (if applicable) to the Technology Utilization Foundation, or fax it with credit card information to (212) 986-7864. To register by phone, call (800) 944-NASA. Government organizations may use a purchase order to register. **Deadline for preregistration is November 20.**

	By 11/20	On-Site
Complete Registration	$240	$285
Three-Day Symposia/Exhibits	$150	$195
One-Day Symposia/Exhibits	$75	$95
Awards Dinner Only	$95	$105
Exhibits Only	— No Charge —	

See next page for descriptions of registration packages.

Preregistrants will receive written confirmations via mail along with their name badge, reception/dinner tickets, and tickets for optional tours (listed below). Badge holders and computerized registration cards must be picked up in person at the Baltimore Convention Center (Pratt Street Lobby) during the following hours:

On-Site Registration Hours

Monday, Nov. 30	9:00 am - 5:00 pm
Tuesday, Dec. 1	7:00 am - 5:00 pm
Wednesday, Dec. 2	7:00 am - 5:00 pm
Thursday, Dec. 3	7:00 am - 4:00 pm

Spouse & Post-Meeting Tours

Tour 1

Baltimore: Its Sights & Seaport

Wednesday, Dec. 2 12:00 - 4:30 pm

Walking tour of the exciting redeveloped Inner Harbor. Begin with lunch at the Chart House Harborside Restaurant, then enjoy a tour of the USF Constellation and a view of the city from the observation deck of the World Trade Center. The remainder of the afternoon will be spent at the famous Baltimore National Aquarium. **$36 per person.**

Tour 2

Baltimore City Tour

Thursday, Dec. 3 9:00 am - 12:30 pm

This narrated tour will let you experience historic Baltimore from the comfort of your motorcoach. Drive by the famous homes of the Otterbein and Federal Hill with stops at the George Peabody Library, the Kirk-Steiff Silversmith's Factory Store, and Fort McHenry. **$18 per person.**

Tour 3

Washington, D.C. Post-Meeting Tour

Friday, Dec. 4 9:00 am - 5:00 pm

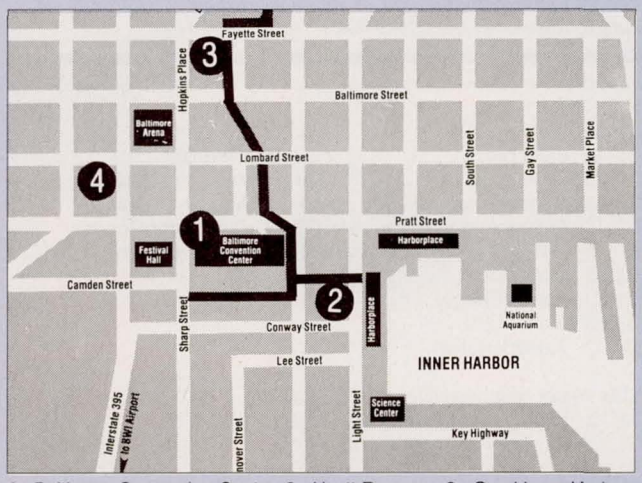
Just an hour drive by motorcoach to our nation's capital where you will spend a full day visiting government buildings, historic monuments, Arlington National Cemetery, and the Smithsonian Complex. **$25 per person.**

Tours will depart from and return to the Baltimore Convention Center. If a tour is sold out or does not meet minimum requirements, your money will be refunded. **Cancellations must be received by November 1, 1992.**

Special Hotel Rates

Book early! Hotel space is limited and requests will be filled on a first-come, first-served basis.When making reservations, you must identify yourself as a participant in the **Technology 2002** conference to receive the special rates.

	Single	Double
Hyatt Regency (headquarters hotel) (800) 233-1234	$103	$115
Holiday Inn (301) 685-3500	$63	$64
Omni Inner Harbor (800) 843-6664	$63	$63



1 - Baltimore Convention Center **2** - Hyatt Regency **3** - Omni Inner Harbor
4 - Holiday Inn (Bold rule line represents Overhead Pedestrian Skywalk)

Transportation To/From Baltimore

Baltimore is serviced by AMTRAK which is located at Pennsylvania Station, five minutes north of the downtown area. BWI Airport is approximately ten miles from the city center and is serviced by more than a dozen airlines. Ground transportation fares are as follows:

BWI Shuttle Express

Downtown hotels — $8.00 one way/$12.00 round trip
The shuttle runs every 1/2 hour from 6 am - 11 pm daily. Tickets can be purchased in the baggage claim area at BWI Airport.

Taxi

Downtown hotels — $12.00 - $16.00

Car Rental Discounts

Technology 2002 attendees are entitled to a special **AVIS RENT-A-CAR** discount. Please call (800) 331-1600 and refer to the **Technology 2002** Discount Number: B796477. Discount is valid Nov. 24 - Dec. 11 and includes unlimited mileage.

Questions? **Call Wendy Janiel at (212) 490-3999.**

TECHNOLOGY 2002

December 1-3, 1992
Baltimore, MD Convention Center

REGISTRATION FORM

Your Badge Will Be Printed From This Information:

NAME _____

TITLE _____

COMPANY _____

ADDRESS _____

CITY/ST/ZIP _____

PHONE _____

Please use a separate form or photocopy for each registrant. Be sure to answer all questions below.

Which of the following best describes your industry or service? (check one)

A) ❑ Aerospace
B) ❑ Electronics
C) ❑ Computers
D) ❑ Communications
E) ❑ Automotive
F) ❑ Chemicals
G) ❑ Materials
H) ❑ Power/Energy
I) ❑ Biomedical
J) ❑ Transportation
K) ❑ Government
L) ❑ Defense
M) ❑ Industrial Equip.
N) ❑ Appliance Manuf.
O) ❑ Consumer Goods
P) ❑ Research Lab
Q) ❑ University
R) ❑ Consultant
S) ❑ Library
T) ❑ Other _____

Your major responsibility is: (check one)

A) ❑ Management other than engineering
B) ❑ Engineering management
C) ❑ Engineering
D) ❑ Research
E) ❑ Other (specify)_____

Your principal job function is: (check one)

A) ❑ General & corporate management
B) ❑ Design & development engineering
C) ❑ Engineering services - Tests/Quality
D) ❑ Basic Research
E) ❑ Manufacturing & Production
F) ❑ Purchasing & Procurement
G) ❑ Other (specify)_____

Which of these products do you recommend, specify, or authorize the purchase of? (check all that apply)

A) ❑ Electronic components
B) ❑ Board-level electronics
C) ❑ Electronic systems
D) ❑ Software
E) ❑ Computers/Workstations/Peripherals
F) ❑ CAD/CAE/CAM/CASE
G) ❑ Mechanical components
H) ❑ Joining/fastening technology
I) ❑ Materials
J) ❑ Plastics & composites
K) ❑ Ferrous & nonferrous metals
L) ❑ Ceramics
M) ❑ Vacuum/cryogenics
N) ❑ Communications/fiber optics
O) ❑ Positioning equip/motion control
P) ❑ Industrial controls/systems
Q) ❑ Data acquisition/recorders
R) ❑ Video/imaging technology
S) ❑ Sensors/transducers
T) ❑ Test/measurement instruments
U) ❑ Lasers/optics
V) ❑ Laboratory equipment
W) ❑ Engineering dept. equipment

FOR FASTEST REGISTRATION
Fax to (212) 986-7864 or call (800) 944-NASA

OR MAIL THIS FORM TO:
Technology Utilization Foundation
41 East 42nd Street, Suite 921, New York, NY 10017

QUESTIONS?
Call (800) 944-NASA or (212) 490-3999

Enter Total $

1. COMPLETE REGISTRATION $240 ..... ( )
Includes admission to **Technology 2002** and National Technology Initiative symposia, workshops, and exhibits for all three show days (Dec. 1-3); a ticket to the Opening Reception on Monday evening, Nov. 30 and to the Technology Transfer Awards Dinner on Wednesday evening, Dec. 2; and a set of the official **Technology 2002** proceedings.

2. THREE-DAY SYMPOSIA/EXHIBITS $150 ..... ( )
Covers admission to the Tech 2002/NTI symposia, workshops, and exhibits Dec. 1-3.

3. ONE-DAY SYMPOSIA/EXHIBITS $75 ..... ( )
Check day(s): ❑ Tues. (includes NTI) ❑ Wed. ❑ Thurs.

4. AWARDS DINNER ONLY $95 ..... ( )

5. EXHIBITS HALL ONLY ..... **FREE**
Check day(s): ❑ Tues. ❑ Wed. ❑ Thurs.

6. SPOUSE/POST-SHOW TOURS ..... ( )
❑ Tour 1 - Baltimore Sights & Seaport $36
❑ Tour 2 - Baltimore City $18
❑ Tour 3 - Washington, D.C. $25

7. ENTER TOTAL PAYMENT DUE ..... ( )
Checks must be made out to the Technology Utilization Foundation. If you are charging your registration to a credit card, complete the following section.

Check one: ❑ Master Card ❑ Visa ❑ AmEx

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CARD NUMBER EXP. DATE

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SIGNATURE DATE

Registrations and Awards Dinner reservations are transferable and may be cancelled until November 20, 1992 subject to a $50 cancellation fee. After that date no cancellations will be refunded.

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PREREGISTER BY NOVEMBER 20
AND $AVE

Take A Moment Now To Complete This Form And Reserve Your Place At Technology 2002, America's Premier Technology Showcase.

Tool Would Grip Round Electrical Connectors

One connector could be installed and removed without disturbing closely spaced neighbors.

John F. Kennedy Space Center, Florida

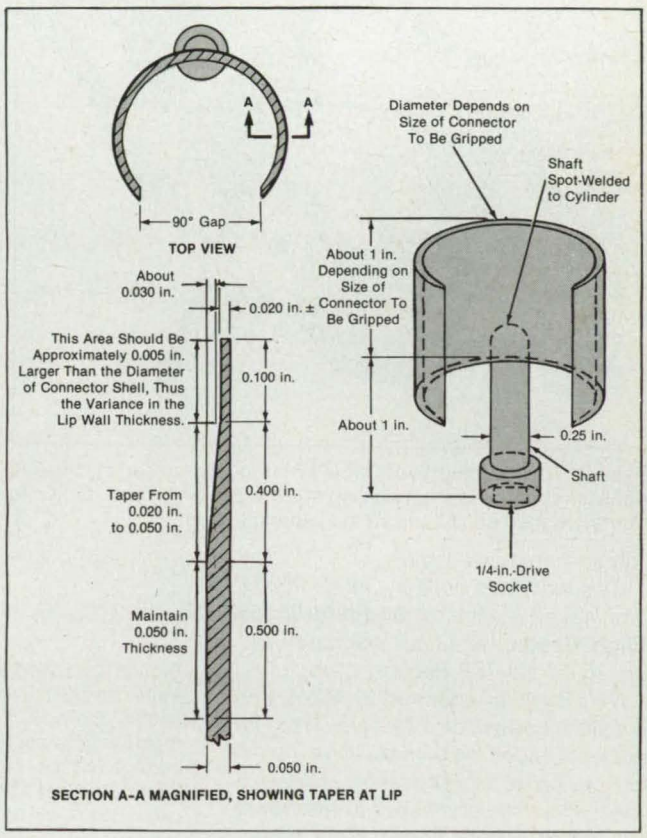
A proposed modified version of a commercially available tool would make it easier to mate and demate round, bayonet-mount, multipin electrical connectors in densely populated connector panels. With the tool, it would be unnecessary to remove adjacent connectors to gain access to the connector of interest. The result would be a saving of time and effort.

The tool would include a cylindrical shell that would partly encircle the connector (see figure). A shaft with a ¼-in. (6.35-mm) drive socket would be spot-welded to the shell. The inner surface of the shell would be smooth and would include a tapered lip. The inner surface of the lip would grip a knurled outer ring on the connector.

A torque wrench could be inserted in the drive socket. The use of the torque wrench would ensure that the allowable torque is not exceeded. In addition, the tool is designed to slip, without damaging the connector, if the applied torque becomes excessive.

A set of tools like this one could be built. Each tool would match a standard connector size.

This work was done by Terrence L. Camarata of McDonnell Douglas Space Systems Co. for **Kennedy Space Center.** *For further information, Circle 31 on the TSP Request Card. KSC-11406*



The **Tool for Installation and Removal of Round Connectors** would be made of stainless steel. The length and diameter of the cylinder would depend on the size of the connector shell to be gripped.

Joystick With Cable Springs Offers Better Feel

Nonlinear compliance accommodates better the natural reactions of the hand and brain.

Goddard Space Flight Center, Greenbelt, Maryland

An improved control joystick allows motion in 6 degrees of freedom and is biased toward the central position and orientation by 16 segments of cable that serve as springs. In comparison with typical prior joysticks, this one is more comfortable for the operator; consequently, it increases the operator's ability to exert control and reduces the operator's fatigue.

The knob and handle of the joystick are mounted on an upper U-bracket. A lower U-bracket is mounted on a stationary support. The upper and lower U-brackets are joined by the 16 segments of cable clamped variously to the upper and lower U-brackets and to intermediary suspended angle brackets; in effect, the assembly is a cable-sprung universal joint (see Figure 1).

The improvement in feel and control results in large part from the nonlinear compliance of the cable-spring assembly. Whereas prior joysticks have exhibited nearly linear variations of restoring spring forces with displacements, this joystick exhibits nonlinear variations, which accommodate better the natural reactions of the hand and brain. Therefore, the operator can function better as part of a feedback control loop.

The compliance (including the linear and nonlinear components of its responses in the various degrees of freedom) can be adjusted by choice of the lengths of the segments of cable; the diameter, material, and number of strands; the degree (if any of pre-twist of the strands) and the angles and distances between segments.

Figure 2 illustrates an example of position and angle sensors that could be added to the joystick assembly for control of a six-degree-of-freedom robot or other system. In this case, the sensors are linear variable-displacement transformers [also called linear variable-differential transformers (LVDT's)]. One end of each LVDT is mounted in a ball-and-socket or other rotary joint on a plate affixed to the upper U-bracket; the other end is mounted similarly on a plate affixed to the lower U-bracket. The mounting positions and orientations of the LVDT's are chosen so that the changes in their lengths yield information on the commanded changes in the six degrees of freedom. By use of the applicable vectorial weighting equations, a computer converts the LVDT outputs into

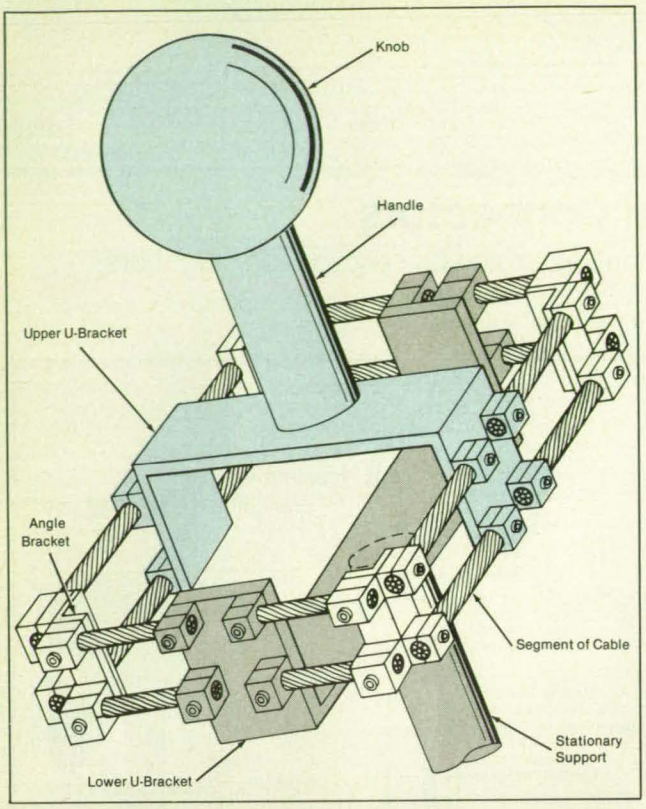


Figure 1. The **Segments of Cable** in this joystick assembly provide nonlinearly varying restoring spring forces, which feel better to operators than do linearly varying spring forces.

the six command signals.

This work was done by James Kerley and Wayne Ecklund of **Goddard Space Flight Center**. *For further information, Circle 35 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 deveiopment should be addressed to the Patent Counsel, Goddard Space Flight Center [see page 24]. Refer to GSC-13187.

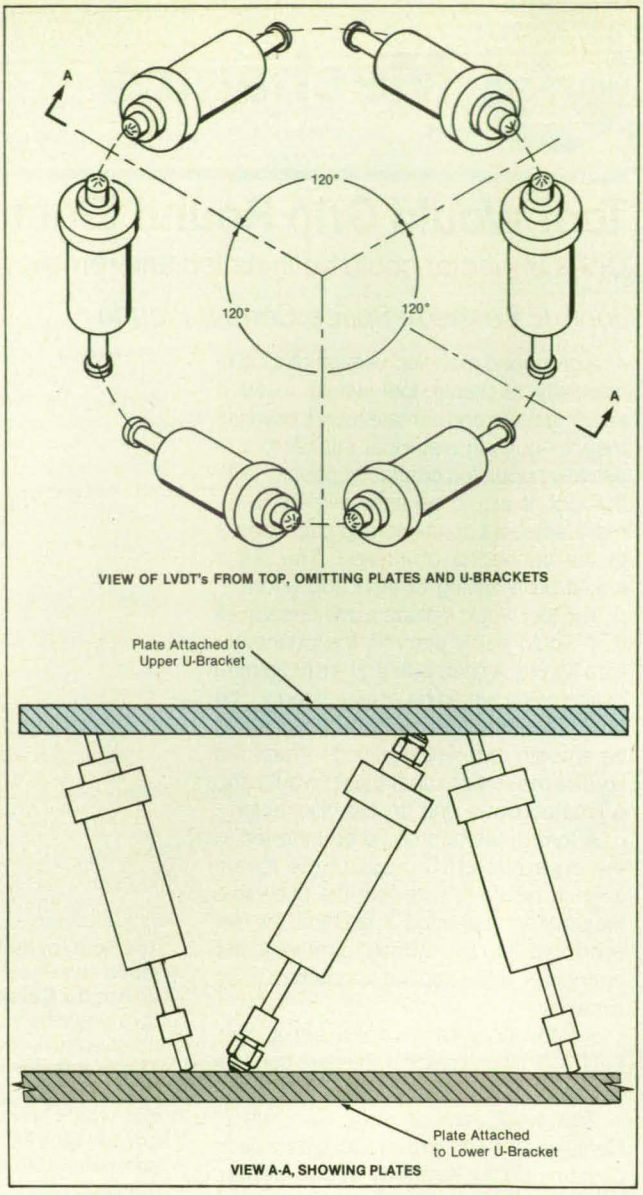


Figure 2. **LVDT's** measure their own extensions and retractions, providing information on the relative position and orientation of the joystick.

Systematic Disturbance of Optimal Rotational Trajectory

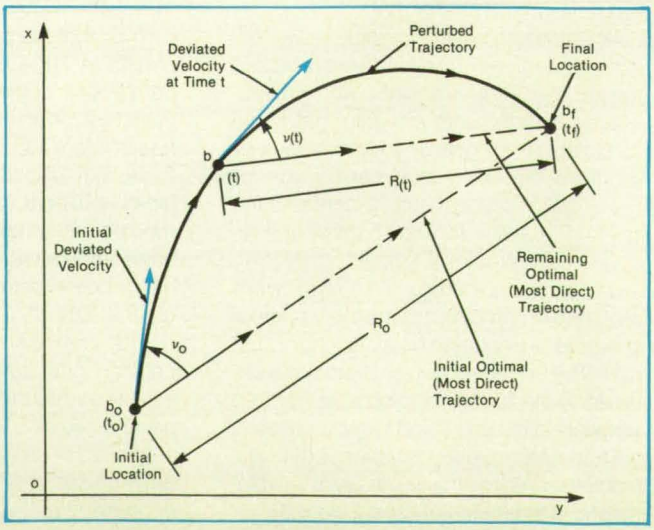
The rotating body would be made to wobble in a prescribed manner.

Ames Research Center, Moffett Field, California

An algorithm introduces a systematic disturbance into an otherwise optimal rotation of a body from a prescribed initial to a prescribed final orientation. An optimal rotation for this purpose is defined as a rotation (usually at constant angular velocity) through an angle α about a single fixed axis specified by Euler's theorem and known as the Euler axis. The perturbed rotational trajectory and the algorithm were devised for use in conjunction with a motion-control program and a three-dimensional computer-graphical display to study the ability of observers to distinguish between optimal and suboptimal rotational trajectories.

The perturbed or suboptimal rotational trajectory is the rotational analog of the

This **Perturbed Translational Trajectory** is a simplified, two-dimensional analog of the perturbed three-dimensional rotational trajectory. In the rotational case, the axis of rotation at time *t* deviates by angle *v(t)* from the optimal (for time *t*) axis of rotation.



perturbed two-dimensional translational trajectory illustrated in the figure. The optimal translational trajectory would be defined as constant speed along the straight line from initial point b_o at time t_o to final point b_f at time t_f. The perturbed or suboptimal translational trajectory is specified in this case by making the velocity vector at time t deviate by angle $\nu(t)$ from the straight line between the deviated (nonoptimal) position at time t and the prescribed final position. The deviation is specified by

$$\tan \nu(t) = [R(t)/R_o(t)]^e \tan \nu_o$$

where R_o = the distance from b_o to b_f along a straight line, $R(t)$ = the distance from the point on the actual trajectory to b_f along a straight line, ν_o = the prescribed initial deviation at t_o, and e is a prescribed exponent that, along with ν_o, determines the shape of the trajectory.

The optimal rotational trajectory through angle α from initial orientation u to final orientation v is given by the quaternion

$$\mathbf{q}_{u \rightarrow v} = \begin{bmatrix} \cos(\alpha/2) \\ e_x \sin(\alpha/2) \\ e_y \sin(\alpha/2) \\ e_z \sin(\alpha/2) \end{bmatrix}$$

where e_x, e_y, and e_z are the direction cosines of the Euler axis in an x, y, z Cartesian coordinate system. The disturbance is introduced in the form of a deviation of the actual axis of rotation from the optimal one, like the nutation (wobble) of a top. In analogy with the translational case, the instantaneous axis of rotation at time t is made to differ by angle $\nu(t)$ from the instantaneous Euler axis of rotation between the deviated (nonoptimal) orientation at time t and the prescribed final orientation. The deviation is specified by

$$\tan \nu(t) = [\alpha(t)/\alpha_o(t)]^e \tan \nu_o$$

where α_o = the angle of rotation about the initial Euler axis from the prescribed initial to the prescribed final orientation, $\alpha(t)$ = the angle of rotation about the Euler axis at time t from the orientation at time t to the prescribed final orientation, ν_o is the prescribed initial angular disturbance, and e is an exponent as before.

The algorithm effects the rotational transformations and solves the differential equations necessary to compute the disturbed trajectory. The motion-control computer program that incorporates this algorithm involves (1) precomputation of those vectors, matrices, and quaternions that remain constant for all trajectories and (2) real-time computations of rotational paths and deviations from the most direct paths. The program is incorporated into an experimental control program for psychophysical studies of human observers' sensitivities to perturbed and optimal trajectories.

This work was done by Arthur J. Grunwald and Mary K. Kaiser of **Ames Research Center**. *Further information may be found in NASA TM-101089 [N90-10575], "An Algorithm for the Systematic Disturbance of Optimal Rotational Solutions."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. *ARC-12700*

Self-Aligning Cranked Latch

This mechanism is useful where the latching process cannot be viewed.

Marshall Space Flight Center, Alabama

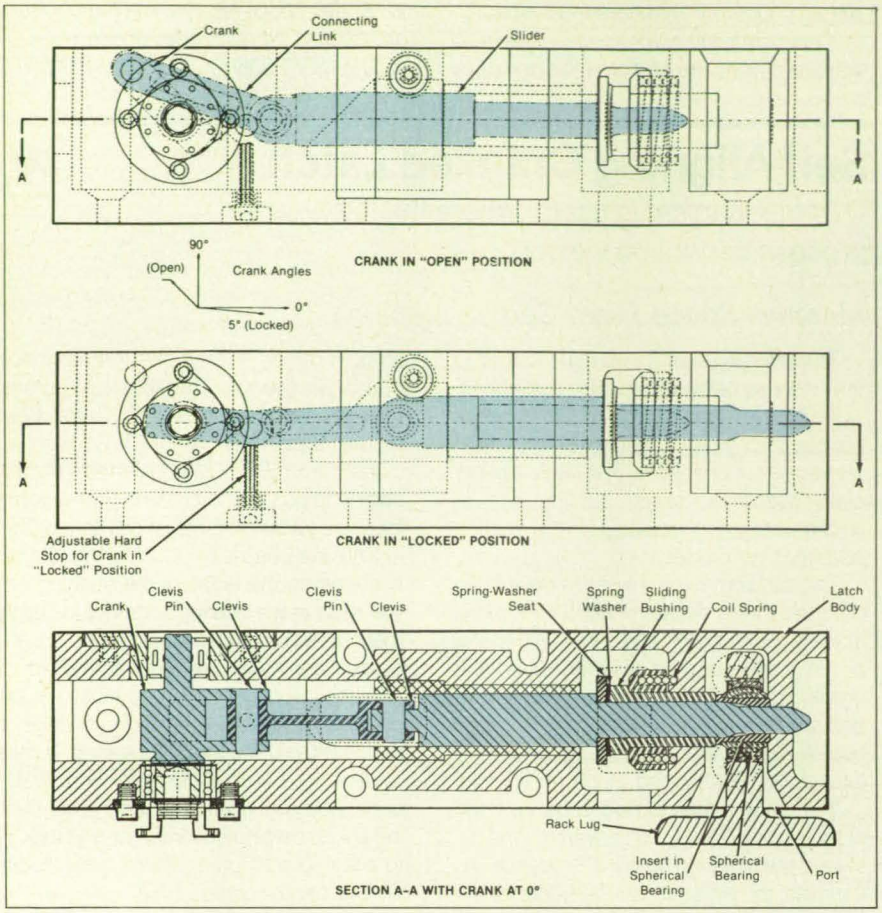
The latching mechanism illustrated in the figure is designed to be quick-acting, self-aligning, and rigid when set. There is no need to provide shims or to adjust otherwise for looseness. The latch is especially useful in "blind" applications, in which users cannot observe the mating and latching process.

The latching mechanism is a driven-pin, rigidized-clevis device in which the pin is actuated by a crank and slider. When the pin is fully retracted (that is, when the crank is at the 135°, or open, position), a port near the end of the latch body is placed over a lug on the structure to which the latch is to be attached (such as a rack).

The crank is then turned, either by hand or by a motor. This action advances the pin toward the top-dead-center (0°) position. As it moves, the pin continuously hunts for the latched position as it follows the tapered, smooth ramps in an insert in a spherical bearing in the lug. The spherical bearing provides a gimbal angle of 5° so that it can readily capture the pin.

As the crank is turned further, the pin begins to push on a bushing that is lightly loaded against the pin by a coil spring. During the final phases of cranking, the ramped surfaces on the faces of the bushing and the insert in the bearing augment the alignment of the pin and simultaneously provide support against shear loads. As the pin approaches top dead center, it forces the bushing tightly against a mating surface on the insert in the spherical bearing. As the pin reaches top dead center, a spring washer deflects slightly and allows the connecting link to continue overcenter and lock into a stable position against a hard stop at an overcenter angle of 5°.

The spring washer is designed to pro-



vide as much locking force as possible without requiring excessive torque on the crank. As it locks, the pin retracts about 0.005 inch (0.13 millimeter) from its most extended position.

This work was done by John W. Redmon, Jr., W. Neill Myers, and Jeffrey Finchenor of **Marshall Space Flight Center** *and Ronald Markovitch and Norris E. Vaughn, Jr., of Sverdrup Technology, Inc. For further information, Circle 54 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 24]. Refer to MFS-28591.

When **The Latch Is Open**, the slider-and-crank linkage is folded, and the pin is retracted into the latch body (top). When the latch is locked, the linkage is extended slightly beyond the top-dead-center position, and the pin engages the insert in the spherical bearing in the lug (middle).

Modular Heat Exchanger With Integral Heat Pipe

The number of critical brazed joints is reduced.

Lewis Research Center, Cleveland, Ohio

A modular heat exchanger with an integral heat pipe has been shown to be effective in transporting heat from a source to a Stirling engine. The modular units are intended to be an alternative to more-complicated heat exchangers that depend on the integrities of thousands of brazed joints. The proposed modular heat exchanger would contain only 40 brazed tubes, in contrast with a competing design that calls for 7,000 such tubes.

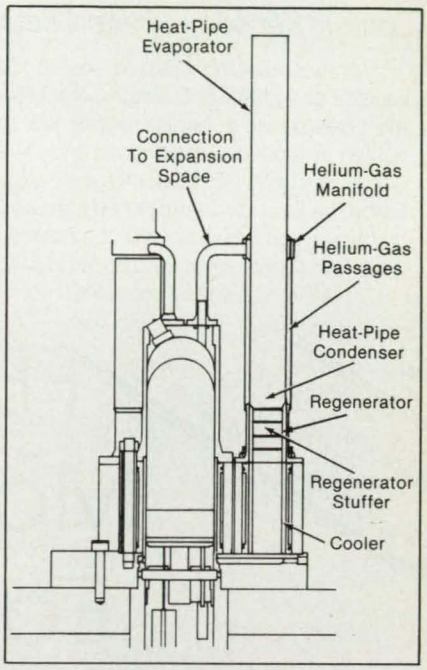
A simplified version of the modular heat exchanger was demonstrated in a small Stirling engine. The test heat exchanger contained only 3 heat-exchanger modules instead of the 40 that would be used in the full-scale Stirling engine, but the operating thermal load per module was similar to that of the full-scale engine design. Each module transported heat at the rate of 1,759 W from a source temperature of 702 °C to a sink temperature of 623 °C.

In each module (see figure), heat from the source vaporizes liquid sodium in the evaporator. In the test engine, the heat comes from electrical resistance; in the intended application, the heat would come from a nuclear reactor. The sodium vapor flows to the condenser, where it gives up its heat to helium gas, turning into liquid as it does. The helium is the working fluid of the Stirling engine. The liquid sodium is recycled to the evaporator through a sintered-metal-powder wick.

This work was done by Jeffrey G. Schreiber of **Lewis Research Center**. *Further information may be found in NASA TM-102097 [N89-25078], "Initial Characterization of a Modular Heat Exchanger With an Integral Heat Pipe."*

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

LEW-15008



Three Heat-Exchange Modules like this one supply heat to a test engine operating on the Stirling cycle.

Power-Tool Adapter for T-handle Screws

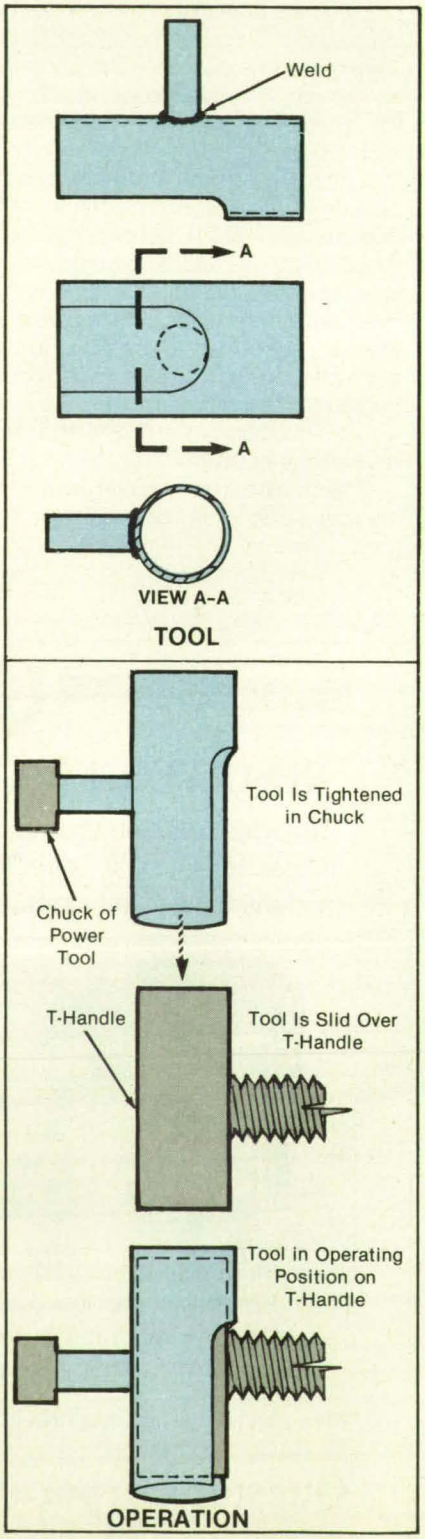
T-handle screws can be turned faster by a motor.

John F. Kennedy Space Center, Florida

A proposed adapter would enable the use of a pneumatic drill, electric drill, electric screwdriver, or similar power tool to tighten or loosen T-handled screws. The operation would thus be done much faster than if the T-handles were turned manually.

The adapter would consist of a notched tube with a perpendicular rod welded to it (see figure). The user would insert the free end of the rod in the chuck of the power tool and slip the notched end of the tube over the screw handle. The user would then operate the tool to turn the handle to either tighten or loosen the screw.

This work was done by Stephen R. Deloach of Lockheed Space Operations Co. for **Kennedy Space Center**. *For further information, Circle 7 on the TSP Request Card.*
KSC-11514



The **Tubular Adapter** is inserted in the chuck of the power tool and over the T-handle.

Natural-Flow Wing

Upper and lower surfaces are contoured independently to take advantage of natural flow.

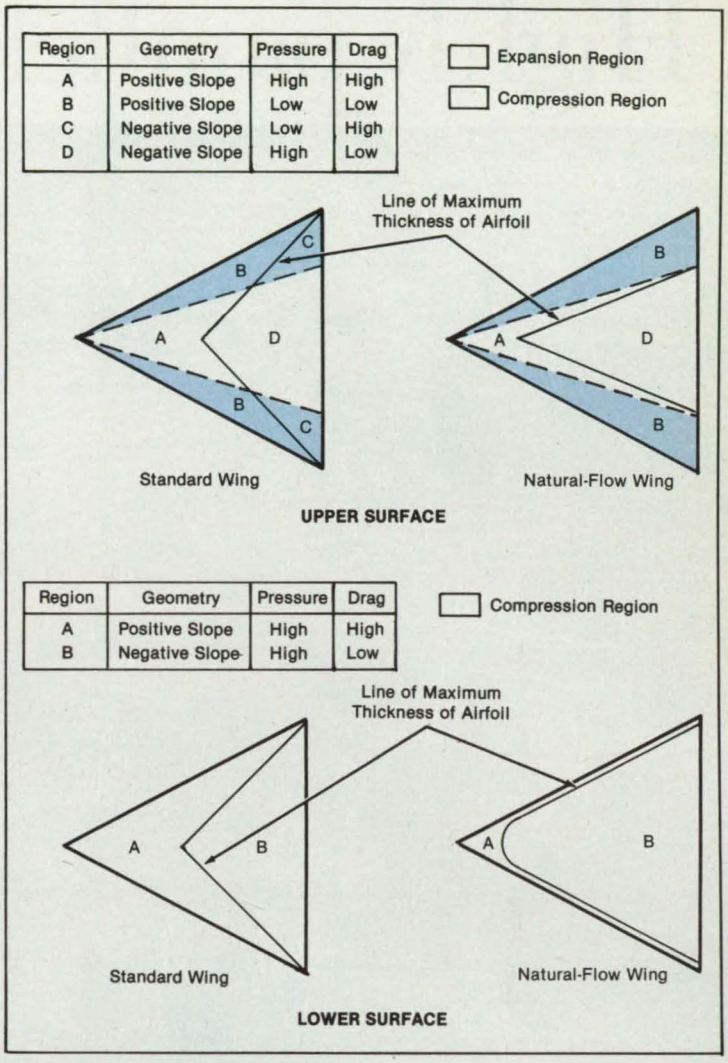
Langley Research Center, Hampton, Virginia

A vast number of wing design schemes have been conceived to provide improved aerodynamic efficiency for wings with moderate to high leading-edge sweeps. However, previous designs were either point designs, which provided improvements in aerodynamic performances over small ranges of flight conditions, or variable-camber designs, which produced limited improvements in aerodynamic efficiencies over fairly broad ranges of flight conditions but resulted in additional complexities, increases in weight, and losses in usable volumes.

To overcome the disadvantages of the foregoing wing-design concepts, a novel scheme has been developed to contour the three-dimensional upper and lower surfaces of a wing independently of one another to take maximum advantage of the naturally occurring flow and the resultant distribution of pressure over a broad mach number and lift range. The natural-flow wing-design concept increases the structural and volumetric efficiencies of swept leading-edge wings by eliminating the need for variable-camber devices for improved aerodynamic performance over broad ranges of flight conditions.

Experimental data and theoretical analysis show that the flow and pressure loading over the upper surface of a swept wing at subsonic, transonic, and supersonic speeds tends to be conical about the apex of the wing. In particular, the flow over the upper surface under lifting conditions is conical in nature and can be characterized by an expansion over the leading edge followed by a recompression to a more positive pressure as the flow moves inboard. However, typical wing shapes are conical about the tips of the wings. The intersection of the conical flow field and the geometry of a typical wing creates regions on the wing that are favorable and other regions on the wing that are unfavorable with respect to considerations of drag. The unfavorable regions, which contribute to drag, are the inboard forward and the outboard aft regions. The other regions of the upper surface have pressure fields that combine favorably with the local surface geometry to reduce drag.

The flow on the lower surface of the wing behaves quite differently at positive angles of attack. The flow over the lower surface is characterized by a nearly constant compressive loading. The pressure depends upon the angle of attack and on the streamwise curvature of the surface and is not very sensitive to the cross-section curvature of the wing. On the basis of these observations, the most beneficial geometry of the lower surface would include as large an aft-facing area as possible.



The **Natural-Flow design** concept maximizes the performances of both the upper and the lower surfaces of a wing.

The natural-flow wing (see figure) is any three-dimensional swept-leading-edge wing in which the wing upper surface is contoured in a nearly conical fashion to align the local surface slopes more favorably with the resultant nearly conical pressure distribution. The lower surface of the wing is contoured to maximize the aft-facing area to provide a more efficient surface for the nearly constant pressure distribution to act.

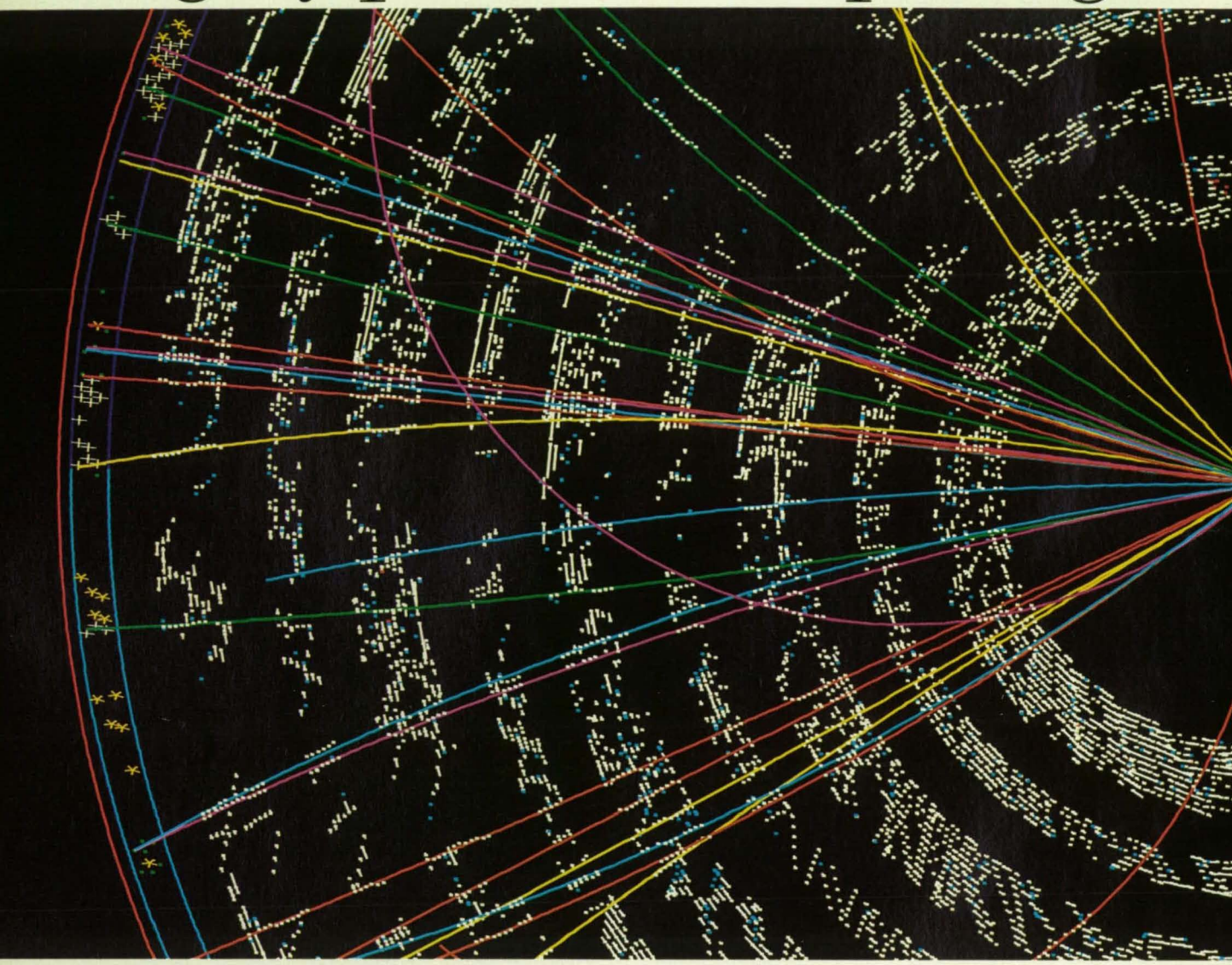
This approach to the design of a wing involves a scheme that contours the lower and upper surfaces at a given cross section to optimize the local cross-sectional slopes of the upper surface. To optimize the streamwise slopes of the upper and lower surfaces, each cross section is sheared vertically to create a reflexed lower surface. The natural-flow wing design approach creates a wing that is nearly flat with mild cumber and minimal twist. The resultant wing has increased forward-facing area on the upper surface forward of the location of maximum thickness of the airfoil, reduced aft-facing area on the upper surface aft of this location, and a reflexed lower surface (aft-facing area).

The natural-flow concept results in a wing design that is efficient over a wide range of lift conditions. Wings designed for efficient supersonic flight should now be able to provide improved performance at lower speeds without resorting to heavy, complex, and expensive variable-camber devices. In addition to its aerospace applications, this natural-flow concept could have far-reaching ramifications for both transportation and military systems.

This work was done by Richard M. Wood and Steven X. S. Bauer of **Langley Research Center**. *For further information, Circle 16 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 24]. Refer to LAR-14281.

Highly parallel computing.



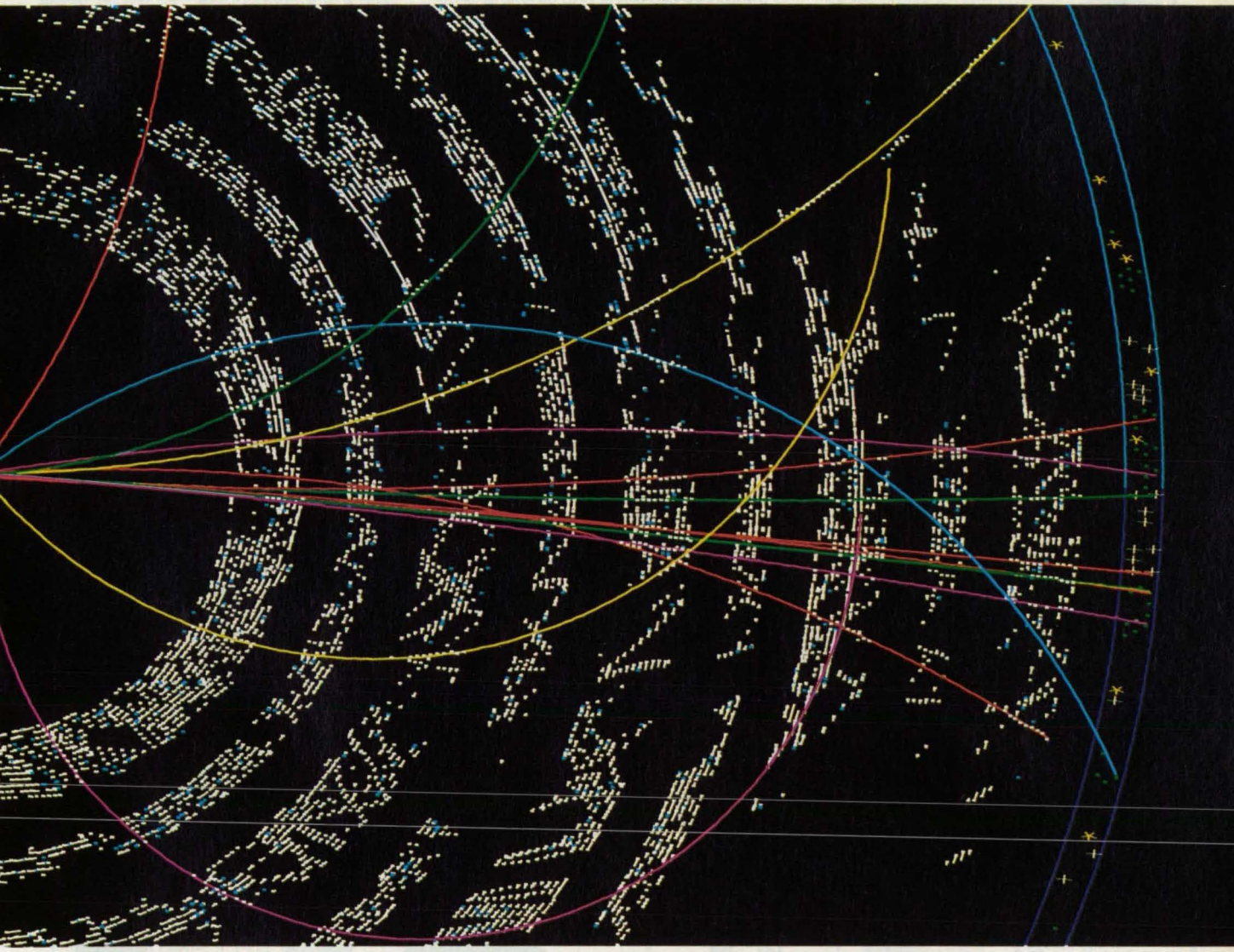
Fermilab is tapping a new

If there's one thing you can count on in science, it's that your data will increase exponentially but your funding won't.

The scientists at Fermi National Accelerator Laboratory (Fermilab) have encountered this problem in a very big way. The data Fermilab processes for subnuclear event reconstruction and modeling has reached 40 terabytes a year. And they've developed an innovative solution to meet their needs.

Instead of relying on supercomputers, Fermilab has distributed a significant part of the workload to clustered IBM RISC System/6000™ workstations. They've combined 108 of them, at latest count, in a LAN-connected

Computer reconstruction of proton/anti-proton collision at Fermilab.



source of power.

processor farm. This farm gives Fermilab a full 3,000 MIPS that can be dedicated to a single parallel processing application.

"The result," as Thomas Nash, Head of Computing at Fermilab puts it, "is better science." At a fraction of the cost of using supercomputers.

Many users are discovering the affordable, scalable power of clustered RISC System/6000 workstations.

The National Center for Supercomputing Applications in Champaign, Illinois, for example, runs superscalar applications on a cluster of seven RISC System/6000s. High performance and reliability are why they selected the RISC System/6000.

BP Exploration (Alaska), Inc. is achieving supercomputer throughput for their reservoir simulation applications by doing batch load balancing on a cluster of five RISC System/6000s. For their computers, software, systems integration and training in the use of batch clusters, they worked in alliance with IBM. We can help you, too – with consulting services, open systems integration and Business Partner software.

If you'd like to make some discoveries of your own about the power and economy of RISC System/6000 parallel processing, call IBM Technical Computing Systems at 1 800 472-4966.

IBM

Fixture for Testing Ball Bearings Under Radial Loads

Variable test loads could be applied smoothly.

Marshall Space Flight Center, Alabama

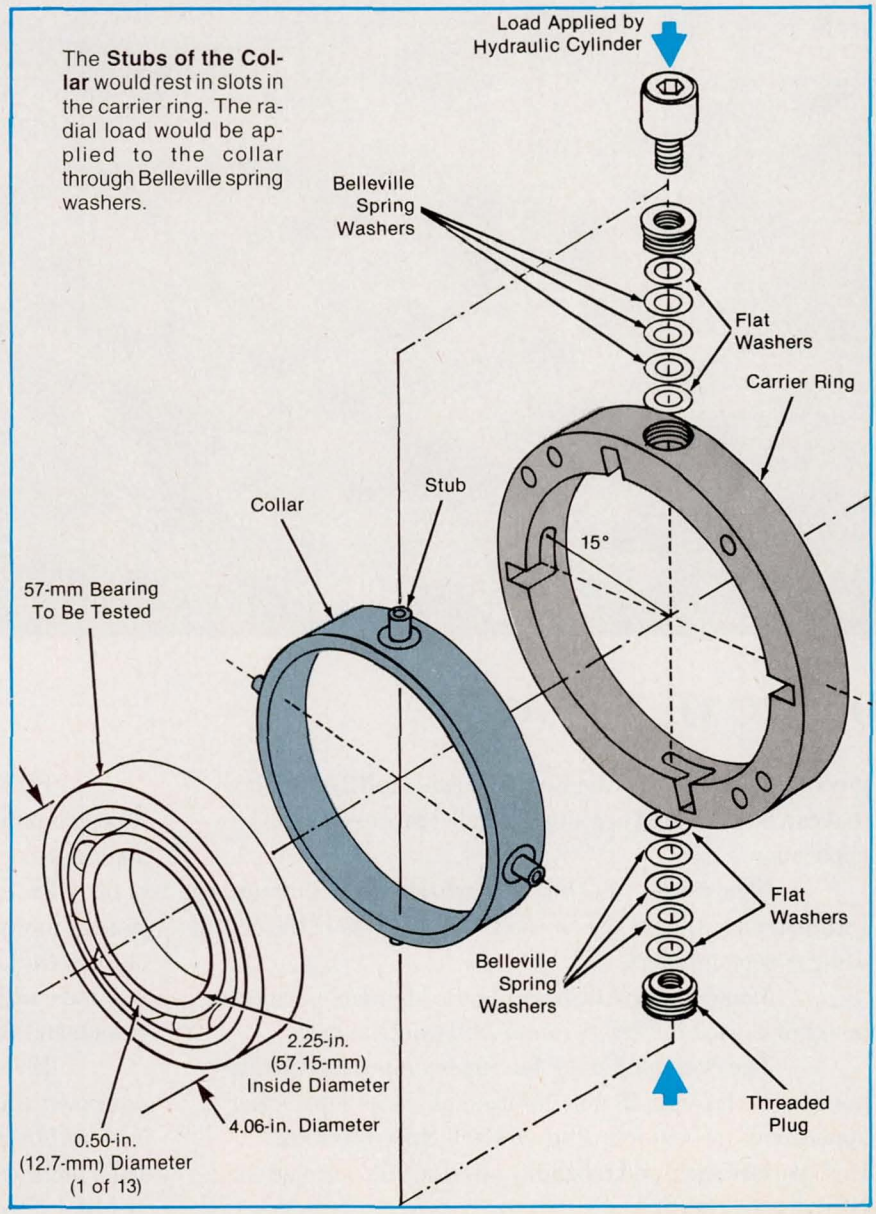
A proposed fixture for mounting large ball bearings during tests would facilitate the application of variable, known radial loads. The fixture would prevent gross movement of the bearing in either radial or axial directions.

The fixture was designed for quick-turnaround tests at cryogenic temperatures to investigate wear in the ball bearings of the high-pressure-oxidizer turbopump of the main engine of the Space Shuttle. The fixture would be used to establish an extensive collection of data on bearings intended for use at cryogenic temperatures. Similar fixtures could be designed to test bearings for other applications.

A variable-load hydraulic cylinder would apply the load through Belleville spring washers to a collar restrained by a carrier ring (see figure). The load would be applied smoothly because the collar and outer race of the bearing would flex in the carrier ring. The inner race of the bearing would be mounted on a shaft that would be rotated at the specified speed during application of the specified load.

This work was done by John Gibson of **Marshall Space Flight Center**. *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 24]. Refer to MFS-28589.



Water-Cooled Total-Temperature Probe

A high-temperature probe has been tested in a supersonic wind tunnel.

Langley Research Center, Hampton, Virginia

Interest in the properties of hot supersonic jet plumes has increased over the years, and this interest motivates the measurement of the mean flow properties of hot jets in current research. A knowledge of these mean flow properties aids the prediction of jet noise and may guide concepts for reduction of jet noise.

A research effort was initiated to determine whether a satisfactory design could be found to extend the present technology of measurement by uncooled probes into the high-temperature range by use of water-cooling techniques. Experiments were conducted in the NASA Langley Supersonic Jet Noise Facility. Water-cooled supersonic total-pressure, static-pressure, and total-temperature probes were developed to study high-temperature jet plumes. The probes were supported in the flow by a supersonic wing.

The experiments were conducted in three phases. The purpose of phase 1 was to develop and test the concept of water-cooled probes. In phase 2, the most efficient cooling design determined in phase 1 was used in the production and testing of the probes. Phase 3 was devoted to the observation and thermal analysis of the total-temperature probe.

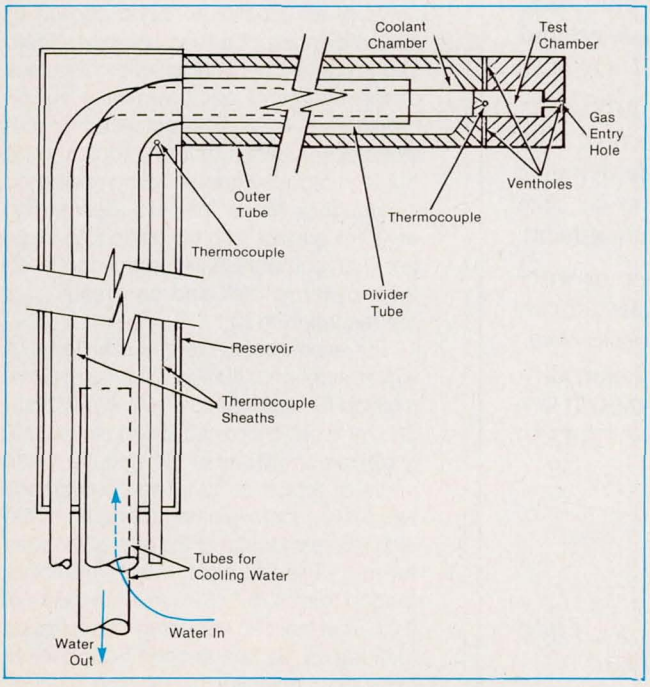
A water-cooled nozzle of 3.54-in. (8.99-cm) exit diameter was used in the tests. It was designed for exit mach 2 at a total temperature of 2,000 °F (1,093 °C). Water-cooled probes capable of operating under these conditions were tested. Data at the jet-exit planes and along the centerline of the jet were obtained for total temperatures of 900 °F (482 °C), 1,500 °F (816 °C), and 2,000 °F (1,093 °C). The total-temperature probe tested up to 2,000 °F incorporated an annular cooling system up to, but not beyond, the thermocouple lead inside the probe (see figure). The lead extended into the test chamber to sense the temperature of the supersonic external flow. A portion of the thermocouple sheath formed a liquid-tight seal between the test chamber and the coolant chamber of the probe. The rate of transfer of heat across the thermocouple bead was greater when the coolant was turned on than when the coolant was turned off. The data obtained initially from the total temperature probe has an average error of 11.2 percent, largely due to the presence of the water coolant. However, a heat transfer analysis was performed to account for the effect of the cooling system on the probe's thermal response, resulting in an average calculated total temperature error of 1.9 percent.

The selected design of the total-temperature probe is both novel and significant. It should be applicable in the development of jet engines and in research on fast flows of hot gases.

This work was done by Nicholas T. Lagen of George Washington University and Garland D. Reece of **Langley Research Center**. *Further information may be found in NASA TM-102612 [N90-25645], "Evaluation of Water Cooled Supersonic Temperature and Pressure Probes for Application to 2000 °F Flows."*

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

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 24]. Refer to LAR-14435.



The **Annular Cooling Design** proved the better of the two designs tested.

Books and Reports

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

Absorption of Crushing Energy in Square Composite Tubes

Energy-absorbing capabilities of different materials scale divergently.

A report describes an investigation of the crash-energy-absorbing capabilities of square-cross-section tubes made of two different matrix/fiber composite materials. The focus of the investigation was upon the geometric scalability of the energy-absorbing characteristics.

Crash-energy-absorbing structures in helicopters consist primarily of landing gear and subfloor beam structures. Considerable data have been developed on the crushing responses of circular tubes. A subfloor beam structure typically consists of an assemblage of flat and curved beam elements.

Earlier research had indicated that the crushing responses of subfloor beams resembled those of their constituent elements. The curved sections crushed in modes similar to those reported of round tubes, and the flat sections of beams crushed in modes similar to those of square-cross-section tubes. These results suggested that a better understanding of the crushing responses of square-cross-section tubes would provide deeper insight into the crushing responses and designs of subfloor beam structures.

In these series of experiments, static crushing tests were conducted on graphite/epoxy and Kevlar®/epoxy tubes of square cross section to study the influence of the sizes and shapes of the specimens on the energy-absorption capabilities and scalability thereof. The static crushing tests were performed in a 540-kN capacity universal hydraulic testing machine. Load platens were set parallel to each other prior to initiation of the tests, and all tubes were compressed at the same rates. The loads and deflections of the crosshead were recorded by an automatic data-acquisition system. Tests were stopped when the tubes had been crushed 5.08 cm, one-half of their original length. Three replicate tests were typically performed on each material and width of the cross section.

Both the graphite/epoxy and Kevlar/epoxy tubes crushed in a progressive and stable manner. The ratio between the width of the cross section and the thickness of the wall of the tube was determined to affect the energy-absorption capability significantly. As this ratio decreases, the energy-absorption capability increases nonlinearly. The energy-absorption capability of Kevlar/epoxy tubes was found to be geometrically scalable, but the energy-absorption capability of graphite/epoxy was found not to be geometrically scalable. The results found in this study will be useful to anyone attempting to build energy-absorbing composite structures.

This work was done by Gary L. Farley of the U.S. Army Aerostructures Directorate at **Langley Research Center**. *Further information may be found in NASA TM-80987 (USA AVSCOM TM 87-B-3) [N80-73573], "Energy-Absorption Capability and Scalability of Square Cross Section Composite Tube Specimens."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.
LAR-14343

Schlieren Photographic Studies of Dynamic Stall

Dynamic stall occurs at lower angles of attack at higher speeds.

The report describes stroboscopic Schlieren photographic observations of flows of air around an airfoil oscillating sinusoidally about a fixed angle of attack. This is one in a continuing series of studies of the effects of compressibility on dynamic stall — studies motivated by previous observations that an airfoil can be made to produce greater lift by oscillating it through a range that includes angles of attack greater than the static stall angle but that compressibility significantly affects dynamic stall and can result in a net reduction in lift.

The experiments were conducted in a wind tunnel on a National Advisory Commission for Aeronautics (NACA) 0012 airfoil of 7.5 cm chord oscillating sinusoidally with an amplitude of 10° about a mean angle of attack of 10°. The photographs were taken looking along the span of the airfoil (perpendicular to the axis of the wind tunnel). Free-stream mach numbers ranged from 0.15 to 0.45 in increments of 0.05. The reduced frequency of oscillation (defined as half the angular frequency of oscillation multiplied by the time required to traverse a distance equal to the chord

at the free-stream speed) ranged from 0 to 0.15 in various increments. These mach numbers and reduced frequencies were chosen to encompass the conditions that occur on the retreating blades of helicopter rotors in forward flight.

The results of the experiments are presented as schlieren pictures at selected angles of attack as the airfoil undergoes a cycle of oscillation at a selected combination of mach number and reduced frequency. Some quantitative data extracted from the schlieren pictures are also presented. These results indicate the following:

- At all mach numbers and reduced frequencies used in the tests, a dynamic-stall vortex forms near the leading edge and is convected along the upper surface of the airfoil at approximately 0.3 times the free-stream speed. The origin of the vortex is not clear.
- At all mach numbers, as the reduced frequency is increased, the initiation of the dynamic-stall vortex is delayed until the oscillation brings the airfoil to a higher angle of attack.
- The effects of compressibility are significant at free-stream mach numbers greater than 0.3: as the mach number increases beyond 0.3, dynamic stall occurs at decreasing angles of attack.
- No shocks are seen near the leading edge of the airfoil at the mach numbers and reduced frequencies used in the tests.

This work was done by L. Carr of **Ames Research Center** *and M. Chandrasekhara of the Naval Postgraduate School. Further information may be found in AIAA paper 89A-25019, "Flow Visualization Studies of the Mach Number Effects on the Dynamic Stall of an Oscillating Airfoil."*

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

ARC-12471

Developing a Navier–Stokes Algorithm for Supercomputers

A computationally efficient scheme exploits parallel processing.

A report discusses the development of an algorithm for the solution of the Navier–Stokes equations of flow on parallel-processing supercomputers. Typically, the approach taken to solve a specific problem in fluid dynamics depends on the problem. Here, the development involves the combination of various prior techniques to form an algorithm that can compute flows in a variety of complicated three-dimensional configurations. The subject matter should be of interest to

researchers who are looking for ways to structure their problems for greater computational efficiency.

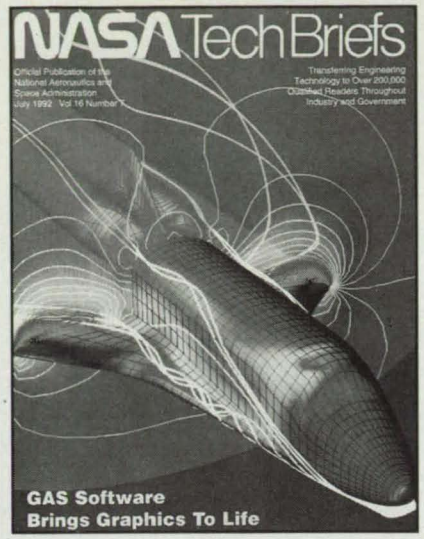
The research described in the report starts with testing of the feasibility of several approaches to computation and the suitability of combinations of these approaches. The algorithm that is developed includes an explicit finite-difference numerical-integration scheme applicable to flows represented by a hierarchy of mathematical models ranging from Euler (inviscid) to full Navier–Stokes (viscous). This finite-difference scheme is adapted to parallel processing and is robust, but without further modification it would converge on solutions slowly. Convergence is therefore accelerated by the incorporation of multigrid schemes in which computational domains consist of coarse global grids with local finer subgrids embedded in them in regions defined by the physics of the flows.

The characteristics of the flow in question are also used to determine which mathematical model is appropriate for solution in each region, thereby reducing not only the number of grid points at which a solution must be obtained, but also the amount of computation needed to obtain that solution. Acceleration of the computation to the steady state is achieved by applying multiple-grid schemes on each of the subgrids, regardless of the particular model equations being solved. Because each such set of equations is put in explicit, finite difference form, which is easy to parallelize, one can exploit the vector- and parallel-processing capabilities of advanced supercomputers.

A set of two-dimensional and three-dimensional model problems that involve internal flows of some complexity without requiring extensive expertise in the definition of geometry or the generation of grids is chosen for testing. Preliminary testing of each component of the algorithm is carried out in two dimensions, extended to three dimensions, and then integrated into the three-dimensional solution scheme. Computed flows are presented, but the main focus is on performance; that is, on the goal that the computed flows remain invariant while the simulation time is reduced by various techniques under test.

This work was done by Julie M. Swisshelm of **Ames Research Center**. *Further information may be found in NASA TM-102188 [N89-25959], "Development of a Navier–Stokes Algorithm for Parallel-Processing Supercomputers."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.
ARC-12637



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Direct-Interface, Fusible Heat Sink

Heat is transferred directiy from warm water to ice.

Ames Research Center, Moffett Field, California

A nonventing, regenerable, and self-contained heat sink (see Figure 1) absorbs heat in the melting of ice by direct contact with a forced flow of warm water. (The warm water is the coolant fluid.) Such a heat sink, which was designed specifically to cool an astronaut in a space suit, could be a component of a low-power portable refrigerator intended to operate for a short time in a picnic or camp setting, for example.

The heat sink consists of an elastic bladder, cast from a two-part polyurethane elastomer, that contains water and ice and that is penetrated by two identical sets of female and male connectors (see Figure 2). The bladder is filled with water until it is in slight tension. Upon freezing, the bladder is stretched a little more by the expansion of the ice. When water in the cooling loop is initially pumped into the bladder, the flexible wall is separated from the ice, stretching the bladder even more. As the ice melts, the bladder relaxes, and when the pump stops (at the end of the cooling cycle), the bladder is again under slight tension. The heat sink can be disconnected from the cooling loop at this point, its water refrozen, and the process repeated.

The connectors are specially designed to prevent leaks, to be invulnerable to freezing of the water, and to be easily and quickly connectable and disconnectable. The two female portions of the connectors are embedded in the elastic wall of the heat sink, and water in them is frozen along with that in the rest of the heat sink. After the water in the heat sink has been completely frozen, the male portions of the connectors are inserted into the female halves, and the flow of warm water is initiated.

At first, the warm water flows through the inlet male connector and into the empty cavity of the inlet female connector. Because the path is blocked by ice, the water returns through an annular passage in the inlet male connector and travels through a bypass tube to the outlet male connector. Upon leaving the outlet male connector, the water returns to the object to be cooled. The warm water quickly melts the ice in and around the female connectors. Once the ice around the female connectors has melted, the external bypass line is fully closed, so that some or all of the flow passes between the ice and the elastic bladder from inlet to outlet.

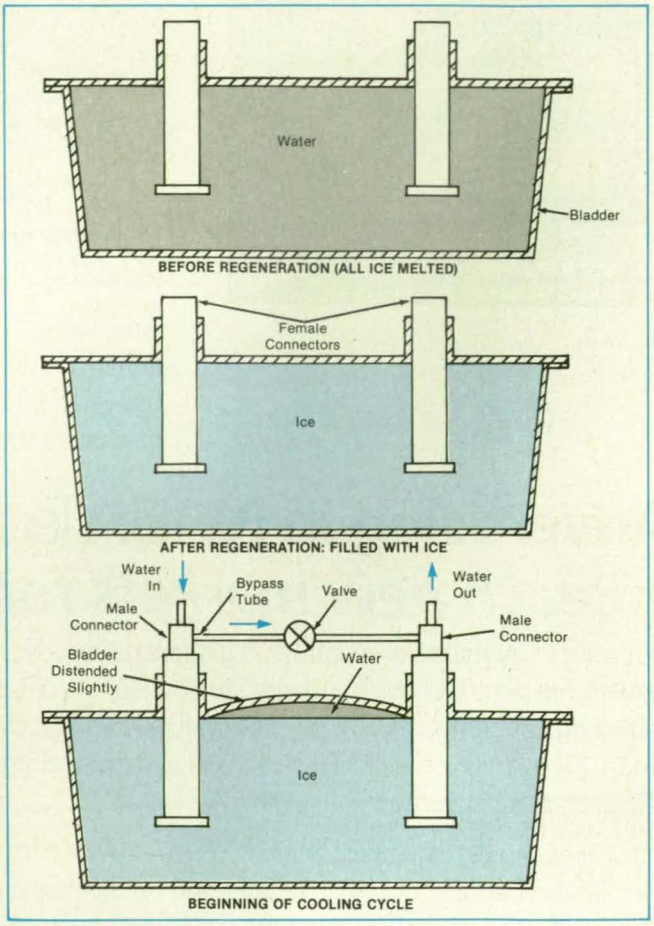
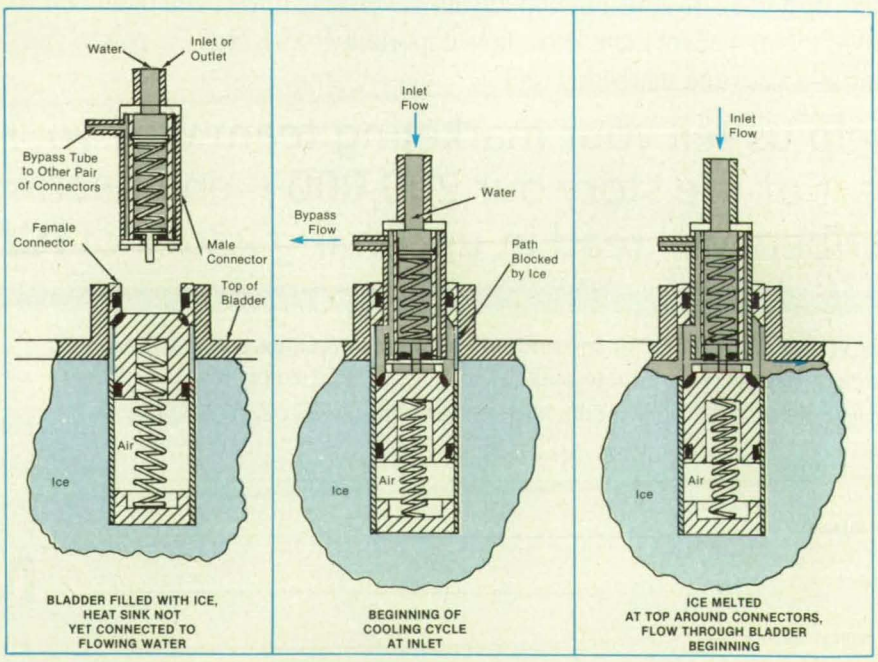


Figure 1. The **Regenerable Heat Sink** is shown at three stages of operation.

Figure 2. The **Connectors and Flows** are shown in more detail at three stages of operation, beginning with the second stage shown in Figure 1.



The rate of transfer of heat to the melting ice is controlled by adjusting the proportions of flow in the bladder and a bypass tube. This adjustment is accomplished by use of a valve in the bypass tube. The female connector provides a jetting action

that increases turbulence in the flow in the bladder; this, in turn, increases mixing during the later stages of melting to maintain proper heat-transfer rates and fully utilize the ice.

A prototype of the heat-sink system was tested. Approximately 23 lb (10.4 kg) of water was used, and the total heat capacity was 3,841 Btu (1,125 Wh). In this system, a heat-transfer rate of at least 2,000 Btu/h (about 600 W) was maintained until (and for a short time after) all the ice had melted (approximately 1 h).

This work was done by Curtis Lomax and Bruce Webbon of **Ames Research Center**. *For further information, Circle 44 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Ames Research Center [see page 24]. Refer to ARC-11920.

Robot Control Based on Spatial-Operator Algebra

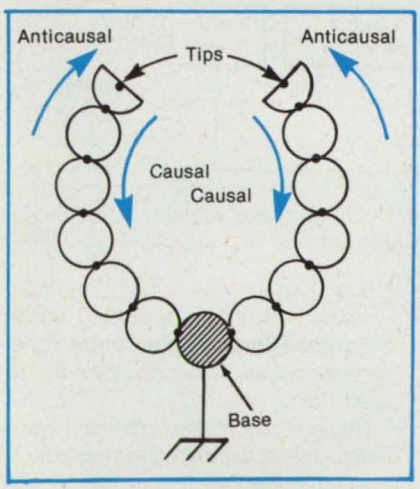
Complicated dynamical problems like that of two cooperating robot arms can be solved more easily.

NASA's Jet Propulsion Laboratory, Pasadena, California

A method for the mathematical modeling and control of robotic manipulators is based on the spatial-operator algebra that has been developed in recent years and described in several previous articles in *NASA Tech Briefs*. The spatial-operator algebra provides a concise representation and a simple, high-level theoretical framework for the solution of manipulator kinematical and dynamical problems that involve complicated temporal and spatial relationships; e.g., two multiple-link robot arms cooperating in the manipulation of an object.

To recapitulate from the previous articles: The elements of the spatial-operator algebra are linear operators, the domain and range spaces of which consist of forces, torques, velocities, and accelerations. The operators are called "spatial operators" because they show how the forces, torques, velocities, and accelerations propagate through space along a manipulator arm from one rigid link to the next (see figure). The operators are also implicitly equivalent to tip-to-base or base-to-tip recursions, which can easily be turned into algorithms by projection onto appropriate coordinate frames.

Recursive algorithms can be derived immediately from abstract spatial-operator expressions by inspection. Thus, the transition from an abstract formulation through an abstract solution to the detailed imple-



This **Graph Represents Two Multiple-Link Robot Arms:** the nodes represent links, while the edges represent joints. Spatial operators show how dynamics and kinematics propagate in the causal (tip-to-base) and anticausal (base-to-tip) directions.

mentation of specific algorithms to compute the solution is greatly simplified. Such economy of thought and representation has led to the development of a very simple program with which the user can interact to execute the maneuvers of cooperating robot arms with simple high-level commands like "lift," "squeeze," "grasp," "transfer," and "insert."

The control method has been implemented in an object-oriented software library in the Ada language that enables programming and execution of computations for the control and coordination of the two cooperating arms. Problems that can be addressed by the software include the generation of trajectories for transfers of objects, automated allocation of work to each arm during execution of a task, and hybrid force/position control to enable the arms to apply a prescribed internal force to an object while transferring it. The complexity of the computations is made completely transparent to the user because the spatial-operator algebra allows a very abstract description of the manipulation problem and of its corresponding solution.

This control method will enable the automated execution of a wide range of new manipulator tasks that cannot be performed easily with one robot arm. Examples of such tasks include handling and manipulation of cumbersome, oddly shaped and extended objects; the handoff of objects from one arm to the other; handling of flexible objects like long booms or large panels; assembly of structures or subassemblies from simple structural elements; and simultaneous manipulation of two or more objects in a workspace.

This work was done by Guillermo Rodriguez, Kenneth K. Kreutz, and Abhinandan Jain of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 17 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 24]. Refer to NPO-17918

Sorbent-Bed Crop-Drying System

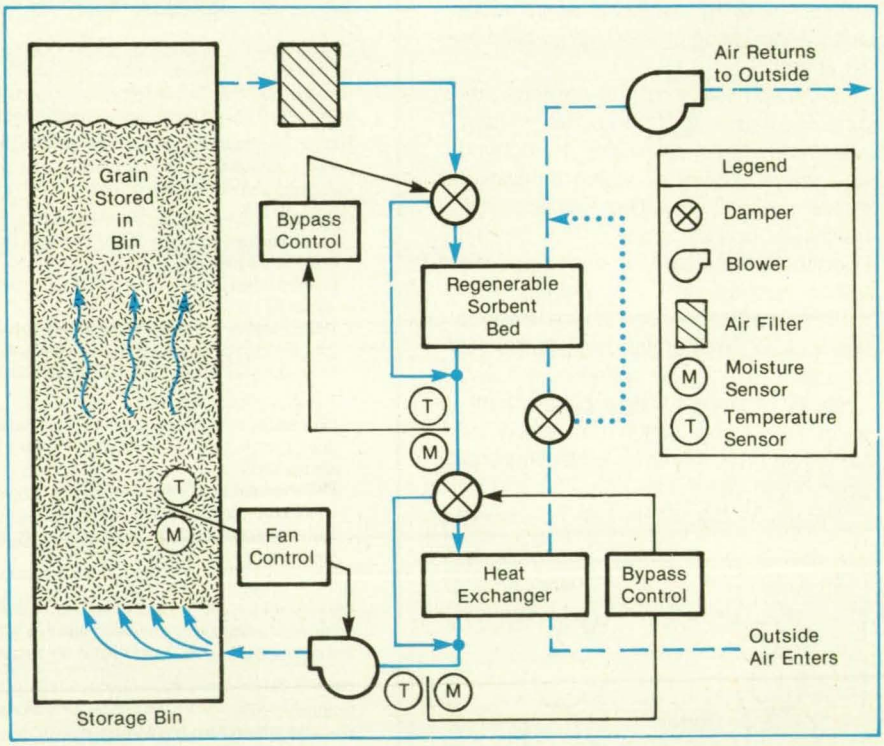
Some water and heat would be removed from recirculated air.

Marshall Space Flight Center, Alabama

A proposed aeration system would help to reduce spoilage of stored grain or other crop stored in bulk. The system would remove some of the moisture and some of the heat from air flowing into the storage vessel and would help to maintain a more nearly uniform temperature throughout the bin so that pockets of high moisture would not form or migrate. The system would maintain the temperature and relative humidity in the vessel near or below ideal settings of 50 °F (10 °C) and 60 percent, respectively, so that the growth of mold is suppressed and insects remain dormant or die. The system would be suitable for such storage vessels as grain bins and shipping barges.

The system (see figure) would include a heat exchanger and a regenerable sorbent bed of zeolite or other suitable material. A blower would force air into the bin at its bottom, out of the bin at its top, and through a filter, which would prevent grain dust from reaching and clogging the sorbent bed. The filtered air would flow through the sorbent, which would remove moisture from the air. A damper would send part of the airflow through a bypass as necessary to regulate the net moisture content of the overall sorbent-bed and bypass flows.

The dried air would then flow through and be cooled by the heat exchanger, which would transfer heat to the outside air. A bypass would be used here also, to regulate the net temperature of the combined bypass and heat-exchanger airflows. The heat exchanger would remove the heat that would be added in the sorbent bed and would keep the temperature of air in the bin close to that of the outside air. Finally, the dried, cooled air would reenter the bin through the blower.



Air Would Circulate through the bin, sorbent bed, and heat exchanger. Outside air would cool the circulating air in the heat exchanger.

The sorbent would be regenerated from time to time by pumping hot air through it. The hot air could come from the outside in hot weather, from a small electric heater, and/or from the heat exchanger.

The system would include a controller connected to sensors that would measure the temperature and humidity at three points: just downstream of the sorbent bed, just downstream of the heat exchanger, and in the bin. It would adjust the dampers in the bypass loops to obtain the requisite temperature and humidity in the bin.

This work was done by Barry C. Roberts of **Marshall Space Flight Center**. *For further information, Circle 79 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 24].Refer to MFS-28567.

Manual Override for Electromechanical Latch

A manual clutch and crank are used when a primary drive train fails.

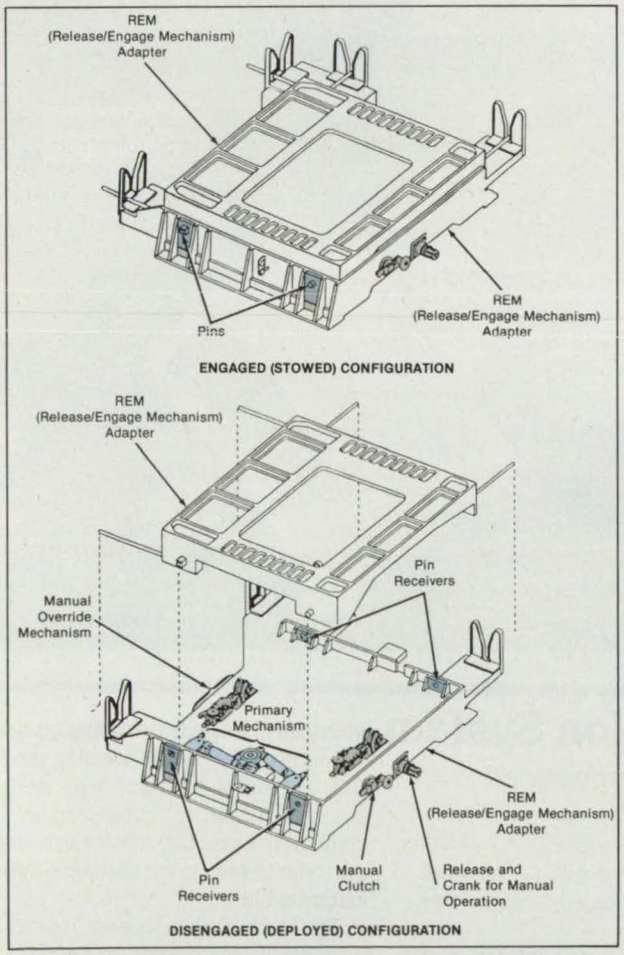
Goddard Space Flight Center, Greenbelt, Maryland

An override mechanism enables a user to operate an electromechanical latching mechanism manually if the primary mechanism should fail. The override feature can be used to latch and unlatch large, heavy objects from a fixed support structure.

The primary, electrically operated latching mechanism includes a worm gear in a drive train. The override feature is needed because if the primary mechanism fails, the object to be latched or unlatched could be stuck in an unsafe, partially latched or partially unlatched position because the worm gear cannot be backdriven.

The user operates a clutch on the manual backup system to disengage the primary system (see figure). The user then cranks a four-bar linkage that retracts or engages pins on the deployable component into pin receivers on the fixed support structure, a function that would ordinarily be done by the electrically driven mechanism. The deployable component is securely latched when the linkage is in an overcenter position.

This work was done by Richard Scott of **Goddard Space Flight Center**. *For further information, Circle 90 on the TSP Request Card. GSC-13383*



The **Manually Operated Release/Engage Mechanism (REM)** moves pin receivers to confine pins on an object to be held. A clutch disengages the electrically driven latch that is normally used.

Cheaper Custom Shielding Cups for Arc Welding

Cups are molded from hobby ceramic.

Marshall Space Flight Center, Alabama

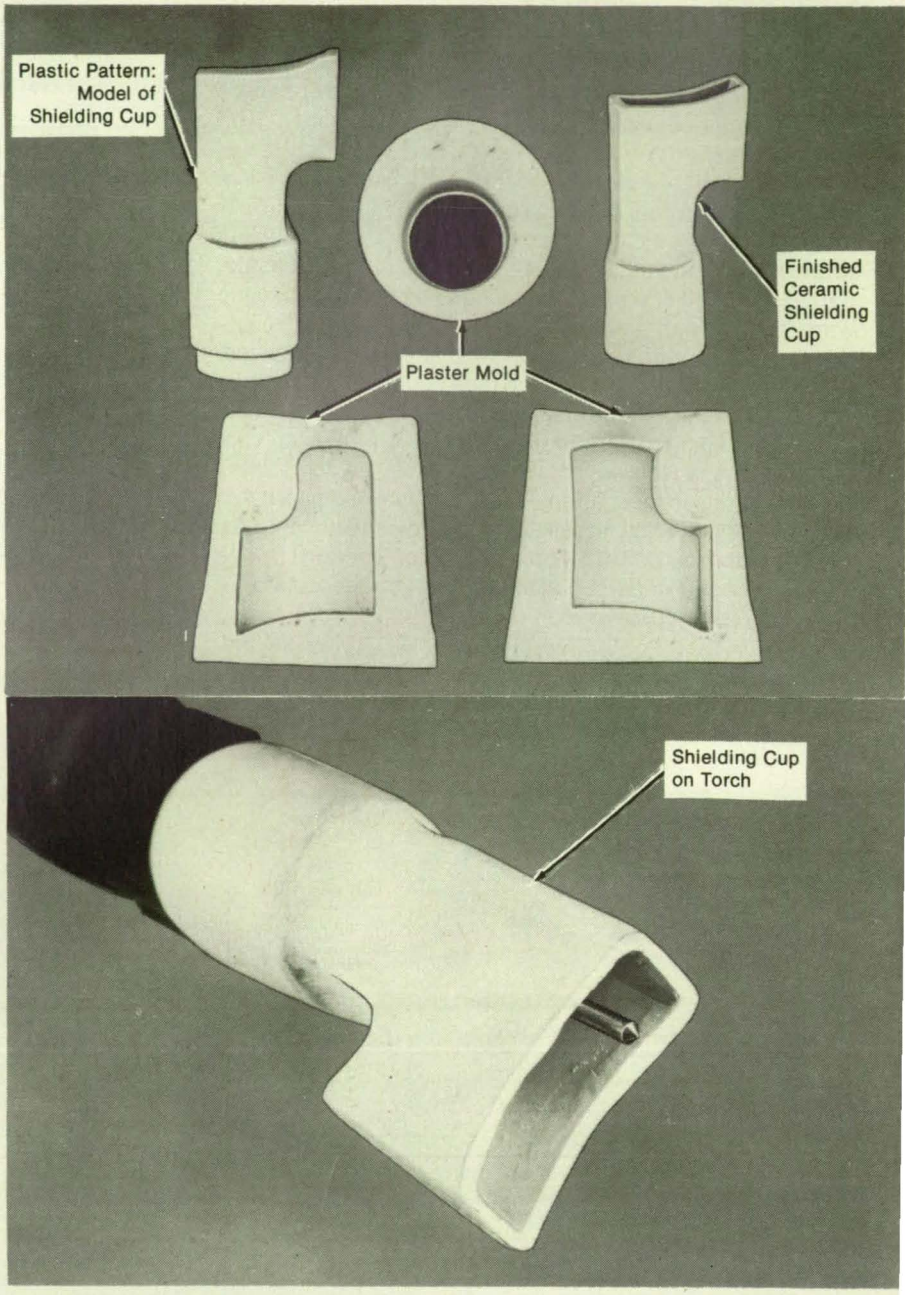
A new way of making special-purpose shielding cups for gas/tungsten arc welding greatly reduces the cost. Special-purpose cups have to be made when the geometry of a workpiece does not accommodate a standard cup. Previously, special cups were machined from lava rock — a costly procedure.

In the new method, a pattern of the cup is first machined in plastic. A plaster-of-paris mold is made of the pattern. Liquid ceramic is poured into the mold. After 10 minutes, the still-liquid ceramic in the middle of the mold is poured away, leaving a ceramic shell adhering to the inner wall of the mold. The solid shell is allowed to harden further in the mold for 2 to 4 h.

The halves of the mold are separated, and the ceramic casting is removed and trimmed to size. The casting thus formed is baked for 1 h at 1,950 °F (1,066 °C). After cooling, the cup is ready for installation on a welding torch (see figure).

The liquid ceramic can be purchased in hobby shops for ≤$4/gal (≤ $1/L) (1990 prices). The overall cost of a molded ceramic cup is about 90 percent less than that of a cup machined from lava rock.

This work was done by Gene E. Morgan of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*
MFS-29815



The **Molded Ceramic Cup** is made by a simple procedure, using inexpensive materials. The cup is shaped to fit a specific weld geometry.

Compact Through-the-Torch Vision System

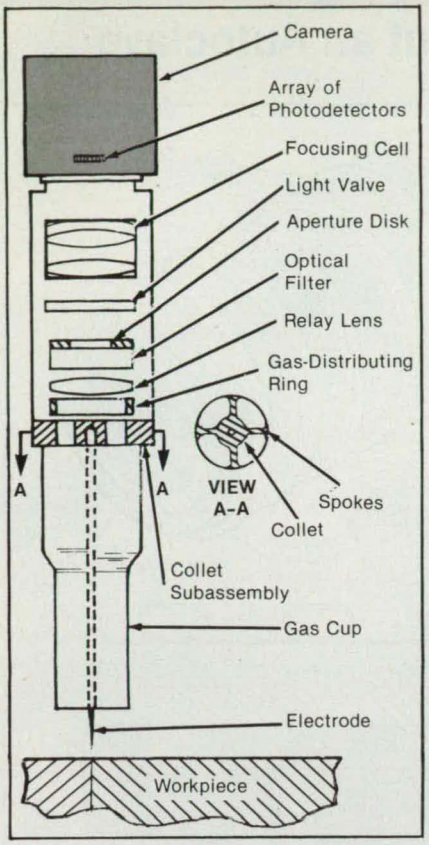
A welding torch and its optical system have been redesigned.

Marshall Space Flight Center, Alabama

Changes in the design of a gas/tungsten-arc welding torch equipped with a through-the-torch vision system make the torch assembly smaller and more resistant to the welding environment. In addition, the vision subsystem produces an image of higher quality, the flow of gas is enhanced, and parts can be replaced more quickly and easily.

The torch houses a coaxial series of lenses and other optical components (see figure). It provides an overhead view of the weld joint and weld puddle that is used for real-time control of the welding process. This version of the torch was designed around a miniature high-resolution video camera. The resulting smaller size enables the torch to weld joints that were formerly inaccessible.

The torch now includes a replaceable optical cell that contains lenses that focus the image onto the array of photodetectors in the camera. Two such cells are avail-



Stacked Optical Elements give the video camera a clear view of the weld area immediately surrounding the electrode tip. The use of a miniature camera and other compact components reduced the size of the torch and the vision system.

able, providing two different focusing ranges: The cell in the torch can be changed to obtain the proper focal length for use with a shorter or a longer gas cup. The outer surface of the body of the focusing cell is textured with axial serrations to facilitate adjustment, and the housing of the focusing cell includes three circumferential slots that provide access for the adjustment.

A lead lanthanum zirconate titanate electro-optical light valve regulates the amount of light that reaches the camera to prevent overexposure during pulsed welding. A pulsed high-voltage control signal is applied to the light valve through a miniature coaxial connector. A compliant mounting ring compresses the light valve against the high-voltage contact pads.

The number of spokes that support the collet that holds the welding electrode was reduced from six to four to reduce blockage of the image area. The spokes also carry current to the welding electrode.

The collet was made shorter and narrower to reduce blockage further. The design of the collet was modified so that the electrode can be released and replaced more easily: It is no longer necessary to remove the collet subassembly to replace the electrode. A special tool was designed to facilitate installation and removal of the electrode. The tool aligns itself and sets the distance through which the electrode protrudes from the gas cup.

A gas-diffusing ring with larger pores — 40 μm instead of 20 μm — gives wider coverage of the weld. An optical band-pass filter was custom-made to block most of the unwanted light from the arc plasma but lets enough light from the weld enter the vision system. A relay lens transmits light to the filter and keeps the welding gas out of the rest of the optics. An aperture disk sets the depth of field. Aperture disks of various sizes are interchangeable. They are blackened, and the surface facing the weld is angled to reduce reflections of stray light. The internal surfaces of the torch are also blackened.

The torch is joined to the camera by a special rotating C-mount adapter. The adapter makes it possible to align the camera squarely with the direction of the weld joint and thereby ensures that the image of the joint is oriented horizontally on the video screen of the welding monitor.

This work was done by Jeffrey L. Gilbert and David A. Gutow of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information, Circle 108 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 24].Refer to MFS-29811.

Curing a Large Composite Cylinder Without an Autoclave

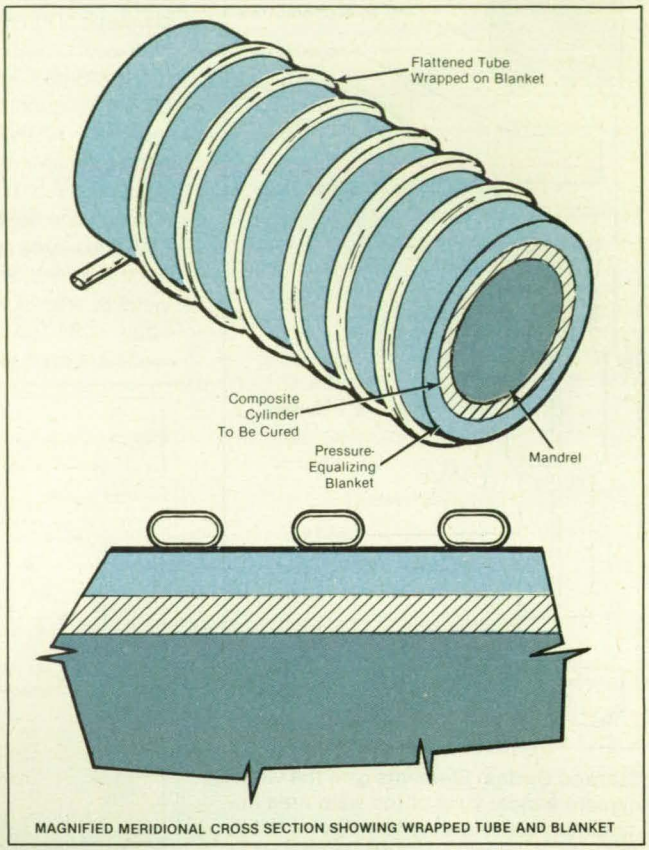
A wrapped tube would provide even pressure.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed technique would provide for the application of heat and pressure to cure a fiber-wound composite cylinder (e.g., a pressure vessel) too large to fit in an autoclave. The uncured cylinder, still on its winding mandrel, would be enclosed in a blanket, and a flattened tube would be helically wrapped on the blanket (see figure).

The interior of the tube would be pressurized, causing the tube to compress the blanket. In turn, the blanket would help to distribute the pressure more nearly uniformly over the surface of the cylinder. The pressure would expel gas bubbles from the composite material. Meanwhile, heat would be applied by conventional methods.

This work was done by Robert E. Frazer of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 84 on the TSP Request Card.*
NPO-18195



A **Tube Wound Around a Composite Cylinder** would apply pressure during curing. The blanket would help to distribute pressure from the tube over the cylinder.

Long-Wearing Wire Guide for Welding Torch

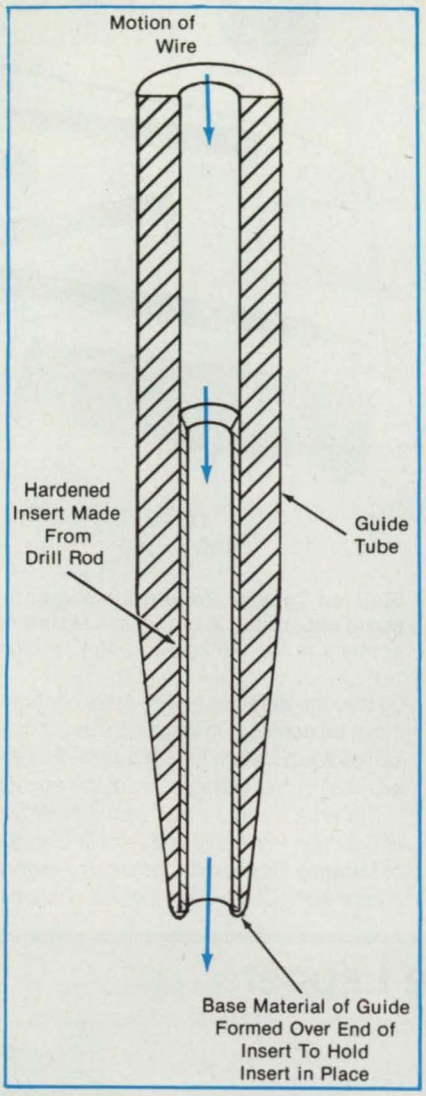
A hard insert protects the relatively soft metal guide tube.

Marshall Space Flight Center, Alabama

An insert for the wire-guide tube on a tungsten/inert-gas welding apparatus extends the life of the guide tube and increases the accuracy of the weld. Ordinarily, a wire guide, which is made of copper or brass tube, wears quickly as the filler wire is fed through it. As it wears, the circular orifice at the tip becomes elliptical or eggshaped. The filler wire then wanders in the orifice, and its position in the weld puddle is hard to control.

The insert, which is made from drill rod, then hardened, wears only negligibly, and the orifice remains circular. The inner (upper in the figure) end of the insert is chamfered to center the tip of the filler wire when the wire is first fed into the guide tube. The copper or brass base material of the tube is formed around the end of the insert to hold it securely.

This work was done by David A. Gutow, Richard K. Burley, Jeffrey L. Gilbert, and Irving Fogel of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available. MFS-29829*



The **Hardened Insert** resists wear by sliding tungsten wire. The chamfer guides the wire into the insert.

Preformed Superconductive Devices

Ceramic superconductors are subjected to high-temperature processing before mounting.

Langley Research Center, Hampton, Virginia

A process forms high-temperature superconductors into such practical electrical components as connectors, coils, and conductors (see figure). The components are based on $YBa_2Cu_3O_{7-x}$ ceramics, which have superconducting transition temperatures of about 95 K and can thus be cooled with liquid nitrogen instead of the more costly liquid helium.

Until now, it has been difficult to make working devices of superconductive ceramics because of the brittleness of these materials. However, brittleness is no obstacle to the improved process, in which the material is preformed into the requisite shape before it is heated to turn it into the ceramic. The process consists of these eight basic steps:

1. Powders of yttrium oxide, barium carbonate, and copper oxide are mixed with polymer binder and cast as a thick film to form a tape.
2. While the tape is still flexible, it is stamped, cut, or otherwise formed into strips of the desired sizes and shapes.
3. The parts thus formed are left flat or formed, as required, into cylinders, rings, or other shapes. Strips can be stacked in layers, if necessary.
4. The parts are sintered to turn them into rigid pieces of superconductive ceramic.
5. Electrodes are applied.
6. The parts are mounted on plates, rods, disks, or other rigid substrates for support and isolation from stress.
7. Lead wires are soldered to the electrodes.

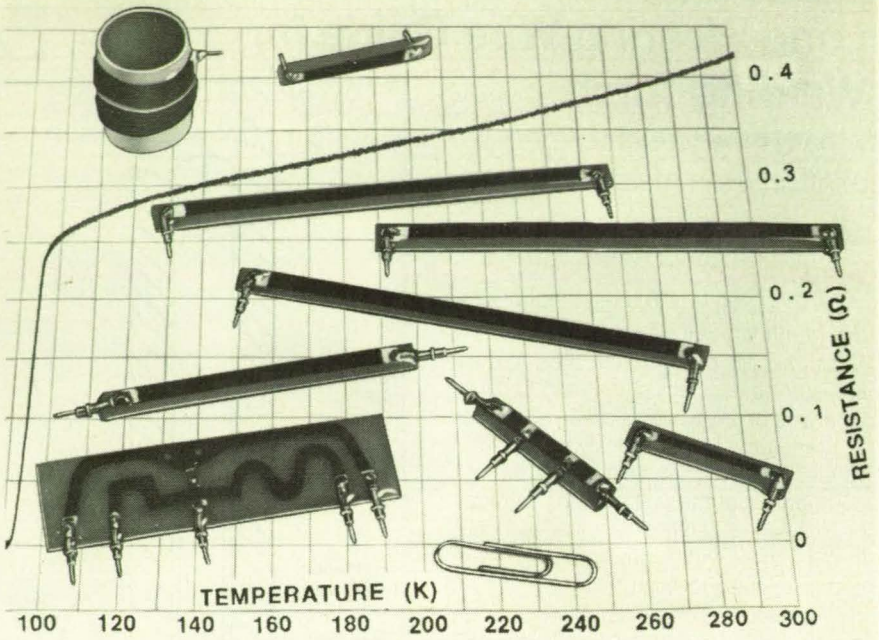
8. The part and substrate are encapsulated to protect the ceramic film from the environment.

Because sintering takes place before the ceramic is mounted on the substrate, the substrate material need not be resistant to high temperatures. In addition, the sintering conditions can be optimized for the ceramic material, without regard for the substrate. An abundance of oxygen can be provided during sintering to obtain maximum superconductivity. Sintering before mounting also eliminates the problem that would otherwise be posed by shrinkage. The substrate can be sized to match the final dimensions of the ceramic.

Substrates can be made of glass-fiber-reinforced circuit-board material, for example. This substrate material reduces the leakage of heat into the ceramic, unlike the silver or copper substrates used in making sintered-in-place superconducting ceramics.

Each ceramic superconductive part can be tested before it is assembled on the substrate. This prevents the waste of time and material in the encapsulation of faulty parts and increases reliability and reproducibility of the finished superconducting devices.

The process has been used to make a grounding link 6 in. (15.2 cm) long for an infrared detector. The ceramic superconductor reduces noise and increases the signal-to-noise ratio. It reduces the transfer of heat from the detector preamplifiers at 90 K to the detector at 4 K. Also, because it can be cooled with liquid nitrogen, it conserves liquid helium for the sensor, thereby increasing the operating life of the sensor.



Sintered Ceramic Preforms in a variety of shapes can be mounted on printed-circuit-board substrates. A plot of the resistance-versus-temperature behavior of the ceramic appears in the background; the resistance drops sharply to zero at about 95 K.

This work was done by Gene H. Haertling of Clemson University and John D. Buckley of **Langley Research Center**. *For further information, Circle 3 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Langley Research Center [see page 24]. Refer to LAR-14395.

Floating Ring-Groove Lapper

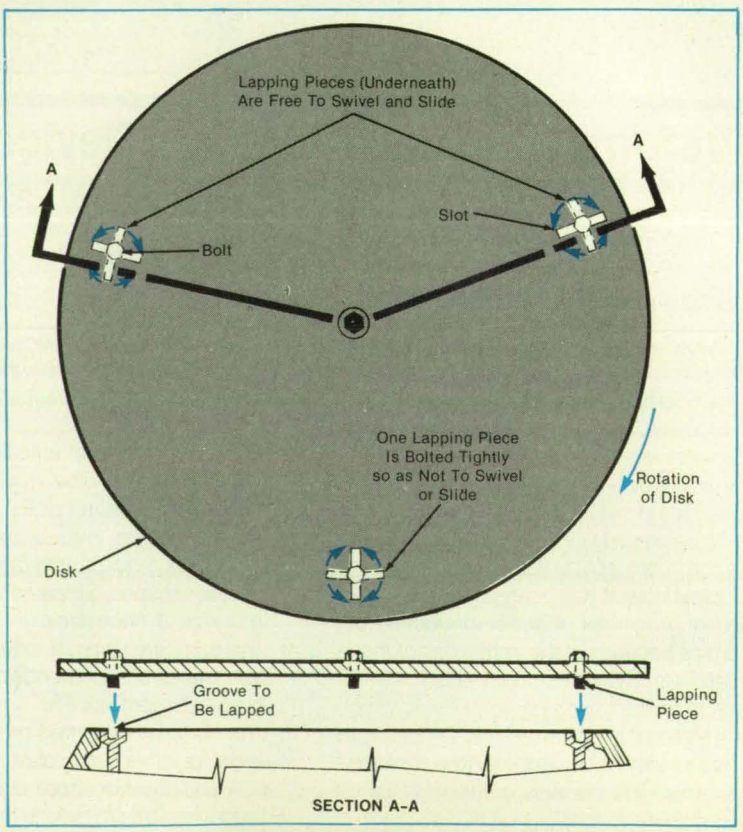
A tool refinishes a warped seal groove.

Marshall Space Flight Center, Alabama

A tool fits in an out-of-round seal groove and laps it to a fine finish without binding. The tool (see figure) is designed to fit the specific groove to be lapped. It includes floating lapping pieces that ride freely in the groove despite its out-of-roundness. The lapping pieces are curved to match the nominal diameter of the groove. They are held by bolts in radial slots in a disk.

The disk is placed over the groove so that the pieces rest in the groove. The disk is centered approximately, and one of the lapping pieces tightened in place in its slot so that it does not move relative to the disk. The two remaining lapping pieces are left free to swivel. The disk is then rotated to lap the groove.

This work was done by Robert L. Williams, Sr., Robert L. Williams, Jr., and Timothy L. Chase of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information, Circle 62 on the TSP Request Card. MFS-29749*



Lapping Pieces Fit in a warped groove. Allowing two pieces to slide and swivel in their slots prevents the lapping tool from binding.

Guide for Assembly of Electrical Connector

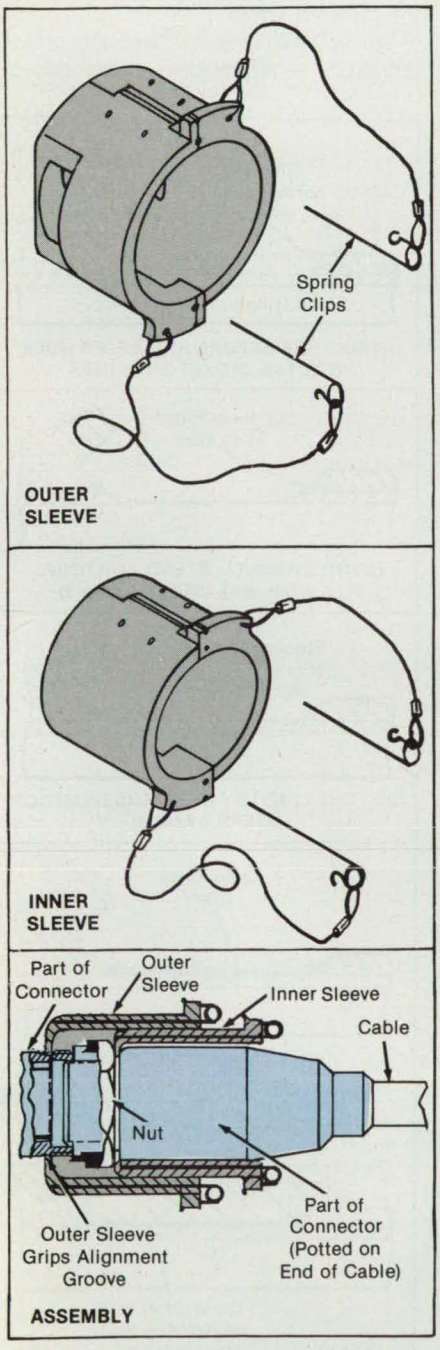
Mating cylinders align mating parts to prevent bending of connector pins.

Marshall Space Flight Center, Alabama

An assembly guide aligns the two mating parts of an electrical connector to prevent the bending of connector pins. The guide consists of two closely fitting cylindrical sleeves, one sleeve sliding within the other (see figure). Each sleeve is split longitudinally and can be separated into identical segments. A pair of spring clips on each sleeve holds the segments together.

The inner sleeve grips the part of the connector that is potted onto the end of a cable. The outer sleeve grips the other part of the connector via an alignment groove on the connector called the "indicator groove." When the two sleeves are engaged, the two parts of the connector are concentric. In this condition, the two parts of the connector halves are self-piloting. The part of the connector on the cable is rotated to engage a keying device on the other part of the connector.

The connector nut is then threaded about two turns into engagement to prevent the two parts of the connector from separating when the assembly guide is removed. Finally, the spring clips are ex-



Mating Sleeves are designed to align the centerlines of the two parts of a connector. The segments of the inner and outer sleeves are held together by spring clips. The inner sleeve grips the part of the connector that is attached to a cable. The outer sleeve grips an alignment groove of the other part of the connector.

tracted, and the cylindrical sleeves are removed from the aligned, mated parts of the connector.

This work was done by Elroy C. Williams of Thiokol Corp. for **Marshall Space Flight Center**. *For further information, Circle 28 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 24]. Refer to MFS-28582.

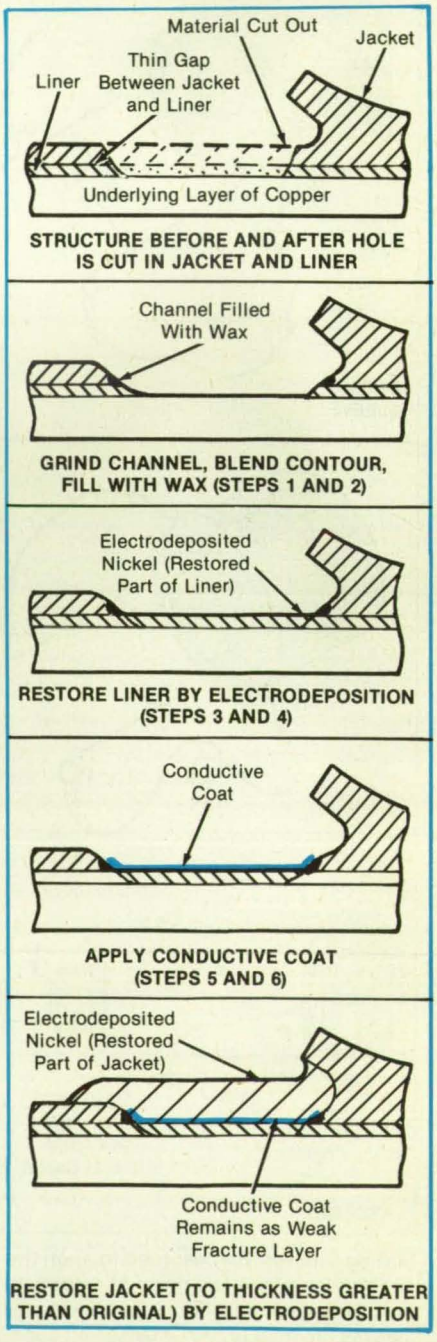
Electroforming Repair of Adjacent Unconnected Layers

A thin conductive coat between the layers acts as a weak fracture surface.

Marshall Space Flight Center, Alabama

A procedure has been devised to improve the repair of a hole through a nickel-alloy layer and a nickel layer that are parts of a larger structure and that are separated by a thin gap. The procedure is a sequence of steps that involve established techniques of electroforming and the associated established techniques of grinding, filling, and masking. The two major distinguishing features of the repair are a wax-filled separation channel around the edge of the hole and a conductive coat that serves as a weak fracture layer between the repaired layers.

The figure illustrates an example of the procedure — a simplified version based



The **Hole in the Liner and Jacket** is repaired in a sequence of grinding, masking, filling, and electroforming steps.

on the original application. In this case, the nickel-alloy layer is called the "jacket," and the other, purer-nickel layer is called the "liner" and is attached by electrodeposition to an underlying layer of copper. The hole to be repaired penetrates both nickel-containing layers down to the surface of the copper. The procedure can be summarized as follows (omitting some intermediate and incidental steps that involve grinding and inspection):

1. Grind the edges of the hole to (a) blend the surface contours of the jacket and liner smoothly with that of the copper, and (b) add a separation channel that straddles the gap and runs along the entire circumference.
2. Fill the channel with wax, and blend the wax to the surface contour.
3. Mask off the exposed liner and copper to prevent plating on them, then plate nickel on the jacket to a thickness of about 0.01 in. (0.25 mm).
4. Unmask the liner and copper, mask the jacket, and plate nickel on the exposed liner and copper up to approximately the thickness of the liner. In essence, this step restores the missing portion of the liner.
5. Unmask the jacket and remove the wax from the channel. Fill the channel with putty or silver/facsimile mixture, and blend this filling flush with the surface contour.
6. Wet-sand the nickel surfaces to prepare them for plating, then apply a layer of silver-filled conductive coating material 0.001 to 0.025 in. (0.025 to 0.64 mm) thick to the surfaces of the channel filling and of the restored portion of the liner that was deposited in step 4. This conductive coat will serve as the weak fracture layer and will occupy the gap between the liner and jacket in the repaired area.
7. Plate nickel on the conductive coat and on the adjacent area of the jacket to restore the jacket to the desired thickness.

This work was done by Daniel J. Burbach and James F. Herkenhoff of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information, Circle 30 on the TSP Request Card.*
MFS-29828

Ambient-Temperature Sputtering of Composite Oxide Films

A multiple-target, sequential-sputter-deposition technique is compatible with low-temperature microelectronic processing.

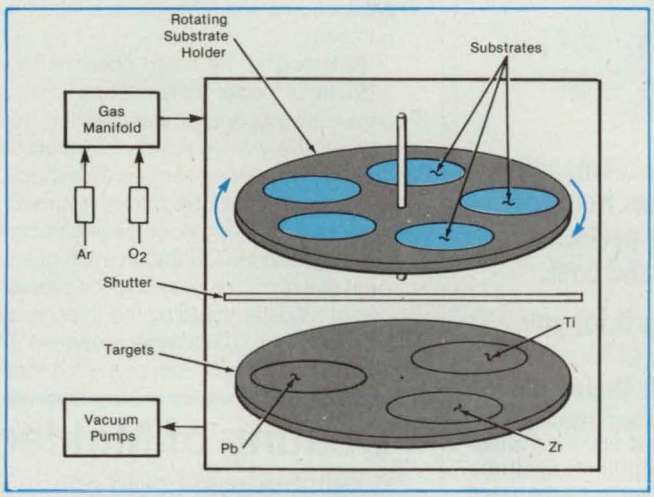
NASA's Jet Propulsion Laboratory, Pasadena, California

A technique for deposition of homogeneous films of multicomponent oxides, such as ferroelectric lead-zirconate-titanate (PZT), on substrates held at ambient temperature has been developed. This technique is based on sequential sputter deposition of the individual metal components, as alternating ultra-thin layers, from multiple targets in a suitable reactive ambient, followed by a moderate-temperature anneal to obtain the desired crystal structure as a single phase.

Deposition is carried out on substrates held on a rotating holder (see Figure 1), and the dc magnetron sputtering targets are powered to different levels, which allows accurate control of the individual constituent flux reaching the substrates, the most critical parameter in achieving stoichiometric deposits. This ensures an optimal solid-state reaction among the constituents during the subsequent annealing/sintering step, leading to the formation of a homogeneous, single-phase deposit.

In addition to the rate of simultaneous sputtering from each target optimized for a given geometry of the deposition chamber, the angular window for deposition of each constituent material is governed by the respective angular-deposition aperture and size of the target. The revolutions per minute (rpm) determine the time window for each constituent deposition. The near homogeneous mixing of the constituents during deposition, therefore, eliminates the need for substrate heating in vacuum.

Individual control of each metal is obtained down to even a fraction of a monolayer thickness in individual layers by selecting the sputtering powers and the substrate-rotation rate. In the case of PZT films, for example, a subsequent post-deposition anneal treatment of as low as 500 °C is sufficient to initiate the crystallization within the deposited multicomponent film, leading to the formation of ferroelectric/piezoelectric films.



Substrates Are Rotated over sputtering targets of lead, zirconium, and titanium. Dc-magnetron sputtering of the constituent metals in a reactive ambient of argon and oxygen leads to formation of the respective metal oxides intermixed on an extremely fine scale in the desired composition.

This separation of the deposition process (at ambient temperature) in vacuum from the sintering step for crystallization in an open-air furnace makes this technique readily compatible to low-temperature microelectronic-fabrication techniques, such as conventional patterning by photolithography using polymeric photoresists. This technique is ideally suited for deposition of a variety of other multicomponent materials, including oxides and nitrides.

In addition to the deposition parameters governing the rates, the angle of incidence of the sputter deposit is also a very critical parameter in determining the morphology and physical characteristics of the films. For example, when all angles of deposition are allowed, the resulting film can be quite rough, opaque, and of ceramic quality. By placing a collimator around each sputtering target to restrict the deposition to a substantially perpendicular incidence, smooth, transparent electro-optic quality films are obtained.

This work was done by Sarita Thakoor of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 91 on the TSP Request Card.*

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

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

Refer to NPO-18221, volume and number of this NASA Tech Briefs issue, and the page number.

Templates Aid Removal of Defects From Castings

Fewer ultrasonic thickness measurements are needed.

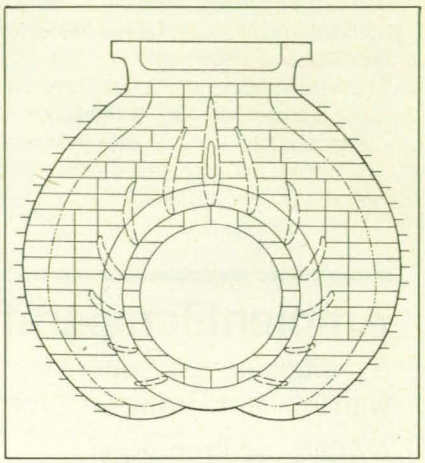
Marshall Space Flight Center, Alabama

Templates have been used to correlate defects in castings with local wall thicknesses. When the defects are ground away, the correlations are used to ensure that excessive material is not removed.

The templates serve as adjuncts to penetrant-dye inspection for surface defects. The templates consist of full-scale reproductions, on clear plastic sheets, of applicable drawings of the cast parts. Grids are superimposed on the drawings (see figure).

The applicable template is placed on a part to be inspected after the part has been coated with penetrant dye. Positions of colored spots (indicative of defects) are noted on the template grid and recorded on the corresponding positions on a reduced reproduction of the template in a laboratory notebook.

Referring to the noted coordinates on a similar template that contains holes, an ultrasonic inspector measures the thickness of the wall of the part at unacceptable defects only — an overall inspection is not necessary. The part is returned to the factory for removal of these defects by grinding. The wall at the location of each such defect can be ground to the allowable depth, as determined by the thickness at that point — no guesswork is needed. The length, width, and depth of each grindout are recorded on the reduced version of the template in the laboratory notebook.



A **Typical Template** is a full-scale reproduction, with gridlines, of a drawing of a casting: in this case, showing the volute side of a turbopump housing. The template is placed over the casting and oriented so that it matches corresponding features on the part.

This work was done by Robert G. Hendrickson of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information, Circle 61 on the TSP Request Card.*
MFS-29838

Coating of Molded Battery Substrates

A suitable coat could enhance properties of surfaces.

NASA's Jet Propulsion Laboratory, Pasadena, California

Suitable materials applied to molds as powders, dispersions, or solutions could not only enable release of the molded parts from the molds but also enhance the properties of the surfaces of these parts. Conceived during the consideration of the molding of a carbon-filled plastic substrate for a lead/acid electrochemical cell, the concept could also be applied to the casting of lead grids, to the casting of other substrates for electrodes of electrochemical cells, or to other molding operations in which powdered materials adhering to the molded parts would improve the properties of the surfaces.

In the case of the molding of a carbon-filled-plastic substrate for an electrode of a sealed lead/acid bipolar cell, there is a tendency toward poor adhesion of the active material to the substrate. In the proposed method, adhesion would be enhanced by incorporating the active material into a surface layer during molding; the mold would be coated with powders of one of the commonly used lead/acid paste materials — such as lead oxides, lead sulfates, and the like — as well as with carbon powder. Because the molding temperatures of a typical plastic are well below the melting temperature of any of these powders, the particles of the powders are expected to maintain their original form and to be partially buried in the surface of the resulting molded substrate. PbO particles would be converted in later processing to PbO_2 on the positive side or Pb on the negative side. The carbon particles would increase the surface loading, resulting in a better bonding interface.

This work was done by Terrance M. Larkin of The Gates Rubber Co. for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 20 on the TSP Request Card.*
NPO-18236

Shrink-Fit Solderable Inserts Seal Hermetically

Connectors can be inserted or holes plugged by soldering in a normally unsolderable housing.

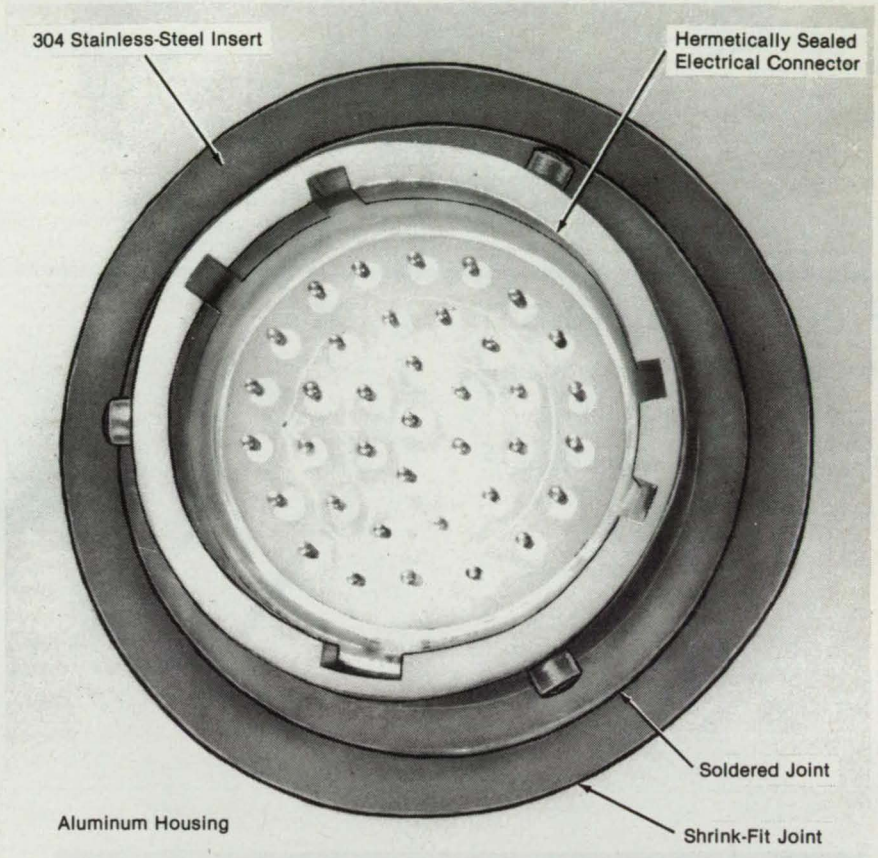
Ames Research Center, Moffett Field, California

A shrink-fit stainless-steel insert in an aluminum equipment housing allows electrical connectors to be replaced by soldering, without degrading the hermeticity of the housing or the connector. Previously, damaged connectors were removed and replaced by welding — a method that could readily destroy electrostatic-sensitive components and harm the housing and internal cables. The steel insert avoids these problems because the connector can be soldered directly to it rather than welded to the unsolderable aluminum housing.

The insert is a flanged 304 stainless-steel sleeve. The housing is made of 6061-T6 aluminum. The insert is machined so that its flange diameter is larger than the diameter of the connector mounting face, its inside sleeve diameter accommodates the connector body, and its outside sleeve diameter is 0.003 in. (0.08 mm) larger than the hole in the aluminum housing for an insert approximately 1 in. (25 mm) in diameter. Larger diameter inserts may have a greater diameter difference. The face of the sleeve flange is coated with 60Sn/40Pb solder. The mounting face of the connector is similarly coated.

The sleeve is immersed in liquid nitrogen at −320 °F (−196 °C), while the housing is placed in an oven at 250 °F (121 °C). When the temperatures of the parts have stabilized, the parts are removed. The sleeve, which has contracted from the cold, is quickly inserted in the hole in the housing, which has expanded from the heat. As the parts return to room temperature, they return toward their original dimensions, forming a metal-to-metal seal between them.

Finally, the electrical connector is inserted in the sleeve, and its mounting face is soldered to the flange face on the sleeve (see figure). The seals between the flange and the housing and between the connector and the flange have proven to be highly resistant to leaks, even after mechanical overloading and thermal shocking.



Placing an **Electrical Connector in a Steel Insert** maintains the hermetic seal of an aluminum housing. However, the connector can be removed and replaced when necessary. It is merely necessary to melt the solder between the connector and the insert, remove the damaged connector, and resolder a new connector in place.

This work was done by William C. Croucher of Martin Marietta Corp. for **Ames Research Center.** *For further information, Circle 97 on the TSP Request Card.*
ARC-11690

Spectrum-Imaging Detector Array With Integrated Filter

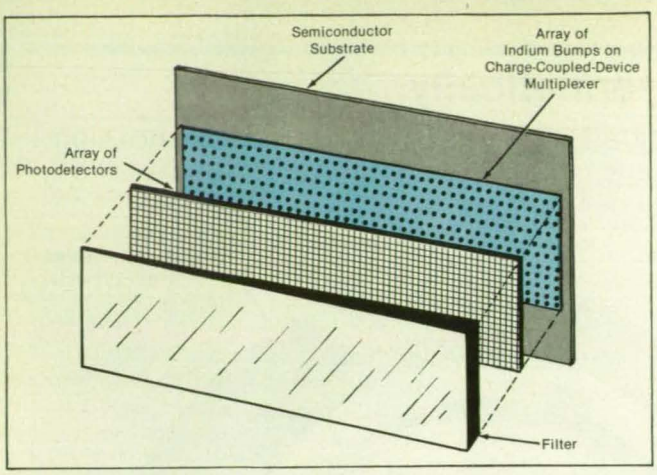
The filter would be deposited directly on the array of photodetectors.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed rectangular array of photodetectors in an imaging spectrometer would include an integral filter, the transmittance of which would vary linearly with distance along one of the rectangular axes (the spectral axis). The filter would be deposited directly on the imaging array. Consequently, unlike a separate filter attached mechanically to the array, it would not thereafter become misaligned or misregistered as a result of mechanical shock, vibration, or differential thermal expansion.

The need for precise alignment and registration of a separate filter cannot be overemphasized. The distribution of transmittance of the filter must be matched to the dispersion of the diffracting element of the spectrometer. If the filter is misregistered as much as one-tenth the detector-element pitch along the spectral axis, the detectors can receive significant amounts of light at unwanted wavelengths. Similarly, rotation of the filter with respect to the array of detectors can cause blurring of wavelengths and loss of signal. Moreover, a gap must be maintained between the filter and the detector to allow for vibrations, but the gap can allow wavelengths to overlap between adjacent columns of detectors — that is, it can cause crosstalk. In addition, the gap can vary widely over the range of operating temperatures.

Coating the array with a multilayer film of linearly distributed transmittance would overcome these disadvantages. Deposition should be carried out before the array is assembled to the accompanying charge-coupled-device multiplexer. This is because the indium bumps that join photodetectors to the cells of the multiplexer soften at about 70 °C, well below the temperature at which the film is formed.



This work was done by Clayton C. LaBaw of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 85 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 24]. Refer to NPO-18317.

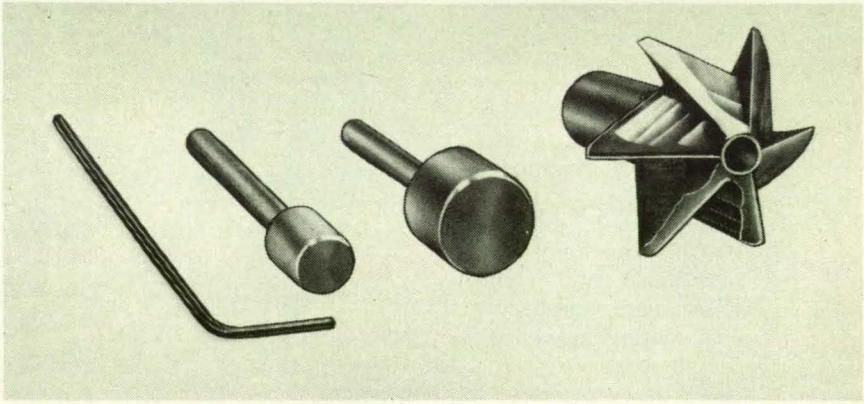
A **Filter of Linearly Distributed Transmittance** would be deposited directly on an array of photodetectors. The array, in turn, would be bonded with indium bumps onto multiplexer.

Precise Countersinking Tool

Precision is achieved with an ordinary hand-held drill.

Goddard Space Flight Center, Greenbelt, Maryland

A tool countersinks holes precisely with only a portable drill or magnetic-base drill; it does not require a costly machine tool. The tool produces 100° countersunk cones up to 1.300 in. (3.302 cm) in diameter.



The **Countersinking Tool and Accessories** enable precise countersinking in a range of hole sizes. A pilot stub like the two shown here is chosen and fastened in the tool with the aid of an allen wrench and a setscrew. The diameter of the stub should be slightly less than that of the hole.

A replaceable pilot stub at the tip of the tool aligns the axis of the countersinking tool with the centerline of the hole to be countersunk (see figure). This ensures a precise cut even with an imprecise drill. The pilot stub is chosen to suit the diameter of the hole; its shaft can be easily inserted into the center bore of the tool and secured with a setscrew.

The tool has six flutes ground from 4340 high-carbon steel that is hardened to a value of 55 on the Rockwell C scale. The negative-rake cutting edges are ground with reference to the axis of the tool so that they can be resharpened readily and accurately. The tool is designed for relatively low cutting speeds.

This work was done by Eric S. Jenkins and William N. Smith of **Goddard Space Flight Center**. *For further information, Circle 67 on the TSP Request Card.*
GSC-13296

Mathematics and Information Sciences

Iterative Bayesian Classification in Polarimetric SAR

A priori probabilities are adjusted according to statistics of local image data.

NASA's Jet Propulsion Laboratory, Pasadena, California

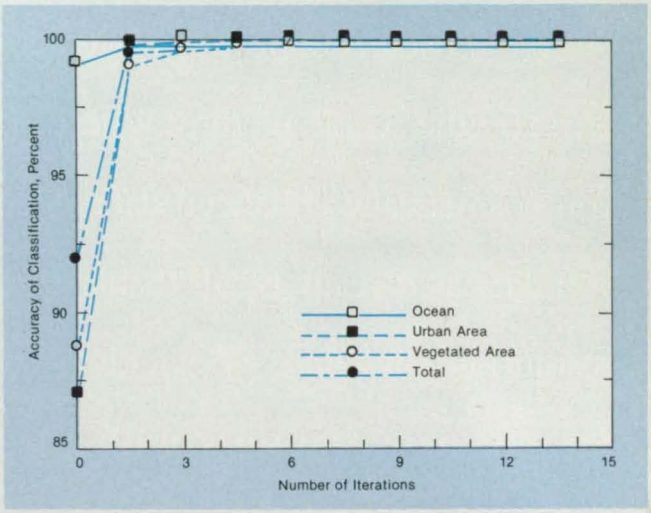
In an improved scheme for the Bayesian classification of the picture elements in a polarimetric synthetic-aperture radar image of terrain, the a priori probability that a given picture element belongs to a given class is adjusted iteratively according to the spatial variation of the statistical properties of image data. Only a few iterations yield a dramatic increase in the accuracy of classification.

The image data for each picture element are its polarimetric radar backscattering data in complex-number (for amplitude and phase), feature-vector representation. As used here, "classification" denotes the assignment of a picture element to a class that corresponds to a particular type of terrain or body of water according to some measure of the similarity or difference between its radar backscattering characteristics and the radar backscattering characteristics of other picture elements that are known or believed to represent that kind of land or water surface.

In this scheme, one uses a measure of difference; namely, a weighted measure, d_m, of the distance between the feature vector, $\mathbf{X}$, of the given picture element and a specified or averagelike feature vector, $\mathbf{X}_m$, of the mth class. The distance measure is given by

$$d_m = -\ln[P_a(m)] + \ln|\mathbf{C}_m| + 3\ln(\mathbf{X}^\dagger \cdot \mathbf{C}_m^{-1}\mathbf{X})$$

where $P_a(m)$ denotes the a priori probability that the picture element belongs to class m, the superscript "†" denotes the complex conjugate transpose, and $\mathbf{C}_m$ denotes the covariance matrix $\mathbf{X}_m\mathbf{X}_m^\dagger$. The picture element is assigned to the class in which d_m is the smallest.



The **Accuracy of Classification of Picture Elements** in a test image increases dramatically in the first few iterations. The zeroth iteration is the initial classification based on spatially unvarying a priori probabilities.

The scheme involves a sequence of classifications. In the first classification, $P_a(m)$ is taken to be constant over the whole image. Typically, the initial $P_a(m)$ is derived from the statistics of the whole image; for example, if it is known that one-tenth of the area in the scene is ocean, then for the class that represents ocean, the initial value of P_a of that class can be set at 0.1.

In the second and subsequent classifications, adaptive a priori probabilities are calculated for each picture element by surrounding that picture element with an $n \times n$ box centered on that picture element, then counting the picture elements in the box that were previously assigned to each class. The chosen size of the box represents a compromise between (1) accuracy of the a priori probabilities (which requires a larger box) and (2) utilization of the local homogeneity of the image statistics and retention of spatial resolution (which require a smaller box). The compromise is reached when the number of picture elements in the box is about 10 times the number of classes used. The figure shows one of the results obtained by applying the scheme, with a 5×5 box, to a polarimetric image of the San Francisco area, with the surface classified as ocean, urban area, or vegetated area.

This work was done by Jakob J. van Zyl and Charles F. Burnette of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 6 on the TSP Request Card.*
NPO-18308

Synchronization of Parallel Discrete Event Simulations

Optimistic and conservative time-stepped synchronization approaches are adaptively combined.

NASA's Jet Propulsion Laboratory, Pasadena, California

An adaptive, parallel, discrete-event-simulation-synchronization algorithm, Breathing Time Buckets, has been developed in the Synchronous Parallel Environment for Emulation and Discrete Event Simulation (SPEEDES) operating system. The algorithm allows parallel simulations to process events optimistically in fluctuating time cycles that naturally adapt while the simulation is in progress. This algorithm combines the best of both optimistic and conservative synchronization strategies while avoiding the major disadvantages of both extremes. The SPEEDES operating system supports Breathing Time Buckets along with other synchronization strategies in an object-oriented paradigm that is portable to various computers, and is fully interactive.

The synchronization of discrete-event simulations on parallel computers poses a major problem, especially in cases where simulated objects on one processor interact (i.e., generate events) frequently with objects on another processor. If care is not taken in synchronizing the parallel simulation, a processor can schedule an event to occur in the past of another processor. This can lead to a violation of causality, which would then result in erroneous simulation results.

There are two philosophies for solving the synchronization problem for parallel simulations. One way is to forbid causality errors to occur. This approach is usually called "conservative parallel simulation." One simple way to ensure causality is to

insist that if an event at time T generates other events, the time stamps of those generated events must be greater than $T+\delta t$. The simulation can then process events in fixed time cycles (or buckets) of duration δt. This approach is called Time Bucket Synchronization. Typically, if δt is large, many events can be processed in parallel. However, large values for δt forbid simulated objects to tightly interact with each other in time. This can be a major drawback.

A second, and more general approach is called "optimistic parallel simulation." Optimistic approaches, such as the Time Warp algorithm, do not place limiting assumptions on the simulation. Causality errors are allowed to occur, but when one is detected, the state of the simulation is rolled back in time, thus undoing the erroneously processed events. Because those erroneous events may have scheduled events for other processors, those scheduled events must be canceled (and rolled back if already processed) by sending antimessages. Cascading rollbacks that generate large numbers of antimessages can cripple the performance of optimistic simulations.

The Breathing Time Buckets algorithm processes events optimistically in time cycles that adapt while the simulation is in progress. The benefit of this algorithm is two-fold. First, there are no limiting assumptions, such as a required minimum δt (required by the Time Bucket approach), that reduce the capability of the simulation. Second, events are processed optimistically (like the Time Warp approach) except that antimessages are never required. Thus, Breathing Time Buckets combines the best of both conservative and optimistic worlds.

The main concept exploited by Breathing Time Buckets algorithm is the "event horizon." The event horizon can be understood by considering a simulation running on one processor (see figure). Events are processed in ascending time order. As these events are processed, they may schedule new events for the future. These new events are collected into a temporary holding list until it is time to process the one with the earliest time stamp. The time tag of this event is called the event horizon. The list of new events is then sorted and merged back into the main event list. Processing then continues for the next cycle.

Not only does this approach lead to an efficient strategy for managing the time-sorted nature of the event list, but it also provides a means for performing parallel simulation. Breathing Time Buckets exploits the fact that events processed in a given cycle do not interact with other events in the same cycle. These events can then be processed independently on different processors in parallel.

Events are processed in two phases. In phase one, events are processed optimistically, but their messages for scheduling

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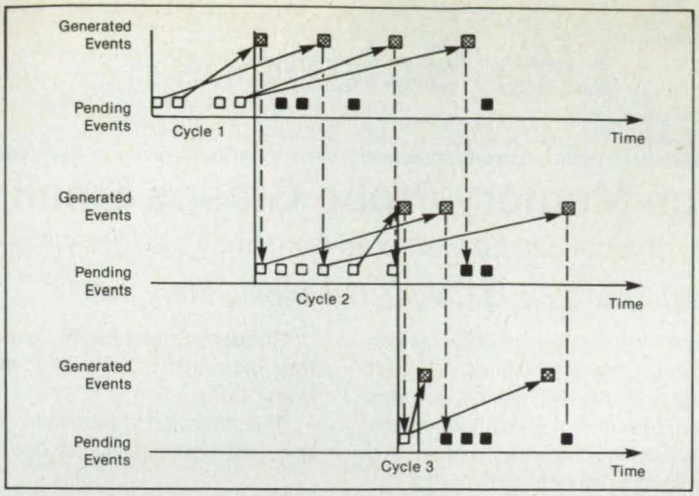
events on other processors are not released immediately. By using asynchronous broadcasts and non-blocking synchronizations, the event horizon can be detected by the parallel processor. Only when all of the processors have crossed the event horizon are the messages generated by events up to the event horizon released. This means that all messages released by the simulation are valid. Phase two then begins by sending (and receiving) valid new messages, which in turn schedule events.

It is likely that events are optimistically processed beyond the event horizon because the event processing cycle does not stop until all processors have crossed the event horizon. When this happens, some events may have to be rolled back. However, this does not involve much overhead since rollback only requires the state of the simulated object to be restored and for the messages from bad events (which have not been released yet) to be discarded. Antimessages are never needed.

The one limitation of the Breathing Time Buckets algorithm is that a reasonable number of events must be processed in each cycle per processor for the highest efficiencies. An analytic model has been developed that predicts how many events on the average are processed in each cycle. This model further gives us guidelines on how to extract parallelism in parallel discrete event simulations. We find that as a rule, large simulations perform better in the Breathing Time Buckets algorithm than do small simulations.



This is an **Example of Processing Events** in cycles defined by the event horizon.

The Breathing Time Buckets algorithm supports unrestricted parallel discrete event simulation with minimal overhead. High speedups have been achieved using both a queueing network and a military simulation as benchmarks. Combined with the interactive support provided by the SPEEDES operating system, this algorithm is well suited for modeling communication networks, for large-scale war games, for simulated flights of large aircraft, for simulations of computer equipment, for mathematical modeling in general, for interactive engineering simulations, and for depictions of flows of information.

This work was done by Jeffrey S. Steinman of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 41 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, NASA Resident Office – JPL [see page 24].Refer to NPO-18414.

Shape-Memory Probe Grasps Small Objects

Foreign objects can be extracted from body cavities with minimal risk.

Goddard Space Flight Center, Greenbelt, Maryland

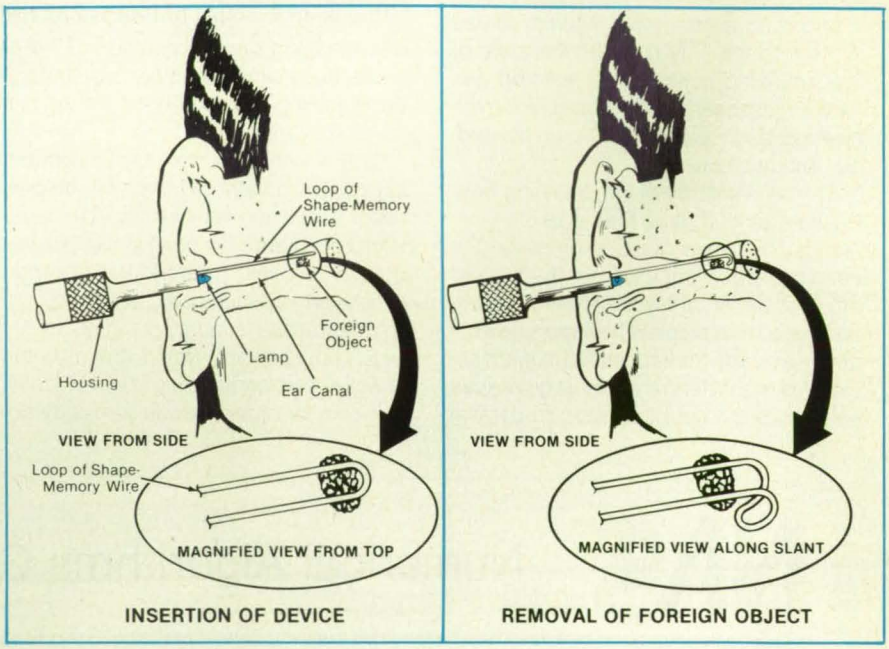
A device removes foreign objects from the ear canal, nose, or throat with little risk of damage to tissue. The device includes a thin, flexible wire that is inserted into the obstructed cavity. The wire is made of a titanium/nickel or other shape-memory alloy. Once the wire is properly positioned, it is made to bend into a hook, tweezer, or other "remembered" grasping configuration by heating it above a critical temperature. The bend surrounds the offending particle, which can then be extracted.

The new device makes it unnecessary to insert a curette, pair of forceps, or other relatively large, unwieldy instrument into an ear, nose, or throat and thus eliminates the danger of puncturing the eardrum or other tissue.

The device (see figure) includes a cylindrical housing (like a common flashlight, but narrower) from which an elongated loop of shape-memory wire extends. After the tip of the loop has been inserted into the cavity so that it overlaps the foreign object, the operator pushes a switch on the housing to send a small electrical current through the loop. The current heats the wire to slightly above body temperature; the wire then "remembers" its bent shape. The source of current could be a battery in the housing or could be an external transformer and rectifier.

This work was done by Earl D. Angulo of **Goddard Space Flight Center**. *For further information, Circle 24 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Goddard Space Flight Center [see page 24]. Refer to GSC-13306.



A **Loop of Shape-Memory-Alloy Wire** is inserted into the ear canal. A small lamp helps the operator guide the tip to a foreign object. Heated by current, the tip grasps the object.

Apparatus Induces and Fixes Small Aquatic Organisms

The apparatus is small, compact, light in weight, and self-contained.

Ames Research Center, Moffett Field, California

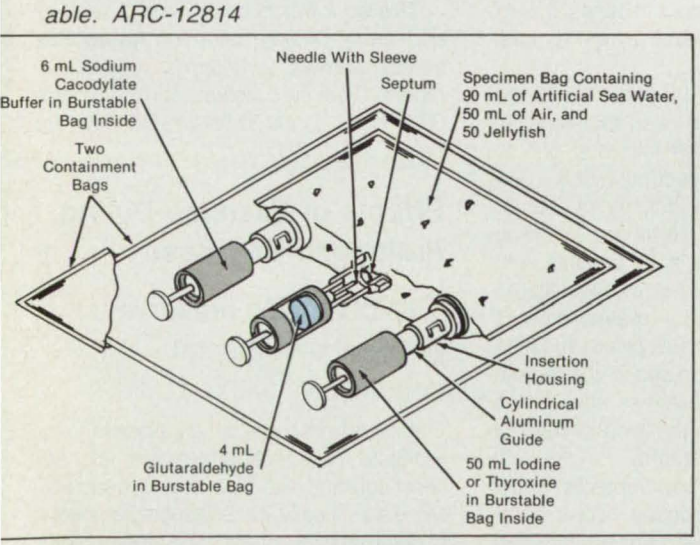
A portable, self-contained apparatus is designed to induce and fix live jellyfish and other, small aquatic organisms in microgravity. It is small, light in weight, and reliable, unlike previous apparatuses of the same type. Operation of the apparatus requires a minimal amount of a technician's time. It should be adaptable to use in biological tests and experiments at remote locations on Earth.

The apparatus (see figure) isolates the live organisms from toxic substances until the desired time of introduction. It includes a set of plastic syringes, each containing an inner, sealed, burstable bag filled with a desired solution. The syringe is secured to a cylindrical aluminum guide, which slides into a plastic housing. The housing connects the syringes to a bag that contains the specimens. The housing includes a rubber septum through which the solutions are injected. This system provides two levels of containment between the toxic substances and specimens with no leaching of chemicals into the specimen bag prior to time of introduction.

At the time of introduction of solution from a given syringe, the technician forces the cylindrical guide that holds the syringe into the housing, thereby forcing the needle of that syringe through the septum. The technician then pushes the plunger of that syringe until the bag bursts and the contents are injected into the specimen bag. The technician is isolated from toxic substances by two outer bags, providing at least three levels of containment of fluids.

The apparatus was designed for use on *Aurelia* jellyfish—an extremely fragile organism. It was tested on the ground with *Aurelia* and proved highly successful. It was found that the entire sequence of operations can be completed in about 15 seconds.

The work was done by Christopher Todd of Insystems for **Ames Research Center**. *No further documentation is available. ARC-12814*



The Syringe-and-Bag Assembly is a compact, lightweight self-contained, portable apparatus that can be used to introduce various liquids to aquatic organisms at desired times.

Books and Reports

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

Gravity, Calcium, and Bone: Update, 1989

Data on effects of gravitation on skeletal adaptation, calcium metabolism, and growth processes are reviewed.

A report reviews recent short-term flight and ground-based experiments that bear on the effects of 1 g and 0 g on skeletal adaptation, calcium metabolism, and growth processes. The results of these studies indicate that two principal components of calcium metabolism — the calcium endocrine system and bone — respond promptly (within days) to changes in the orientation of the body in gravitation and to weightlessness. The vitamin D hormone may be the best candidate for mobilizing bone mineral early, and gravity-dependent gradients that probably involve the cardiovascular system may have a significant role in its distribution at the whole-body level. These observations provide a better perspective for the interpretation of mineral-balance studies in healthy ground-based and astronaut subjects.

During inactivity or weightlessness, net losses in bone minerals may be attributable more directly to alterations in the functions of the gastrointestinal tract and kidney and changes in diet than to direct gravitational effects. However, studies do show a link between gravity and the distribution of and deposition of bone minerals. Thus, the effects of spaceflight or bed rest on the biomechanics of bones appear to be more severe than they are on total body bone mass.

The concentration of minerals in the lumbar vertebrae has been monitored in several recent studies following one in 1983 that reported a reduction of 3.8 percent in the average density of the 2d through 4th lumbar vertebrae following therapeutic bed rest in 28 patients with prolapsed intervertebral disks. Quantitative computer tomography measurements made on four cosmonauts before and after they spent 6 months in space in a regime that included daily exercise showed no significant change in the average density of the 2d lumbar vertebra.

Studies of bed-rest subjects show varied individual responses. In one study, five out of six non-exercising bed-rest (horizontal) subjects showed no reduction in bone density in the 2d through 4th lumbar vertebrae; the remaining subject showed a 3-percent decrease. Another study reports increases of up to 12.6 percent in density of the spongiosa of the lumbar vertebrae of three bed-rest subjects after 120 days at 5° head-down tilt.

In a study of 19 subjects designed to test the effect of isokinetic and isotonic exercise on the tolerance of bedrest subjects to standing after bed-rest, measurements of density of minerals on the 2d through 4th lumbar vertebrae before and after 30 days at 6° head-down tilt revealed no differences between either exercise group and the control (no-exercise) group. However, two subjects in the isokinetic-exercise group showed significant density changes, −7 and +10 percent, respectively, with changes in serum parathyroid hormone (PTH) in the opposite directions. This is consistent with the known effects of PTH in enhancing bone resorption.

There are also indications that changes in the serum level of the vitamin D hormone, 1,25-D, may play a role in the mobilization of bone calcium. Recent proposals that PTH governs the differentiation and number of bone cells and that 1,25-D governs cell activity are suggestive of the following sequence of events as an explanation of data from four astronauts on circulation hormone levels measured before, during, and after a 7-day spaceflight: enhanced mobilization of calcium from bone related to the observed transient increase in 1,25-D, followed by suppressed mineralization in unloaded bones after a few days, with no increase in the number of osteoclasts or osteoblasts. The results of experiments with rats suggest a gravity-dependent distribution of mineral in the whole skeleton, affected by responses of the cardiovascular system to changes in position and gravity. These experiments also showed a decrease in bone strength without changes in bone density.

This work was done by Sara B. Arnaud and Emily Morey-Holton of **Ames Research Center**. *To obtain a copy of the report, "Gravity, Calcium, and Bone: Update, 1989," Circle 37 on the TSP Request Card. ARC-12717*

Effects of Exercise During Prolonged Bed Rest

Exercise helps preserve physical and mental condition.

A report describes an experiment to investigate the effects of periodic, intense, short-duration exercise during bed rest. More specifically, the investigators sought to determine the efficacy of isotonic (cycle) and isokinetic (flexion/extension) leg exercises in counteracting the deleterious effects of bed rest upon the physical and

mental conditions of the subjects.

Nineteen men, aged 32 to 42 years, were divided into three groups: a control group of five for whom exercise was not prescribed, a group of seven who performed the isotonic exercise in a supine position, and a group of seven who performed the isokinetic exercise in the supine position. The exercises were performed near peak levels for 30 min in the morning and 30 min in the afternoon 5 days per week.

The experiment began with a 7-day ambulatory control period during which the subjects equilibrated on a standardized diet of normal fresh and frozen foods. This was followed by 30 days of bed rest (interrupted by the prescribed exercises) with the beds tilted 6° down at the head ends. The experiment concluded with 4.5 days of ambulatory recovery.

For each subject, data were taken on the capacity for work (measured in terms of the peak rate of uptake of oxygen), endurance and strength of the muscles, tolerance to sitting up, equilibrium, posture, and gait. Data were also taken on atrophy of the muscles, mineralization and density of the bones, endocrine analyses concerning vasoactivity and fluid and electrolyte balances, intermediary metabolism of the muscles, mood, and performance.

While significant changes in density of the lumbar spine and radius were not detected in the majority of subjects, there were clear effects of the exercises on some aspects of mineral and fluid metabolism. The isokinetic exercise prevented increases in sublingual cell minerals observed in controls, hypercalciuria after 27 days, and decreases in both major calcium regulating hormones. Magnetic resonance spectroscopy measurements of muscle phosphorus revealed that the high index of reserve energy (phosphorus/phosphocreatine ratios) in controls after bed rest was also prevented only in the isokinetic-exercise subjects tested by an isometric exercise. On the other hand, plasma volume was maintained by an isotonic exercise. These results suggest that isotonic and isokinetic exercises have different effects on mineral and fluid metabolism. Elements of both types of exercise may be needed to counteract the deleterious metabolic effects of bed rest.

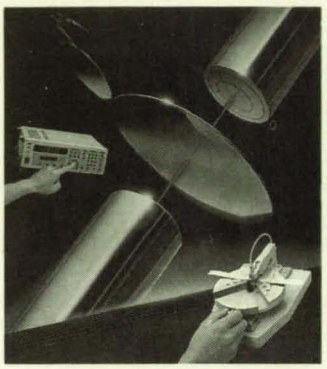
The subjects were found to have maintained a relatively stable mood, high morale, and high esprit de corps throughout the study. The performance of almost every subject improved in nearly all tests. The isotonic exercise, as opposed to isokinetic exercise, was associated more with decreasing levels of psychological tension, concentration, and motivation; and improvement in the quality of sleep. The capacity for work was maintained during bed rest with isotonic exercise; it was not maintained with isokinetic or no exercise.

In general, there was no significant decrease in strength or endurance of arm or leg muscles during bed rest, despite the atrophy of some leg muscles. The tolerance to sitting up was reduced similarly in all three groups following bed rest. Bed rest resulted in significant decreases in the stability of posture and of the self-selected lengths of steps and stride, and speed of walking. These characteristics were not influenced by either exercise regimen. Pre-bed-rest responses were restored by the 4th day of recovery.

This work was done by S. Arnaud, P. Berry, M. Cohen, J. Danelis, C. DeRoshia, J. Greenleaf, B. Harris, and L. Keil of **Ames Research Center**, *E. Bernauer of the University of California, M. Bond of Loredan Biomedical, S. Ellis of San Jose State University, P. Lee and R. Selzer of NASA's Jet Propulsion Laboratory, and C. Wade of the Letterman Institute of Research. Further information may be found in NASA TM-101045 [N90-13926], "Exercise Countermeasures for Bed Rest Deconditioning."*

Copies may be purchased [prepayment required] from the National Technical Information service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700
ARC-12190

New on the Market

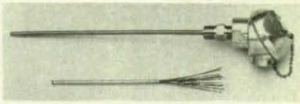


The CL-250 system from Ono Sokki Technology Inc., Addison, IL, employs a unique processing technique for highly accurate **noncontact thickness measurements of conductive and semiconductive materials**. The system calculates thickness from gap capacitance regardless of the material type, magnetization, color, roughness, or relativity. The technique also is immune to magnetic fields and ambient light.
For More Information Circle No. 800

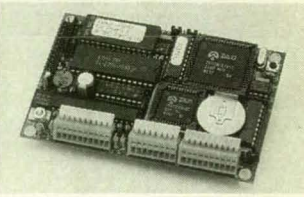
BBN Systems and Technologies, Cambridge, MA, has announced Release 2.2 of its BBN/Probe™ **time series analysis software**. The interactive data reduction, analysis, and graphics package offers direct access to gigabytes of data from such sources as telemetry and flight test systems, simulations, vehicle and range testing, and physiological recordings. New features include calendar time format to support applications where data is collected over long periods at slower rates and multiple vertical axis scales for overlaying data with different scales on a single graph panel.
For More Information Circle No. 790

The DynaSight® **computer workstation viewing accessory** from Origin Instruments Corp., Grand Prairie, TX, is a low-power optical radar that enables dynamic perspective displays and head-controlled pointing systems. The compact, self-contained sensor opens a 3D virtual window on real-time displays to extend the user's ability to comprehend complex spatial arrangements in 3D models.
For More Information Circle No. 796

A **3D input peripheral** developed by Pixsys, Boulder, CO, simplifies the use of 3D CAD and computer graphics software. The FlashPoint and FlashTracker 3D digitizing systems measure 3D points in space to track the motions of people, equipment, or instruments and create computerized models of real-world surfaces. The devices are easily configured by the user for integration into virtually any commercial or custom software package.
For More Information Circle No. 798



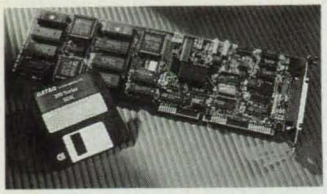
Delta M Corp., Oak Ridge, TN, has introduced a line of **thermocouples** that employs nontoxic Hafnia (HfO_2), a highly stable insulation material compatible with the same refractory materials as potentially hazardous beryllium oxide. The thermocouples can measure process temperatures up to 2200° C, and are available in S, R, B, G, D, and C types with sheath materials of alumina, molybdenum, tantalum, platinum, or zirconia.
For More Information Circle No. 794



The Little PLC™ miniature control computer from Z-World Engineering, Davis, CA, is C-programmable and measures just 4" x 3". Priced at $195, the **programmable logic controller** features eight optically isolated inputs, eight relay driver outputs, a built-in switching power supply, and RS-485 serial communications. A simple expansion bus with open architecture allows unlimited inputs and outputs.
For More Information Circle No. 788

C.ITOH Technology Inc., Irvine, CA, has introduced the D880 **graphic LCD module**, designed to provide a simple man-machine interface while saving space. Operator instructions such as sequencing, timing, and system status are available on a keypad enhanced with changing color alerts that blink or beep. The D880 integrates a low-power graphic LCD, utilizing super twist technology, with a custom IC driver—all on the key cap of a single-pole, single-throw, momentary-contact switch measuring less than one square inch.
For More Information Circle No. 792

New on the Market



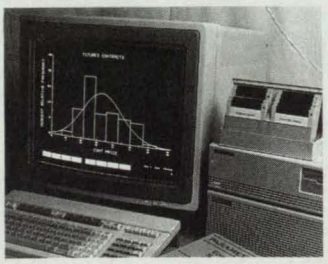
Dataq Instruments Inc., Akron, OH, has introduced a line of low-cost Windows-compatible **data acquisition hardware products**. The boards feature wide measurement ranges, the broadest programming flexibility available, input and output scan lists, dual DMA operation, free driver software, on-board counter/timers, signal averaging, burst sampling, analog triggering support, and "potless" digital calibration.
For More Information Circle No. 774

A **sealed lever latch** manufactured by Southco Inc., Concordville, PA, easily accommodates both milled and CNC routed panel preparation plans. The latch installs in a single rectangular hole and provides overall sealing performance to meet or exceed NEMA 12 and IP 65 requirements. A flange helps compress an optional perimeter gasket for maximum sealing and also masks cosmetic panel irregularities caused by routing or sawing the installation hole.
For More Information Circle No. 786

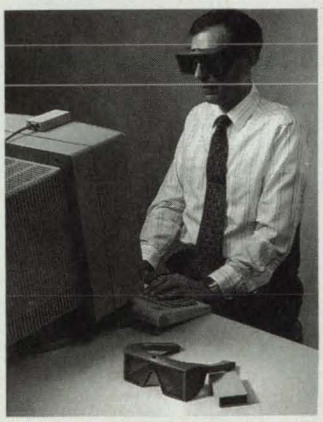
AVX Corp., New York, NY, has announced a .1μF, X7R multi-layer **ceramic chip capacitor** in an 0603 case size. Offering circuit designers maximum board density, the capacitor's X7R dielectric allows only a 15% change in capacitance value over an operating range of -55 to 125° C. The capacitor is well-suited for applications in harsh environments or where temperature variations occur.
For More Information Circle No. 784

An on-line **infrared temperature measurement system** from Wahl Instruments Inc., Culver City, CA, has high-resolution optics to measure surfaces as small as .019" diameter through glass ports. The model HSM672 Heat Spy® infrared monitor enables small surface measurements where contact measurements are impractical. Accuracy is ±1.0% of reading, and the unit has push-to-test internal calibration.
For More Information Circle No. 776

SNAP, a PC-based system for **displacement field measurement** from TAU Corp., Los Gatos, CA, automatically measures physical displacement within materials stressed to the point of deformation and failure. Highly accurate displacement field measurement compares the position of selected points on the material's surface—before and after stress is applied by thermal or mechanical loads—allowing users to calculate safe stress levels.
For More Information Circle No. 782

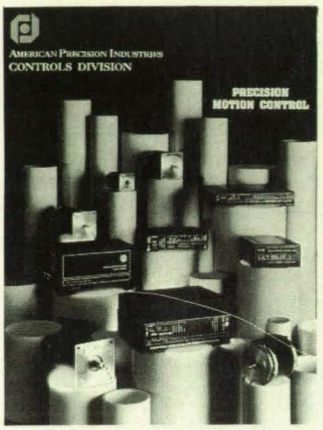


Parametrics Inc., Loveland, CO, has released the Statistical Analysis Library software package containing over 500 proven **statistical and graphical algorithms**. The package requires no programming and is designed to take the user step-by-step from data entry through all phases of data analysis and presentation. A data manipulation front end allows users to edit, scan, join, list, select portions, recode data sets, and create subfiles.
For More Information Circle No. 780



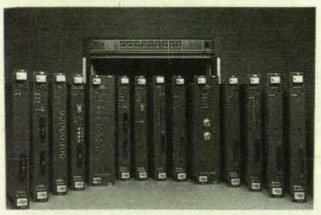
Tektronix Inc., Beaverton, OR, has introduced STEREOTEK® MkII **stereoscopic glasses** utilizing patented Pi-cell liquid crystal technology for high contrast. The glasses feature tether-free operation via an infrared link, battery life up to 200 hours under normal operation, automatic flickerless mode, and a large lens area. They can be used to view real-time stereo images by combining cameras, scan converters, and a monitor.
For More Information Circle No. 778

New Literature



The Controls Division of American Precision Industries, Buffalo, NY, has released a guide to **step motor systems** design. The catalog provides an illustrated glossary as well as formulas and helpful hints for system calculations. Sections address indexers, step motors, modular drives, packaged systems, and accessories.
For More Information Circle No. 702

A brochure released by Micro Assembly Systems Inc., Willimantic, CT, details the Stick-Screw System, an **assembly tool** designed to speed assembly time, improve quality, and reduce costs. The system employs an air-powered rotary driver and "sticks" of up to 90 serially-connected hex-head screws.
For More Information Circle No. 704



KineticSystems Corp., Lockport, IL, has published a VXIbus (VMEbus extensions for instrumentation) product catalog describing over 35 new I/O modules for **real-time data acquisition and control** applications. The catalog includes analog and digital I/O, counters, pulse generators, signal conditioners, and transient recorders.
For More Information Circle No. 706

The *Capacitor Handbook* from CJ Publishing, Olathe, KS, combines capacitor theory with circuit application advice. The first chapter covers capacitor fundamentals with subsequent chapters dedicated to the various dielectric capacitor types including ceramic, plastic film, aluminum electrolytic, tantalum, glass, and mica.
For More Information Circle No. 712

A 12-page brochure from METRUM Information Storage, Littleton, CO, describes the capabilities and features of its RSS-600v and RSS-48b **automated tape storage libraries**. By combining state-of-the-art robotics and the high-density RSP-2150 tape drive with reliable, low-cost ST-120 tape cartridge media, the products offer high data storage capacities per square foot of floor space, high data transfer rates, and fast data access time.
For More Information Circle No. 708

A brochure released by Arvin TD Center, Columbus, IN, describes its **thermal diffusion process**. An advanced method of hardening steel surfaces to reduce galling, seizure, and corrosion, the TD process reduces downtime, tool maintenance, and replacement and lubrication costs. TD-treated materials have a surface hardness ranging from 3200 to 3800 on the Vickers hardness scale.
For More Information Circle No. 710

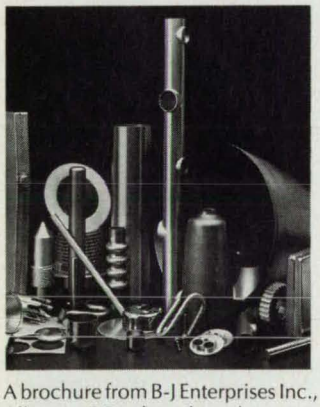
Control Laser Corp., Orlando, FL, has released *Industrial Strength Laser Marketing: Turning Photons into Dollars*, a comprehensive guide to **beam-steered laser marking systems**. The 50-page publication addresses the operation and design of both Nd:YAG lasers and beam-steered laser marking systems, reviews the principles of laser interactions with materials, and covers integration of laser systems with host computers and automated work cells.
For More Information Circle No. 714

A 184-page catalog from AIN Plastics Inc., Mt. Vernon, NY, highlights the company's full lines of mechanical plastics, sheet, rod, tube, film, and accessories. Featured new products include ABS tubing, Pharmed tubing, polypropylene pipe, Hyzod AR polycarbonate sheet, Kynar schedule 80 pipe, Kynar bushing stock & tubing, Vespel plaques, and transparent fluorescent vinyl.
For More Information Circle No. 730

New Literature

A brochure published by Intel Corp., Santa Clara, CA, describes the 80170NX electrically-trainable analog **neural network chip**, which offers an innovative solution to real-time pattern recognition and signal processing problems. The chip combines advanced IC technology with a high-density parallel architecture to deliver greater throughput per dollar than alternative technologies. Its integration and low power requirements make it a high-performance embedded solution for compact, low-power systems implementing small- to medium-size, multilayer neural networks.
For More Information Circle No. 718

The latest edition of the Unigraphics Product Catalog offers a comprehensive overview of **CAD/CAM/CAE products and services** available from McDonnell Douglas Systems Integration Co., Maryland Heights, MO. The Unigraphics system features modules with capabilities in solid modeling, surfacing, analysis, drafting, and machining.
For More Information Circle No. 728

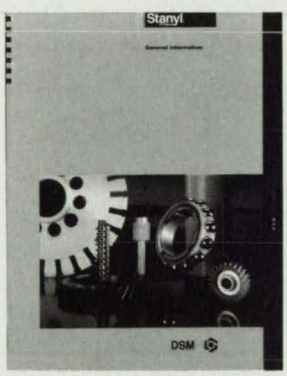


A brochure from B-J Enterprises Inc., Albany, OR, describes the company's expanded capabilities in **manufacturing custom parts and assemblies from refractory and reactive metals**. Capabilities include deep draw forming, spinning, forging, fabrication and welding, CNC turning and milling, tube bending, and stamping. The company specializes in tantalum, niobium, molybdenum, tungsten, zirconium and vanadium metals and their alloys.
For More Information Circle No. 724

The ABCs of DMMs, a 16-page booklet produced by John Fluke Mfg. Co. Inc., Everett, WA, offers a short course on the operation, capabilities, and selection of **digital multimeters** (DMMs). It features sections on the common uses of a DMM, ac and dc voltage and current measurements, resistance, continuity and diode tests, and multimeter safety.
For More Information Circle No. 722

A **static control products** catalog from Graseby Plastic Systems Inc., Marlboro, MA, introduces a variety of products including the Statproof Zinc-Free Floor Finish and a heel grinder with a new D-ring fastening system. Instructions are included for such applications as workstation, mobile personnel, test and measurement, material handling, clean room, and office products.
For More Information Circle No. 716

Minco Products Inc., Minneapolis, MN, has released an updated design and capabilities brochure for **flex-circuits**. The 28-page guide features expanded coverage of rigid-flex circuits and surface mount technology, and a section on impedance and electrical noise control for high-speed signal transmission. It also discusses the differences between hardboards and flex-circuits, explains manufacturing steps, lists recommended tolerances, and defines common flex-circuit terms.
For More Information Circle No. 726



DSM Engineering Plastics, Reading, PA, has released a brochure on its Stanyl® 46 **nylon** that provides performance data and a complete properties profile of all grades. Stanyl 46 offers a more symmetrical chain structure and a better crystallization rate than other nylons, yielding excellent heat and chemical resistance, high stiffness and low creep at elevated temperatures, and reduced cycle times for injection molding.
For More Information Circle No. 720

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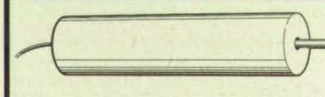

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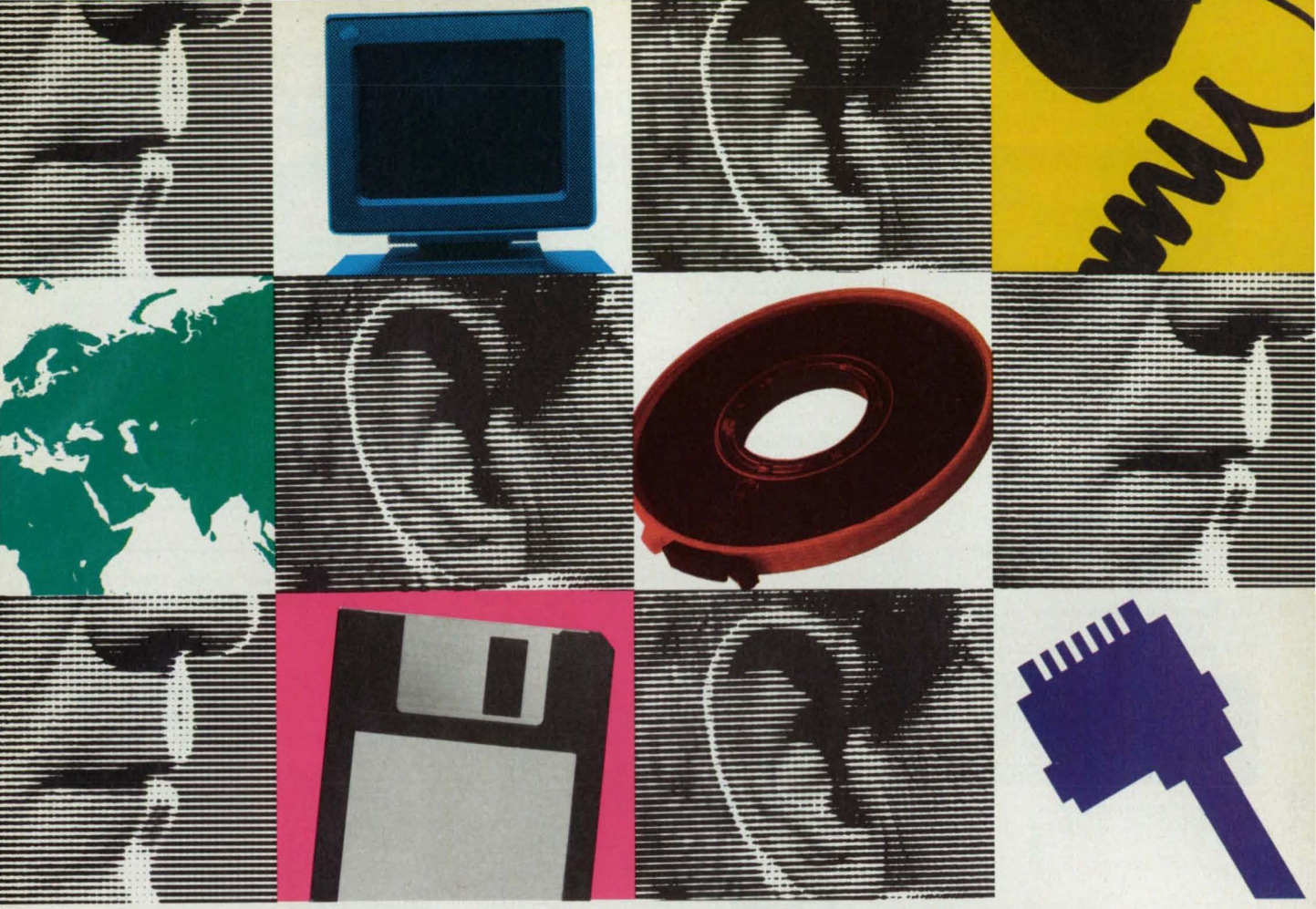
Subject Index

(Continued on page 146)



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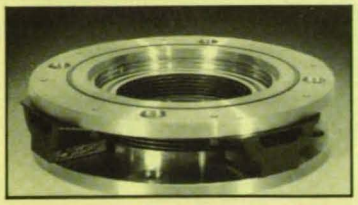

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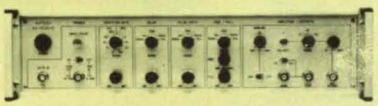

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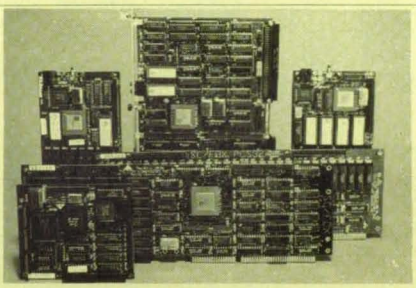

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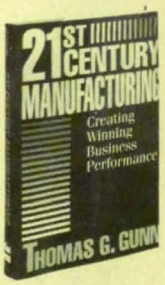

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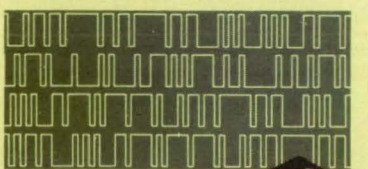

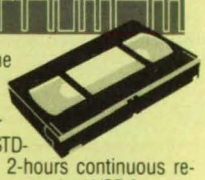

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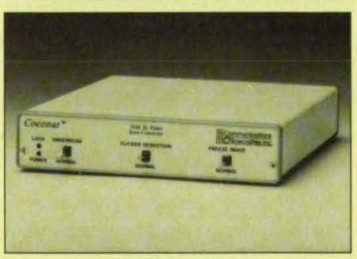

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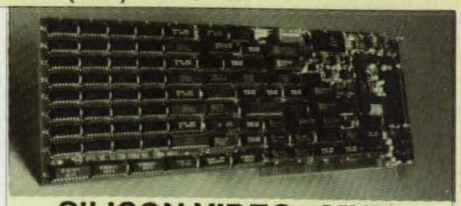

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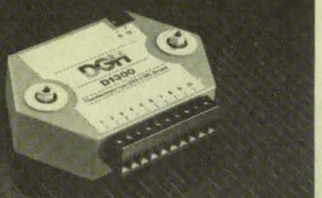

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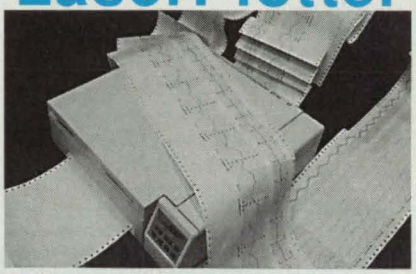

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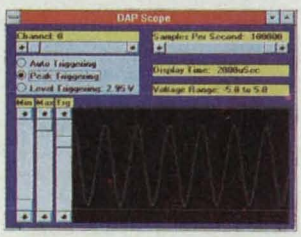

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With Jack, analyses formerly and painstakingly accomplished with blueprints, databases, and small plastic figures have graduated to dynamic 3D modeling. "Jack can model environments as diverse as the space shuttle, a submarine, or a tractor," said Dr. Norman Badler, head of University of Pennsylvania's Department of Computer and Information Science. "And we continue to develop it with an eye toward extensibility." John Deere & Co. recently used Jack for visibility and body sizing during development of an earth-moving vehicle, and other industrial customers are applying it to control room access. "Any human-machine interface is fair game for Jack," said Badler.

The model's body consists of 39 segments, 38 joints, and 88 degrees of freedom, including a 17-segment flexible torso, while fully-articulated hands add 30 segments, 30 joints, and 33 degrees of freedom. All parts are programmed to move automatically in response to commands from a standard three-button mouse and pop-up menus. Simple mouse movements allow the user to view Jack from any distance or perspective, and a window on the screen shows the view from Jack's vantage point. The user has access to as many "Jacks" as needed, which can be configured to the proportions and abilities of many different people.

"Jack's greatest asset is its extraordinary interactivity," said Badler. "It's as easy for an engineer to manipulate Jack as his CAD model." According to Badler, the average user can operate Jack after two days of training.

Currently configured for Silicon Graphics IRIS 4D and INDIGO workstations, additional versions of Jack are being developed for IBM RS/6000 and X-Windows-compatible systems. The software can work alone or interface with a variety of CAD systems, including AutoCAD, SDRC I-DEAS, MultiGen, Pro/Engineering, and BRL-CAD.

Multiple Jacks can be used to analyze multi-person environments.

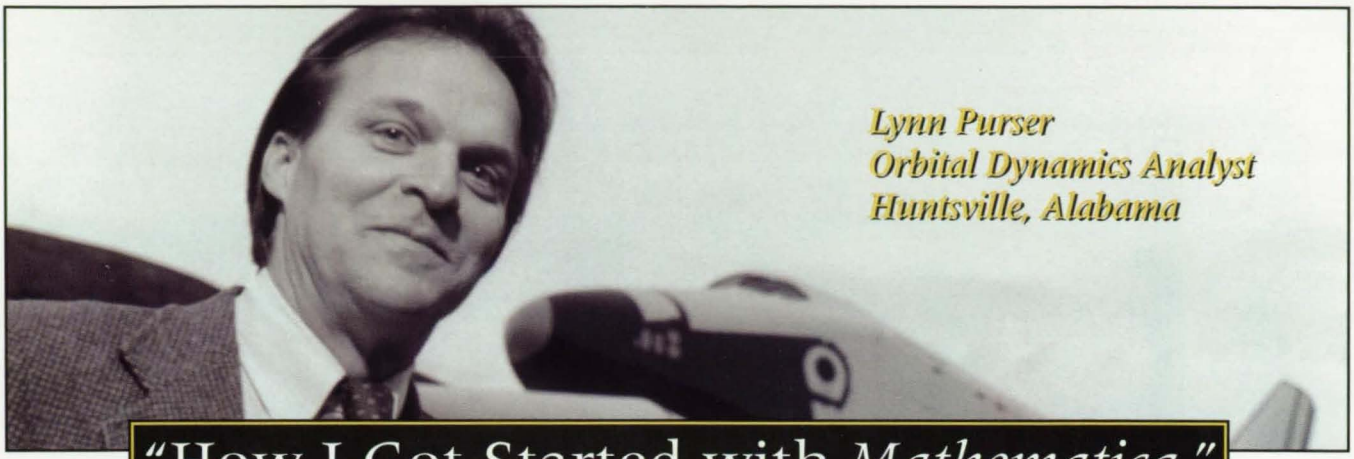
Jack is the product of research dating back to the late 1970s. NASA's Johnson Space Center (JSC) was the initial investor in the program. "We also gave Jack its first real-world problems to solve," said James Maida, director of JSC's Graphics Analysis Facility. Jack's earliest tasks addressed reach and visibility, later extending to strength modeling and collision avoidance. Other major supporters of the program include the Army Research Office and Army Human Engineering Laboratory.

University of Pennsylvania scientists are working to realize Johnson researchers' recommendation of a natural language interface. "Within five years," said Badler, "we expect Jack to be responding to verbal English commands."

JSC functions as a co-researcher toward advancement of the computer science behind such models, returning data to the University of Pennsylvania for use in the next version of Jack. Other contributors include a team at Ames Research Center that has incorporated Jack into MIDAS (Man-machine Integration Design and Analysis), a human factors CAE system, in which he represents a helicopter crewmember.

"The ultimate goal," said Maida, "is a human model exhibiting motion, strength, hearing, voice, and even some cognitive skills." ❑

For more information about the technology described in this article, contact: David P. Harding, University of Pennsylvania, Suite 300, 3700 Market Street, Philadelphia, PA 19104; (215) 898-9585.



Lynn Purser
Orbital Dynamics Analyst
Huntsville, Alabama

"How I Got Started with *Mathematica*®"

I admit, when I first read about *Mathematica*, I was a little skeptical. I guess mathematicians are like anybody else. Sort of like auto workers being replaced by robots—some mathematicians were skeptical of something that might replace them. So when my firm offered an in-house training seminar on *Mathematica*, I decided to see what all the talk was about.

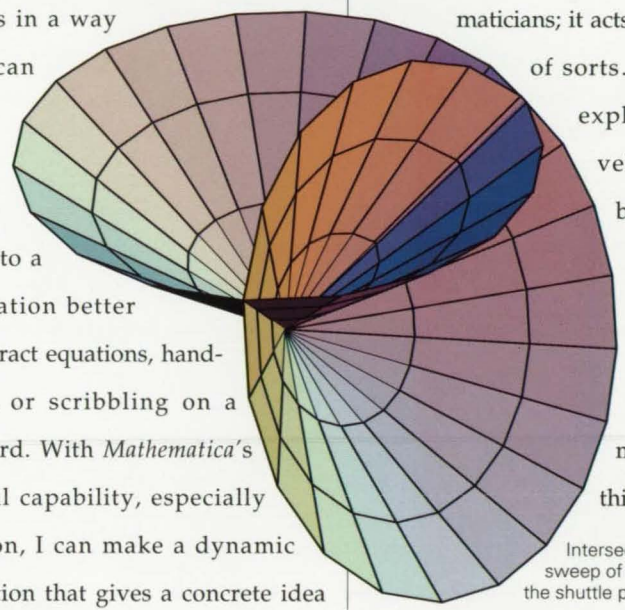
Photo Courtesy of NASA

That class was fun. I tried to do things beyond what the teacher was covering—the rudimentary stuff about *Mathematica* syntax. I wanted to do animation and play with the graphics. I was taken with the visual dimension of it.

Working on NASA projects, I have to solve problems and present my solutions in a way others can understand. People respond to a visualization better than abstract equations, handwaving, or scribbling on a blackboard. With *Mathematica*'s graphical capability, especially animation, I can make a dynamic presentation that gives a concrete idea of what I'm talking about.

Then there's the symbolic power. For example, the first project I tackled with *Mathematica* involved a nasty algebraic equation. I solved it on my own and then let *Mathematica* solve it. We both came up with the same answer. But my solution took a few hours and *Mathematica*'s took a few minutes.

Now I use *Mathematica* regularly. I don't think it will ever replace mathematicians; it acts as an assistant of sorts. It helps you explore and develop concepts, by handling the tedious details. In that way, you're free to concentrate on more important things.



Intersection of fields of sweep of two sensors in the shuttle payload bay.

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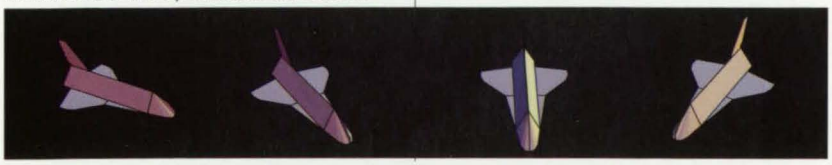

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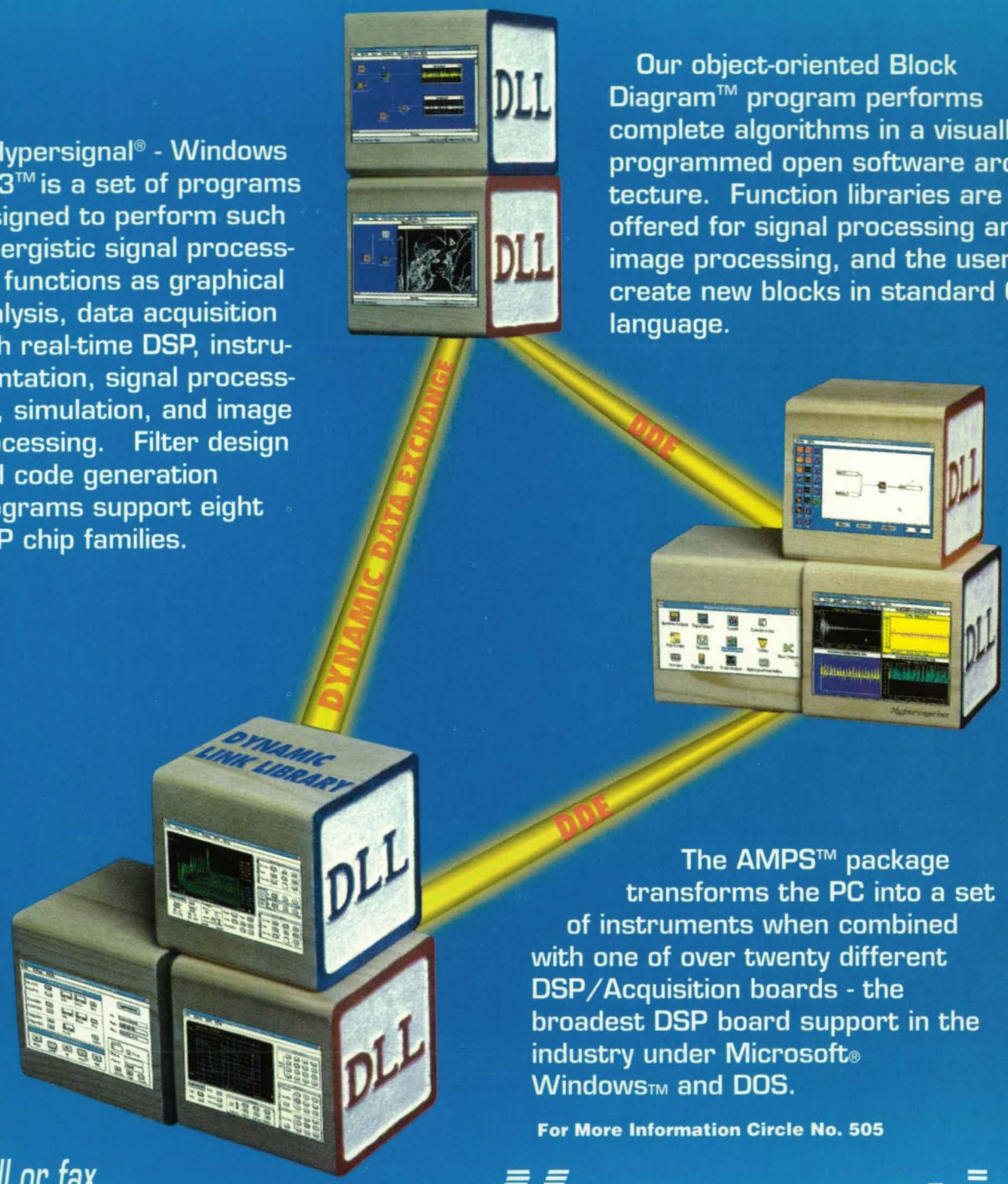

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