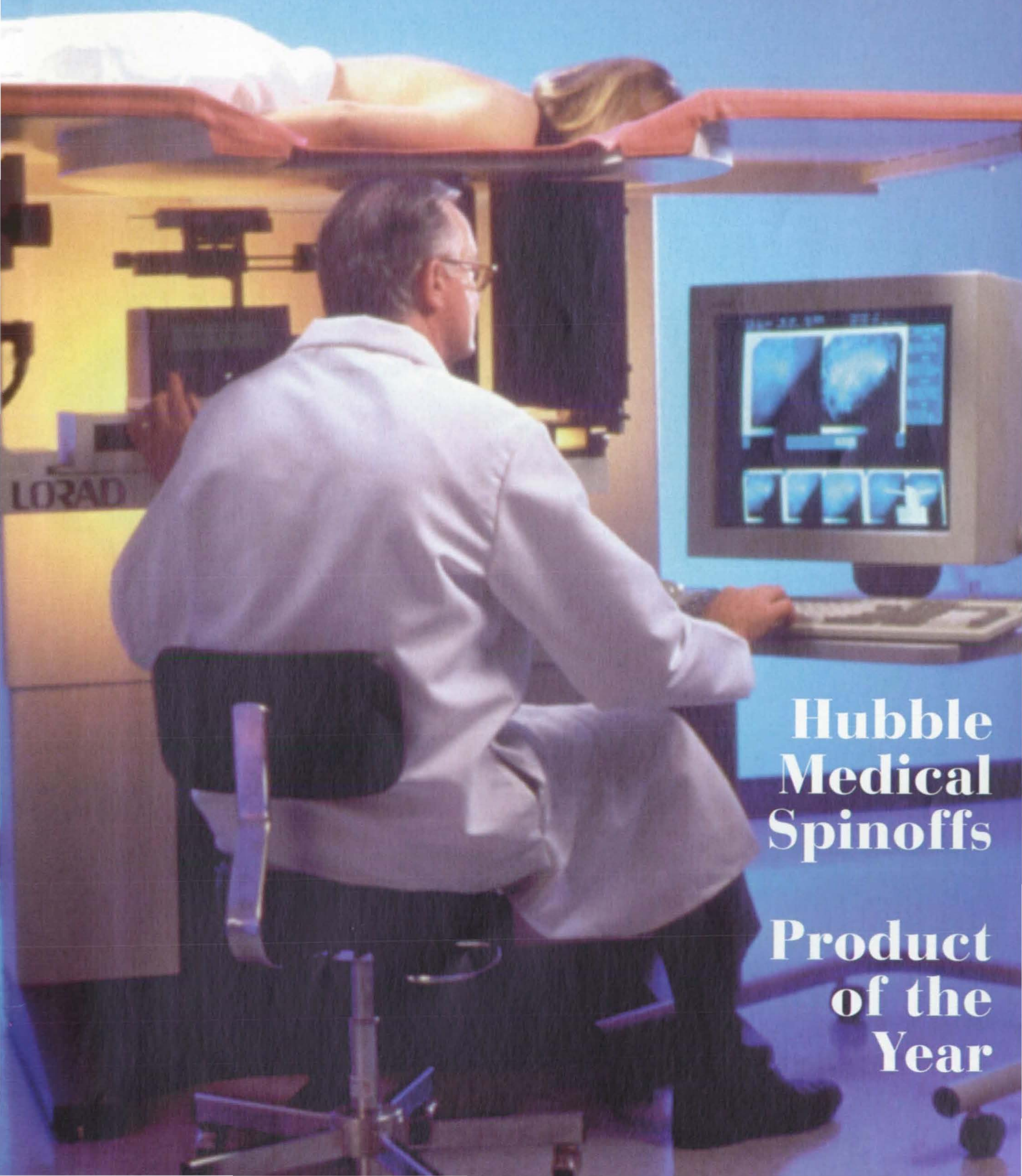
February 1996

Vol. 20 No. 2

NASA Tech Briefs

The Design/Engineering Technology Digest



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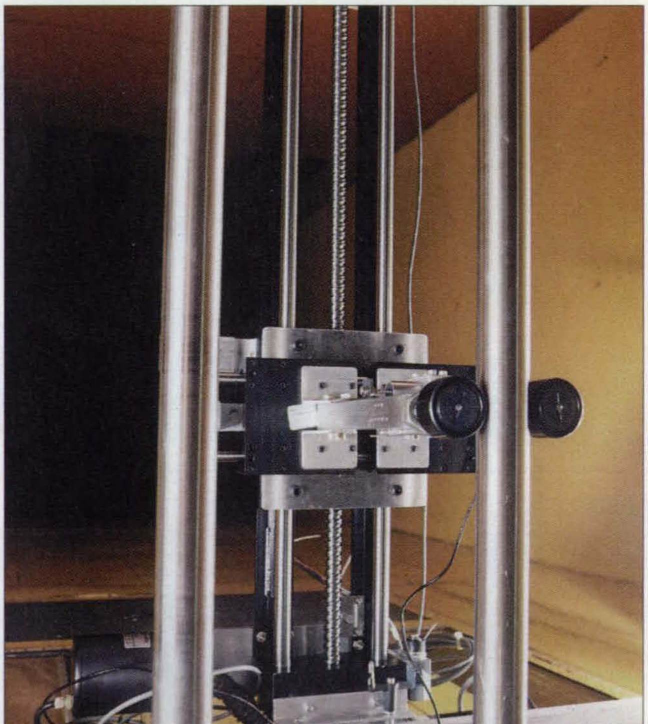

A semiautomated apparatus measures ice thickness in the icing-research tunnel at Lewis Research Center. The measurements determine the degree of uniformity of icing conditions for experiments on aircraft models. Ice accumulates on nine vertical bars, the diameters of which are measured to determine the thickness of the ice. A measuring head travels on rails parallel to a bar. For more information, see the Tech Brief on page 72.

Photo courtesy of Lewis Research Center

Contents *(continued)*

DEPARTMENTS

On the cover:

Research originating from the Hubble Space Telescope has been transferred to new methods of early breast cancer detection. The LORAD Corporation's Stereo Guide™ Breast Biopsy System uses advanced charge coupled device (CCD) technology developed for the Hubble to perform non-surgical needle biopsies. For more information on the LORAD system and other Hubble-derived technologies, see Mission Accomplished on page 18.

Photo courtesy of LORAD Corporation

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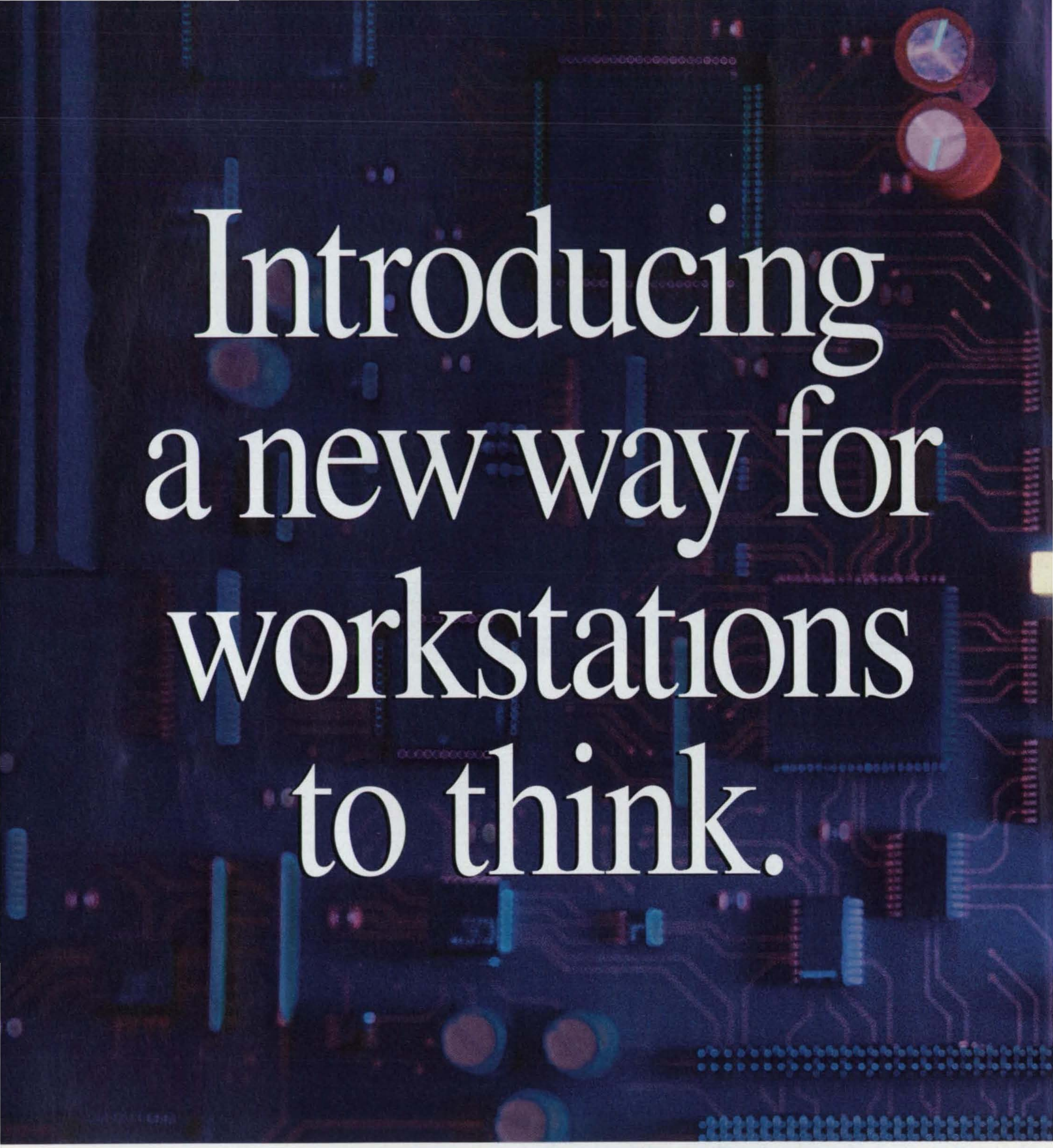

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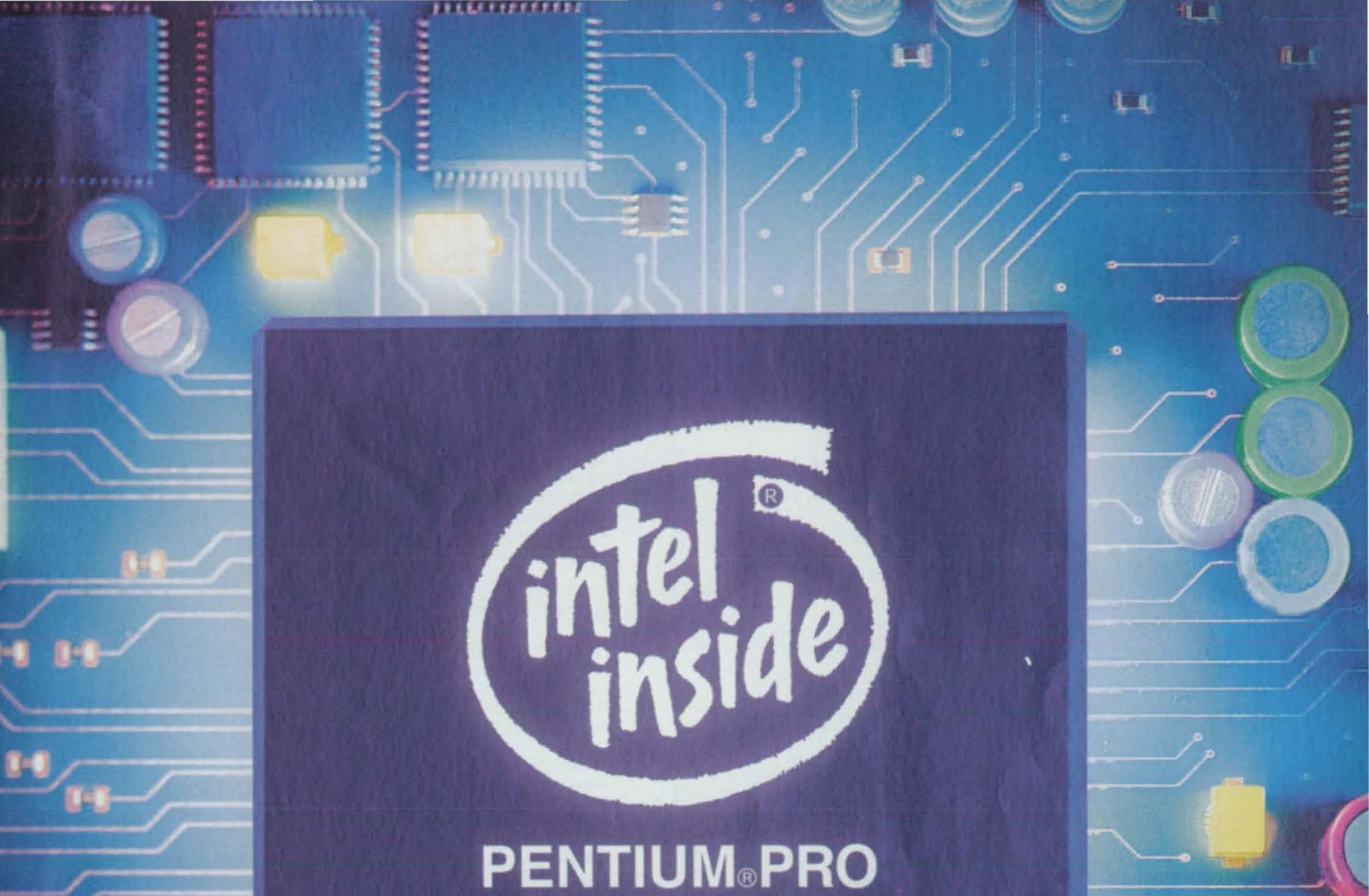
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PATENTS NASA

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Tunable CW Diode-Pumped Tm,Ho:YLF_4 Laser Operating At or Near Room Temperature

(U.S. Patent No. 5,457,706)

Inventors: Brendan T. McGuckin and Robin T. Menzies, Jet Propulsion Laboratory

Eyesafe 2-micrometer holmium lasers have potential in such applications as altimetry, ranging, low-altitude wind-shear detection, and atmospheric remote sensing. But carbon dioxide and water absorption bands overlap the holmium emission spectrum, limiting its range through the atmosphere. The invention inserts a quartz etalon into the laser cavity, permitting tuning into the high-transmissivity regions between the absorption bands. Laser crystal temperature control further refines tuning, and an external reference etalon provides wavelength stabilization.

For More Information Write In No. 750

Rotary Latch

(U.S. Patent No. 5,464,301)

Inventor: Joel M. Kramer, Johnson Space Center

Aeronautical latch systems often involve over-the-center linkages to grab and retain latch pins, have many moving parts, and are relatively expensive. This rotary design totally encloses the latch pin, insuring that loading will not result in premature release of the latch pin, and can be either remotely or manually operated. Designed as an aeronautical launch restraint, the latch can be used in many industrial, commercial, and residential applications.

For More Information Write In No. 751

Preparation of Polymeric Diacetylene Thin Films for Nonlinear Optical Applications

(U.S. Patent No. 5,451,433)

Inventors: Donald O. Frazier, Samuel P. McManus, Mark S. Paley, and David N. Donovan, Marshall Space Flight Center

Though solid-state polymerization of diacetylenes yields attractive nonlinear optical properties, a better way of making both monomeric and polymeric thin films is necessary for practical nonlinear applications. This improved method produces amorphous diacetylene polymeric films by simultaneous polymerization of diacetylene monomers in solution and deposition of them onto the surface of a transparent substrate through which ultraviolet light has been transmitted. The resulting films show high optical quality and exhibit large third-order nonlinear optical susceptibilities.

For More Information Write In No. 752

Circular Electrode Geometry Metal-Semiconductor-Metal Photodetectors

(U.S. Patent No. 5,451,769)

Inventors: James A. McAdoo, Elias Towe, William L. Bishop, and Liang-Guo Wang, Langley Research Center

High-speed metal-semiconductor-metal (MSM) photodetectors operating at speeds of 1 GHz and above have widespread uses in optoelectronic integrated circuits, particularly for telecommunications. But the current rectangular interdigitated electrode design in MSM detectors has disadvantages. Instead, the present device has circular or spiral electrodes, which eliminate "crowding" of electric field ends near the ends of the rectangular electrodes, and better match the usually circular intensity distribution of optical signal sources such as lasers and LEDs.

For More Information Write In No. 753

Carbon-Carbon Grid For Ion Engines

(U.S. Patent No. 5,465,023)

Inventor: Charles E. Garner, Jet Propulsion Laboratory

Present state-of-the-art grid members for use in ion discharge apparatuses are fabricated from molybdenum sheets, but their coefficient of thermal expansion results in thermal distortion that becomes more severe as the grid diameter increases. The new method has woven carbon fibers in a matrix of carbon, with the fibers oriented to provide a negative coefficient of thermal expansion for at least a portion of the grid member's operative range of use.

For More Information Write In No. 754

Control Method for Prosthetic Devices

(U.S. Patent No. 5,458,655)

Inventor: Richard J. Bozeman, Jr., Johnson Space Center

The invention is a control system and associated method for controlling a prosthetic device, particularly for below-the-elbow amputees. Incorporating the widely favored and easy-to-use "shrug" controller, the invention extends the hook-and-cable system's limited control mechanism to one that controls a plurality of sub-prostheses, which in normal use provides for sequential or specific control of each finger digit and for wrist rotation and the like, derived from a transducer actuated by shoulder/back-muscle movement.

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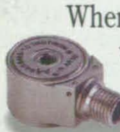
Get A Grip On Your Vibration Measurements.



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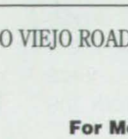

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Mission Accomplished

When the Hubble Space Telescope was deployed on April 24, 1990, it was expected to provide views of the universe unlike any that had ever been obtained using ground-based systems. Today, the Hubble has done just that...and more. In addition to supplying astronomers with breathtaking images and invaluable information on the origins and future of our universe, the Hubble also has made contributions to improve health and quality of life on Earth.

Research originating from the Hubble project has been the basis for two advances in the early detection of breast cancer. A breast biopsy system incorporating digital imaging technology originally developed for the project currently is in use across the country. And image processing software being tested by Space Telescope Science Institute researchers promises to be a significant advance in the detection of microcalcifications—an early sign of breast cancer.

A Space-Based Alternative

Digital imaging technology developed for the Hubble has been transferred to a new, nonsurgical breast biopsy system that is less traumatic and greatly reduces the pain, scarring, radiation exposure, time, and money associated with surgical biopsies. Called stereotactic large-core needle biopsy, the technique is performed using a needle rather than a scalpel, and creates only a small puncture wound. Instead of requiring general anesthesia, the patient is conscious under a local anesthesia.

The traditional surgical biopsy involves a guide wire that is run into the breast to isolate the mass. The surgeon follows the wire and digs out a sample of tissue. Recuperation time is about one week, and subjects the patient to a significant amount of suturing and scarring.

The Charge-Coupled Device (CCD) imager used in the new system comprises silicon chips that convert light directly into an electronic or digital image that can be manipulated and enhanced on a computer. During the development of the Hubble Space Telescope Imaging Spectrograph (STIS), which is scheduled to be installed on the Hubble in 1997, scientists at NASA's Goddard Space Flight Center in Maryland discovered that the existing CCD technology would not be sufficient for the Hubble's requirements. NASA contracted with Scientific Imaging Technologies (SITe) of Beaverton, OR, to further develop the CCD, making it more sensitive at a lower cost. Since mammography and astronomy share some common imaging requirements—high resolution to detect small details, and capturing structures spanning various brightness levels in a single image—using the CCD for mammography was a logical transfer of the technology. SITe applied the technology to manufacturing CCDs for digital spot mammography, providing breast tissue images that are sharper than any obtained through conventional x-rays. Although stereotactic biopsies were performed before the improvement of the CCD, the technique has been refined to take less time. Previously, two x-rays were taken and developed, then measurements were obtained from the film images, which were fed through a computer to find the coordinates of the abnormal mass. The process took about 15 to 20 minutes, during which time the patient had to remain immobile.

At Technology 2005 last October, Mark Jaster (right), commercialization manager of the Hubble Space Telescope Project, described the Hubble's technology spinoffs to NASA Administrator Daniel Goldin.

Using SITe's improved CCD, LORAD Corporation of Danbury, CT (203-731-8350) developed the LORAD Stereo Guide™ Breast Biopsy System. It incorporates a special phosphor that enables the CCD to convert x-rays to visible light, providing x-ray vision for the digital camera.

The digital camera locates the abnormality, the radiologist takes images of the mass from two different angles, and the computer finds the coordinates of the mass based on the two images. The patient lies face down on a specially designed table, under which the imaging device and needle are mounted. A small sample of the mass is extracted with the needle. The patient can leave the office after the procedure, with only a small puncture wound and no recuperation time. The digital images are stored on computer disks and may be downloaded to other locations.

The patient is exposed to only half the radiation of the conventional x-ray technique, since digital imaging exposes only a small portion of the breast to radiation. And unlike x-ray film, digital images can be enhanced by computer, allowing evaluation almost immediately.

Needle biopsy procedure time is reduced by one-half to one-third, and the cost is reduced from about $3500 for the surgical procedure to about $850 for the non-surgical method. Use of the new technique could save $1 billion in national health care costs, since each year more than 500,000 American women require breast biopsies.

More than 600 LORAD systems are in use in the US, and 200 additional systems are scheduled to begin operation in clinics and hospitals this year. New applications for the SITe CCD technology in medical devices and industrial/scientific equipment are under development.

For information on CCD technology, contact Barry Rahimian at SITe; Tel: 503-671-7100.

Cancer Detection In Focus

Two months after the Hubble Space Telescope was launched in 1990, engineers discovered that the 94-inch main mirror was flawed, causing light collected by the mirror to be spread into a fuzzy halo instead of being focused to a sharp point. This situation, while of significant concern to astronomers, actually was the catalyst for a major development in the early detection of breast cancer.

Researchers at the Space Telescope Science Institute (STScI) in Baltimore were called upon to develop image processing software to correct the Hubble's loss of dynamic range and spatial resolution. As a result, the STScI scientists—along with medical researchers from Johns Hopkins University and the Lombardi Cancer Research Center at Georgetown University Medical Center in Washington, DC—have developed and are testing a technique to detect microcalcifications in digitized mammograms.

Dr. Benjamin Snavely, program director for advanced technologies and instrumentation in astronomical sciences at the National Science Foundation (NSF), discovered that some medical images used by the Lombardi Center were similar to astronomical images obtained by STScI scientists from the Hubble. He further determined that detecting a microcalcification was similar to locating a faint star in a blurry telescope image. Dr. Snavely arranged for researchers from STScI and Lombardi Center to combine their respective disciplines to develop the image processing technique. The collaboration was awarded a $50,000 grant from the NSF.

The technique was used by Drs. Robert Hanisch and Richard White of STScI to identify calcifications in four separate test cases. The testing involved variance normalization, a technique that the STScI researchers had advanced much further than the medical team. Additional tests will be run against standard digitized mammograms, measuring overall performance in comparison to other microcalcification detection methods. The new technique would greatly improve on the conventional visual inspection method of detecting lesions, which carries a risk of human error.

More Stellar Progress

In addition to medical advances, the Hubble Space Telescope Project has been the driving force behind a significant partnership between the semiconductor industry and NASA that would combine efforts in developing new fabrication capabilities in ultra-precision optics for use in microlithography equipment and scientific spacecraft. According to Mark Jaster, Hubble Space Telescope commercialization manager, the initiative progressed in 1995 from a white paper to the formation of a national team with a partnership agreement under review and industrial funding of $360,000. If successful, the partnership will save resources for both NASA and the semiconductor industry, reduce risk to future NASA space science missions, and enhance US semiconductor industry competitiveness.

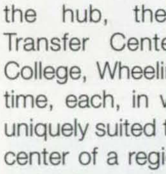
Sensors developed for future instruments on the Hubble may be used to identify worn high-voltage power line insulation. An average region suffers power outages 38 times within a year, primarily due to aging, ineffective line insulation. Last year, the Multi Anode Microchannel Array (MAMA) sensor technology moved from the proposal stage through a market study and proof-of-concept testing, which proved that the device is effective for detecting the corona of escaping electricity in daylight, and may be superior to current detection methods. Studies will continue this year to determine if the device can be priced competitively for the marketplace.

For more information on Hubble-derived technologies, contact Mark Jaster at NASA's Goddard Space Flight Center, Hubble Space Telescope Project; Tel: 301-286-9232.

NASA's Regional Technology Transfer Centers

"A network within a network." That is how the staff at the Center for Technology Commercialization (CTC) aptly describes its role as one of the six NASA Regional Technology Transfer Centers (RTTCs). Each of them reaches out to its national brethren, as well as to the hub, the National Technology Transfer Center at Wheeling Jesuit College, Wheeling, WV. But at the same time, each, in ways that are similar but uniquely suited to its locale, stands at the center of a regional network linking federal laboratories with state and local agencies, universities, and businesses.

The RTTCs, funded by NASA and aligned with the six Federal Laboratory Consortium regions, opened their doors in January 1992. Since then they have established regional ties to more than 70 state and local organizations, creating a national web to enable U.S. companies to learn of, evaluate, and acquire NASA and other federally-funded technologies for commercial exploitation.



Center for Technology Commercialization (CTC)

CTC, serving the Northeast from Westborough, MA, defines its mission as making American companies more competitive worldwide through market-driven product and process definition, technology acquisition, and product commercialization. The corporation's "inner" network comprises eight Satellite Technology Transfer Centers located in the six New England states, New York, and New Jersey. These are responsible for knowing industrial market needs and capabilities, opportunities, and programs throughout their local areas.

CTC's NASA Business Outreach Program, established in 1993, acts as advocate for Northeast businesses in seeking contracting opportunities with NASA and its prime contractors. The program focuses on small, minority-owned, and woman-owned firms to help them realize the full potential of NASA opportunities for their products, services, and technology areas.

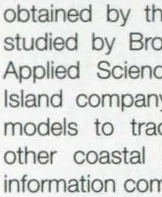
CTC also participates in the Advanced Research Projects Agency's TAP-IN, a program that helps small defense-related companies develop commercial products, enter new markets, and find commercial applications for defense technology. Other resources include CTC's Technical Information Center, which facilitates technology, marketing, and patent research, and document and patent delivery.

Since its inception in 1992, CTC has established four new companies, licensed 26 NASA and federally-funded technologies to private industry, completed 51 partnership agreements between federal laboratories and private companies, provided technical and commercialization services to more than 3000 Northeast companies, assisted small businesses in raising more than $3 million in capital, and helped Fortune 500 companies obtain $1.5 billion in new contracts.

The center helped arrange a three-year $1-million collaboration between Brown University and NASA in which remote sensing data of Narragansett Bay obtained by the space agency will be studied by Brown geological scientists. Applied Science Associates, a Rhode Island company that designs computer models to track water pollutants and other coastal activities, will apply the information commercially.

In another instance, a member of CTC's network assisted in the transfer of satellite antenna technology developed by NASA to KVH Industries, another Rhode Island firm, which will manufacture units for recreational vehicles and trucks. Furthermore, the prominent toy maker Hasbro, after contacting the CTC for help in improving the airworthiness of a flying foam glider, joined with NASA Langley Research Center scientists in a successful collaboration.

For more information: CTC, 1400 Computer Drive, Westborough, MA 01881-5043; (508) 870-0042; Fax (508) 366-0101; William Gasko, director.



Mid-Atlantic Technology Applications Center (MTAC)

Headquartered at the University of Pittsburgh, MTAC calls itself a champion for its industrial clients, aiding them in locating, assessing, acquiring, and commercializing technologies and expertise in the federal laboratory system. Its watchword is its "Cradle to Success" service, in which it provides assistance from the identification of technologies to their use in a product or process.

Recent initiatives include MTAC's efforts to find potential partners to commercialize NASA Langley's LaRC-SI, a moldable, soluble, strong, and crack-resistant polymer with promise for many kinds of protective coatings. (See "NASA Innovations," *NASA Tech Briefs*, October 1995, page 22.) MTAC also is aiding NASA Langley in a similar search involving THUNDER, a high-displacement piezoelectric actuator. Cooperative opportunity program sessions early this year will disclose these new materials to industry, paving the way for licensing their manufacture.

After four Pittsburgh firefighters died in the line of duty in 1994, MTAC coordinated an agreement between the city's Bureau of Fire and NASA Langley in a multifaceted effort to find technologies to improve firefighter safety equipment. Innovations being investigated include an advanced tracking system for locating personnel and equipment in a burning structure; noise reduction and control technologies to improve communications with the on-scene command post; in-mask carbon monoxide management through application of Langley's low-temperature oxidation catalyst, coupled with a warning system; and new lightweight, heat-resistant and self-extinguishing materials for use in equipment, clothing, and hoses.

In the biomedical area, MTAC recently helped a startup company commercialize a portable, handheld noninstrumental immunoassay, and located a test facility for a company designing an accelerometer. MTAC now is helping the Pittsburgh Tissue Engineering Initiative to locate federal technologies associated with engineered tissue, including cell culturing, gene therapy, and organ transplants and regeneration.

Late last year, the center facilitated the signing of a cooperative R&D agreement between the Department of Energy's Pittsburgh Energy Technology Center and Cetek, a Transfer, PA, company, through which Cetek will use the former's facilities to test coatings on advanced combustion systems.

For more information: MTAC, University of Pittsburgh, 823 William Pitt Union, Pittsburgh, PA 16260; (412) 648-7000; Fax (412) 648-7003; Lani S. Hummel, executive director.

Southern Technology Applications Center (STAC)

STAC, housed at the University of Florida's College of Engineering in Alachua, FL, works to expedite technology transfer and economic development throughout the nine southeastern states: Alabama, Florida, Georgia, Kentucky, Louisiana, Mississippi, North and South Carolina, and Tennessee.

STAC's networks crisscross the region in various ways. It recently formed the Southeast Regional Technology Transfer Alliance with the three NASA field centers in its region—Kennedy Space Center, Marshall Space Flight Center, and Stennis Space Center—to leverage NASA technology through bilateral understandings with state economic development agencies, chambers of commerce, small-business development agencies, and others. In the past each member had pursued specific technology transfer endeavors, but the Alliance will bring their combined resources to bear on specific problems.

STAC's Alabama affiliate helped Eggstra Enterprises locate a foam rubber technology developed by NASA for the seats of fighter jets that improved the marketability of its product while reducing the cost of production. As a result, the company expects sales of its "Egg-sercizer" handheld therapeutic wrist and hand exerciser to increase two- to three-fold over the next 18 months.

In an ongoing initiative with NASA Stennis, the Louisiana Business and Technology Center, a STAC affiliate, has helped Cryopolymers Inc. to improve a process used in recycling tires, facilitating the reduction of rubber to "crumb" that can be used in road surfacing, agricultural hose, and culvert piping.

STAC also serves as a mechanism for delivery of federally- and state-funded R&D to the private, academic, and public sectors. Recently the Economic Development Administration (EDA) awarded STAC a grant, matched by the University of Florida, to establish a University Center for Technical Assistance to promote the private-sector use of university and other federal technology.

For more information: STAC, University of Florida College of Engineering, One Progress Blvd., Box 24, Alachua, FL 32615; (904) 462-3913; Fax (904) 462-3898; J. Ronald Thornton, director.

Great Lakes Industrial Technology Center (GLITeC)

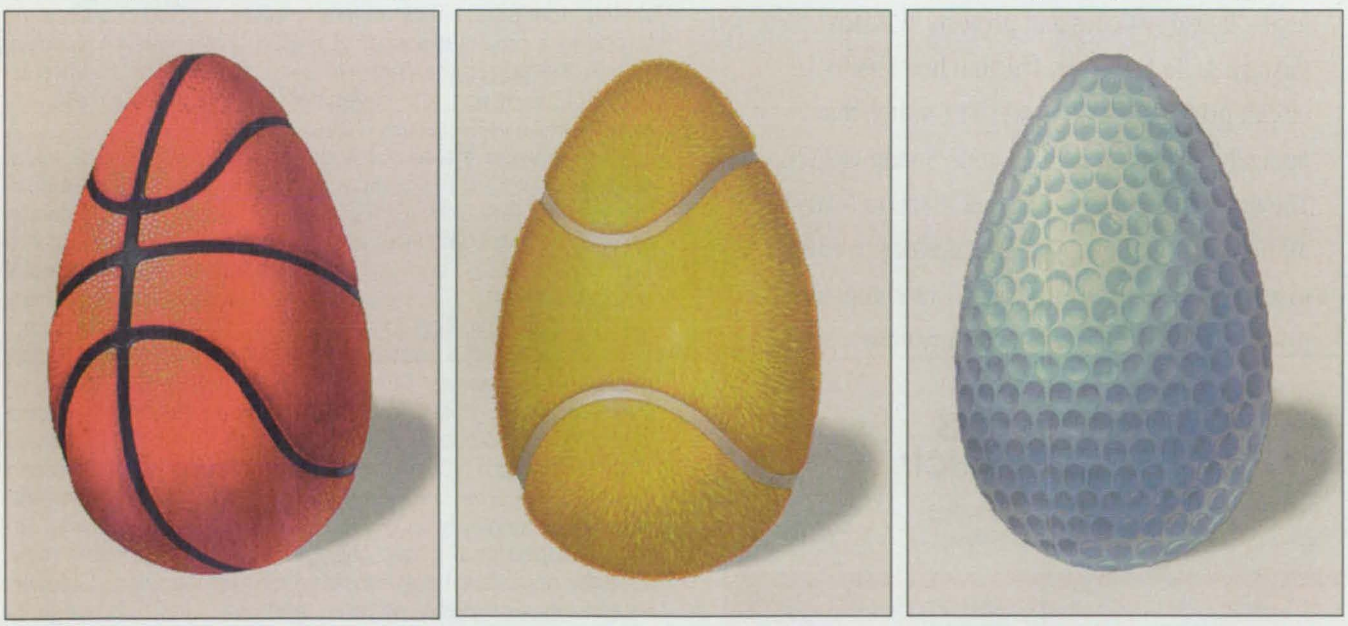
Battelle, the world's largest not-for-profit industrial R&D organization, hosts NASA's midwest RTTC. GLITeC, located in Cleveland, OH, helps industry access NASA and other federal technology and expertise in Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin. A random sampling over a single year showed that GLITeC saved its clients as much as $2-4 million through 236 instances of transfer or commercialization of NASA expertise and knowledge.

Working with GLITeC and NASA's Lewis Research Center (LeRC) in Cleveland, an Ohio company is adapting LeRC composite mechanics software to model concrete microstructures and predict mechanical performance under structural loads. Lewis is extending the reach of the collaboration by modifying its Integrated Composite Analyzer software for polymer matrix composites.

In another case, a Lewis-developed material helped a Michigan company expand its product line. GLITeC arranged for Lewis's technical counseling, testing, and data on the microstructure and metallurgy of LeRC's palladium-chromium alloy to be used as a wire filament for a unique high-temperature strain gauge. The company now manufactures its Harsh Environment Weldable Gauge based on the alloy.

GLITeC and Lewis have assembled the Advanced Coatings and Surface Texturing Consortium, whose members receive a detailed state-of-the-art evaluation of surface treatment technology, as well as consulting and research services tailored to their specific interests. Through the consortium, GLITeC and Lewis are enabling a major manufacturer of medical devices to apply surface modification technology to plastics to expand their use in disposable medical products.

The Chicago Fire Department gave GLITeC a list of technical needs that would improve fire safety, and enlisted its help in finding technologies, manufacturers, and financing. In collaboration with Stennis, GLITeC is pursuing commercialization and application of a device to identify invisible hydrogen and alcohol fires. Anticipating delivery of a prototype to the



The Southern Technology Applications Center was the conduit for transfer of a foam rubber technology developed by NASA to a company that makes these wrist and hand "Egg-sercizers" in various shapes for the sports-minded.

fire department early this year, the team is looking for a commercial partner to license the technology and design a product.

For more information: GLITeC, Battelle Memorial Institute, 25000 Great Northern Corporate Center, Suite 450, Cleveland, OH 44070-5310; (216) 734-0094; Fax (216) 734-0686; Christopher Coburn, executive director.

Mid-Continent Technology Transfer Center (MCTTC)

From its headquarters at Texas A&M University System's Engineering Extension Service in College Station, MCTTC encompasses the largest area of any RTTC, serving fourteen states: Montana, North and South Dakota, Wyoming, Colorado, Nebraska, Iowa, Utah, Kansas, Missouri, New Mexico, Oklahoma, Arkansas, and Texas. MCTTC is at the center of a consortium whose affiliates include the Extension Service's Technology and Economic Development Division, the University of Houston—Clear Lake, the Midwest Research Institute, SaraTech Finance Inc., and the Economic Council of St. Louis County.

Through another of its affiliates, Knowledge Based Systems Inc. (KBSI), also in College Station, MCTTC has a direct impact on the small business community. KBSI is an information systems engineering, modelling, and software development company that specializes in integrated business methods, tools, training, and infrastructure consulting. One of KBSI's clients is the Small Business Accelerator Facility (SBAF), located in a former Texas Instruments plant in College Station. SBAF provides an environment in which small agile manufacturers can refine their manufacturing, information systems, and business practices. KBSI provides liaison between SBAF-housed companies and the MCTTC, and between the companies and the CALS Shared Resources Center in Orange, TX.

One example of the way MCTTC brings together startup commercial enterprises and NASA expertise is CarterCopters Inc. of Wichita Falls, TX. Jay Carter Jr., the company's president and chief designer, approached the center with his innovative design for an aircraft combining a rotor with a fixed wing and propeller that he said would be able to take off vertically, cruise nonstop at 45,000 ft. from Los Angeles to New York at speeds up to 400 mph, and land vertically anywhere, even downtown. MCTTC's initial commercialization assessment was positive, seeing great potential for general aviation. For technical savvy it turned to a project manager at the CTC who was knowledgeable in the aerospace field. He soon became an ardent supporter of the design, and paved the way for Carter to meet with experts at Ames Research Center.

After verifying the aircraft's design and performance tests, Ames encouraged the company to apply for a Small Business Innovation Research (SBIR) grant. CarterCopters received Phase I funding from NASA last fall. Carter got further help on a business strategy and the identification of venture capital sources from MCTTC, and speculates that with private financial support a prototype could be in the air by the end of the year.

It was just such a combination of public and private support that enabled Gateway Technologies of Boulder, CO, to get on its feet. The company licensed enhanced thermal insulation technology developed by Triangle Research and Development Corp. of Raleigh, NC, under SBIR agreements with NASA and the Air Force. The crucial ingredient in their textile fibers and substrates, originally intended for use in space gloves, are microencapsulated phase-change materials that raise heat capacity and slow heat transfer. From its founding, Gateway sought private industry partners, and calls MCTTC's role in its commercialization efforts crucial to its success in lining up sev-

continued on page 85

New Product Ideas

New Product Ideas are just a few of the many innovations described in this issue of *NASA Tech Briefs* and having promising commercial applications. Each is discussed further on the referenced page in the appropriate section in this issue. If you are interested in developing a product from these or other NASA innovations, you can receive further technical information by requesting the TSP referenced at the end of the full-length article or by writing the Commercial Technology Office of the sponsoring NASA center (see page 14).

Cultivating Insect Cells To Produce Recombinant Proteins

Insect cells are grown in a bioreactor and infected with viruses containing selected genes. The genes encode the production of the desired proteins. Use of the insect cells makes the process versatile enough for the production of a wide variety of functional proteins. (See page 79.)

Small, Lightweight Inspection Robot With 12 Degrees of Freedom

A small serpentine robot is designed to perform inspections. The robot can reach around obstacles and through small openings into simple or complexly shaped spaces. (See page 73.)

Coating Silicon-Based Ceramics With Durable Mullite

An improved plasma-spraying process deposits mullite on silicon carbide substrates. These coats are highly desirable for ceramic structural components of heat exchangers, gas turbine engines, and advanced internal-combustion engines. (See page 54.)

Rotary Release Mechanism With Fusible Link

Using an alloy that melts at relatively low temperature, this link couples and uncouples two shafts by merely controlling its temperature. (See page 68.)

Iridium Aluminide Coats for Protection Against Oxidation

Investigated as potentially cost-effective antioxidation coats for the walls of combustion chambers of rocket engines, iridium aluminide coats may also prove useful in laboratory combustion chambers and some chemical-processing chambers. (See page 57.)

Micromachined Ion Accelerators

Advantages include small size and weight, modularity, and compatibility with integrated circuits. Originally intended as thrusters aboard small spacecraft, these accelerators could also be used as sources of ion beams for industrial processes. (See page 36.)

Test-Aerosol Generator for Calibrating Particle Counters

Cheap, widely available medical nebulizers are used to generate the aerosols.

John F. Kennedy Space Center, Florida

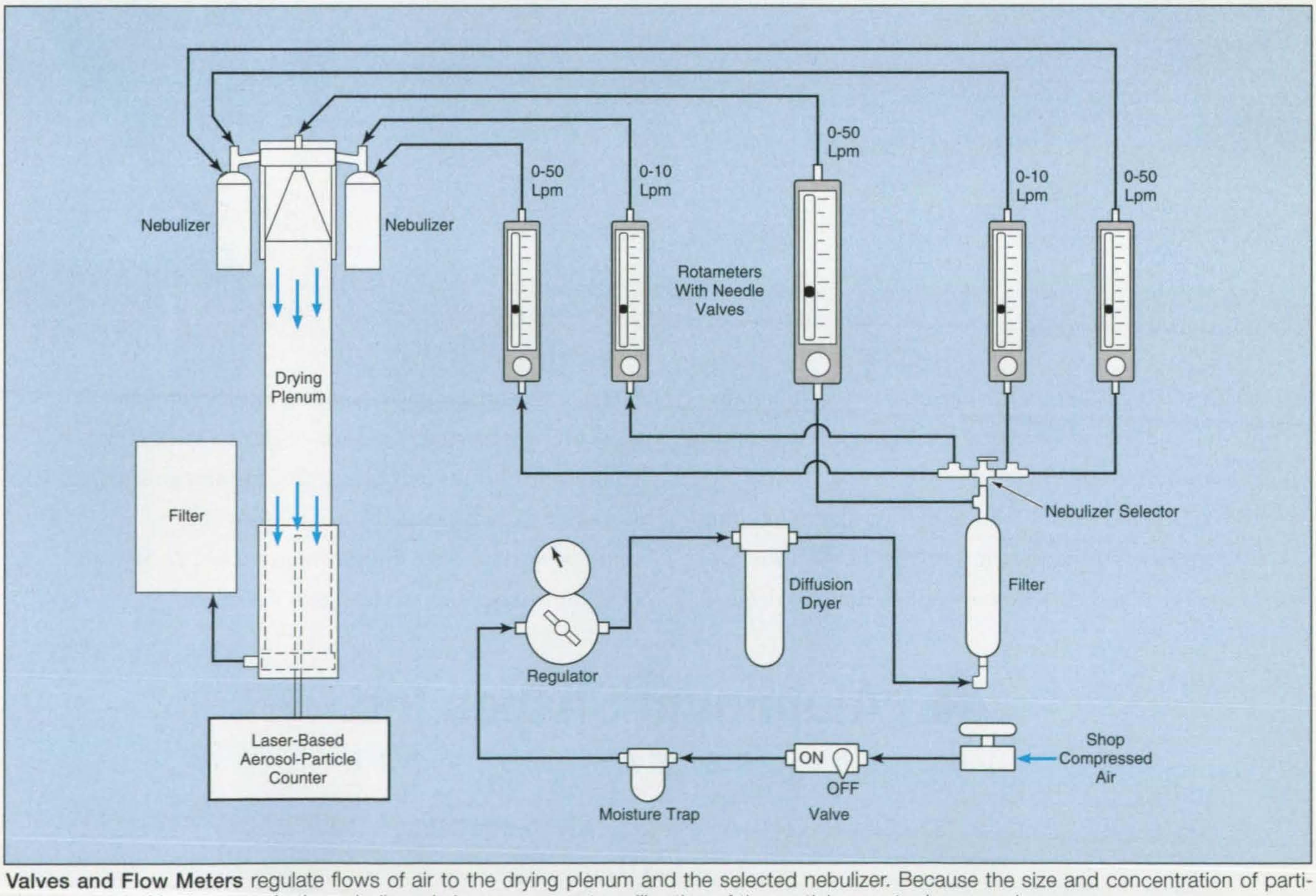
An apparatus generates a clean, stable aerosol stream for use in testing and calibrating a laser-based aerosol-particle counter. The size and concentration of the aerosol particles can be controlled to ensure accurate calibration.

The apparatus (see figure) includes two nebulizers mounted on top of a drying plenum in the form of a vertical cylinder. These are standard, cheap nebulizers of the type used for respiratory therapy. One of the nebulizers is selected for use in a given test or calibration run. Flows of air into the plenum and into the selected nebulizer are powered by compressed air [typically at a gauge pressure between 30 and 50 psi (207 and 345 kPa, respectively)] that has been filtered, dried, and regulated [typically to a gauge pressure between 10 and 15 psi (69 and 103 kPa, respectively)]. Each of the two flows of filtered, regulated air to the selected nebulizer and the flow to the plenum is individually measured and controlled by use of a rotameter with a needle valve.

Each nebulizer includes a reservoir of water in which polystyrene latex spheres of the desired size (typically, a chosen diameter between 0.5 and 7 μm) have been suspended in the desired concentration. The nebulizer includes an atomizer. In the selected nebulizer, flowing air is mixed with the water/particle suspension to form a fog of droplets so small that they can remain suspended in air for a long time. This fog is the source of the desired aerosol.

As the fog descends along the vertical axis of the drying plenum, the water droplets evaporate and the flow of fog or aerosol becomes laminar, resulting in a laminar flow of polystyrene-latex-sphere aerosol at the bottom of the drying plenum. This flowing aerosol is sampled by use of an isokinetic-sampling tube, the outlet of which is connected to the aerosol-particle counter to be tested or calibrated.

This work was done by Paul A. Mogan of **Kennedy Space Center**; *Alois J. Adams of the University of Arkansas at Little Rock; Christian J. Schwindt, Timothy R. Hodge, and Tim J. Mallow of I-NET; and Anh A. Duong and Vyto V. Bukauskas of McDonnell Douglas Space & Defense Systems. For further information,* ***write in 30*** *on the TSP Request Card. KSC-11701*



Valves and Flow Meters regulate flows of air to the drying plenum and the selected nebulizer. Because the size and concentration of particles suspended in the water in the nebulizers is known, accurate calibration of the particle counter is assured.

Laser-Scan Ultrasonic/Thermographic Inspection System

This system would reveal hidden defects.

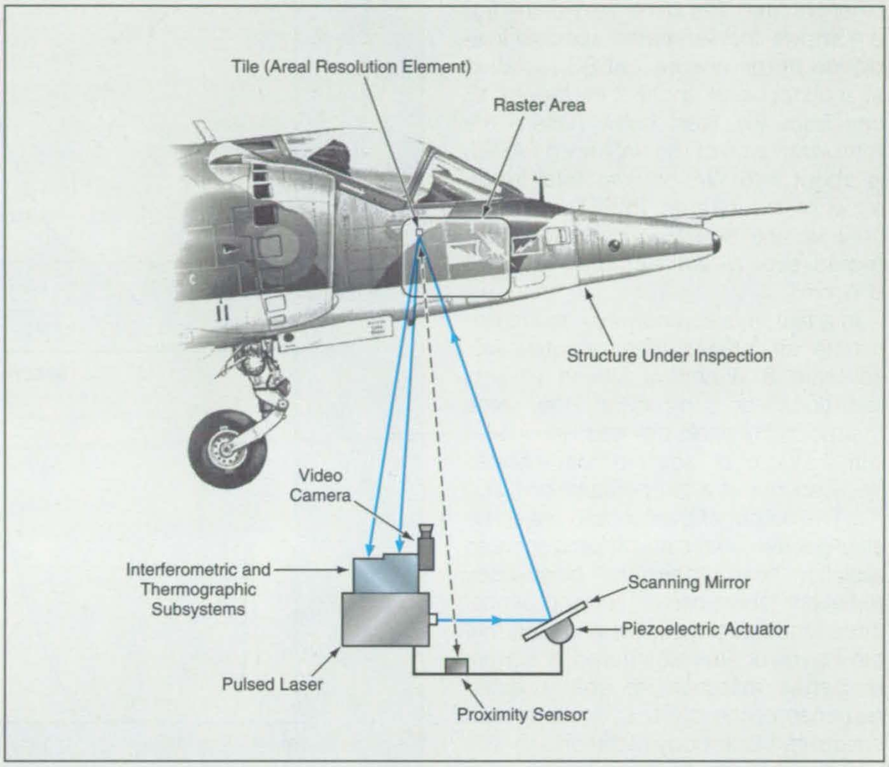
NASA's Jet Propulsion Laboratory, Pasadena, California

The laser ultrasonic/thermographic inspection system is a conceptual instrument that would be used in nondestructive inspection of large areas of structures for subsurface defects. For example, it would be operated in the field to examine aircraft and pressure vessels for hidden cracks. Unlike some other inspection apparatuses based wholly or partly on ultrasonic probing of material specimens, this system would not require contact with the inspected structure or the use of an ultrasonic-coupling medium. The instrument would obtain data in ultrasonic and thermographic C-scans over structural surfaces with contours characterized by surface normal vectors that vary by angles as large as 45°.

A high-power pulsed laser beam would be scanned across a structural surface of interest in a raster pattern, by use of a scanning mirror on piezoelectric actuators. The laser pulses would induce ultrasonic pulses that would propagate through the structure and be reflected by discontinuities. The small ultrasonic surface displacements would be measured interferometrically and would be converted to digital electronic signals for further processing. To set the length scale for the image synthesized from the scan, an interferometric proximity sensor would measure the distance from the instrument to the scanned surface.

Simultaneously, thermographic data would be collected by a thermographic-analyzer subsystem. These data would be processed to determine the reflectivity of the surface to detect surface anomalies to correct the ultrasonic measurements. The thermographic data would also be processed to monitor thermal diffusivity to obtain additional information about defects that are hidden behind the surface and manifest themselves as thermal discontinuities.

An expert-system computer program would analyze the ultrasonic and thermographic data and generate a subsurface-defect image of each tile (areal resolution element) of the raster scan. A miniature video camera would provide an image of the structure and of each tile on the structure, so that each tile could be located in proper geometric relationship with the other tiles in generating the subsurface-defect image of the entire scanned area of the structure.



Ultrasonic Vibrations would be induced by a pulsed, raster-scanned laser beam and would be measured interferometrically. The scanned surface would also be observed thermographically. The data from ultrasonic and thermographic measurements would be fused into an image of subsurface defects in the scanned structure.

This work was done by Yoseph Bar-Cohen and Neville Marzwell of Caltech, Tom Chung of TRW, and Greg Carman of UCLA for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 15*** *on the TSP Request Card. NPO-19260*

Infrared Source for Testing Thermophotovoltaic Cells

An infrared band-pass filter is placed in front of flash lamps.

NASA's Jet Propulsion Laboratory, Pasadena, California

A source of pulsed infrared radiation for testing arrays of thermophotovoltaic cells has been obtained by placing an infrared band-pass filter in front of the large-area pulsed solar simulator (LAPSS) at NASA's Jet Propulsion Laboratory. The source provides infrared radiation within the required infrared spectral region, at the required intensity and approximate spatial uniformity, over a minimum area of 4 by 4 in. (10 by 10 cm).

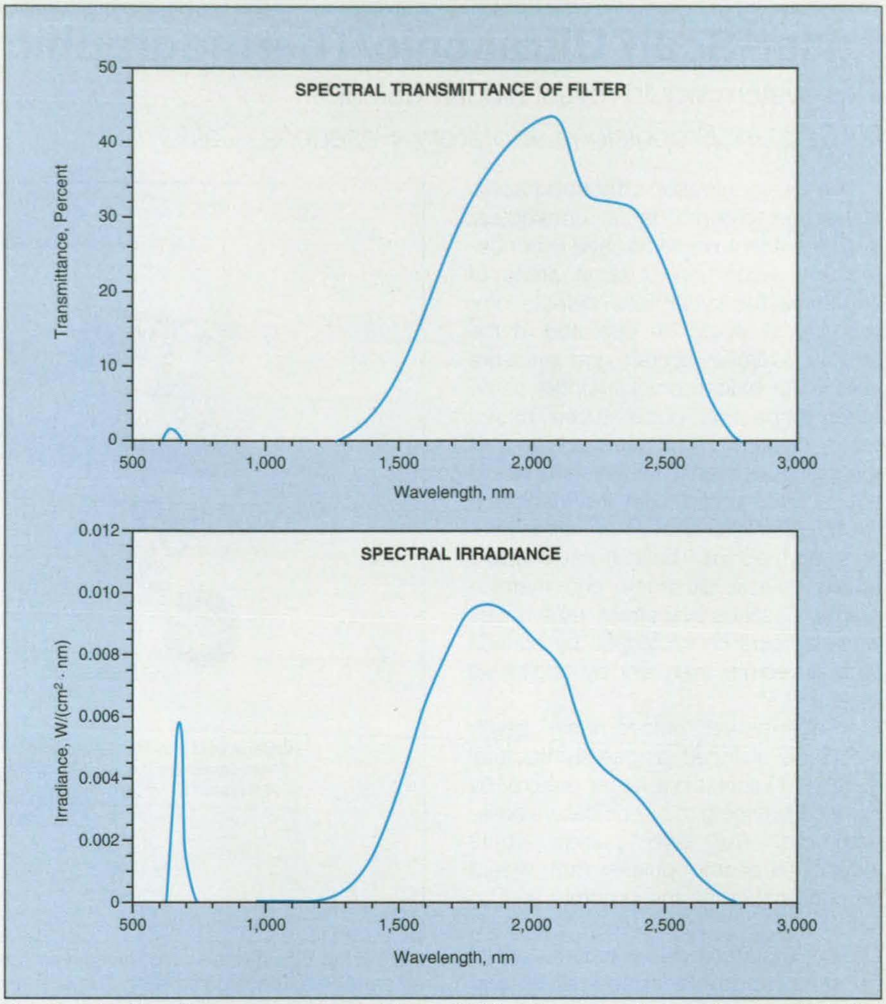
This LAPSS, which has been described previously in *NASA Tech Briefs*, was originally designed to provide intense, pulsed radiation with a close approximation to the solar spectrum and nearly uniform intensity over an area large enough for testing arrays of photovoltaic cells. It includes two flash lamps, placed about 6 in. (about 15 cm) apart, that are pulsed for a period of 1.5 ms — long enough to measure the electrical characteristics of the cells but short enough to prevent significant heating of the cells.

The infrared band-pass filter for

testing thermophotovoltaic cells is made by combining a blue/green band-pass glass absorption filter with a red/infrared band-pass glass absorption filter. The upper part of the figure shows the transmission spectrum of the combination filter. The lower part of the figure shows the estimated spectral irradiance of the filtered LAPSS radiation at a distance of about 7 in. (about 18 cm) from the flash bulbs, where the total irradiance of the unfiltered LAPSS is about 435 W/cm^2. The total irradiance of the filtered LAPSS radiation (that is, the spectral irradiance integrated over all wavelengths) is about 8 W/cm^2.

In a test, this source was used to illuminate an InGaAs thermophotovoltaic cell with 8 W/cm^2 of filtered infrared radiation. For comparison, the same thermophotovoltaic cell was illuminated with 7 W/cm^2 of radiation from a black-body source at a temperature of 1,200 °C. The output of the cell was considerably greater under the filtered infrared radiation than under the black-body radiation (short-circuit current almost three times as large); this confirms that the narrower filtered infrared spectrum is better matched to the spectral response of the cell than is the broad-spectrum black-body radiation.

This work was done by James J. Lin and Robert L. Mueller of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 34*** *on the TSP Request Card. NPO-19493*



The **Spectral Irradiance** was computed by multiplying the spectral transmittance of the filter by a gray-body approximation of the LAPSS spectrum and by a correction factor. The peak in the spectral irradiance at 660 nm can be eliminated by replacing the red/infrared component of the filter with a black glass infrared filter.

Holographic Vibration Testing With Video/Computer Imaging

Results are available sooner than in a prior all-photographic version.

Lewis Research Center, Cleveland, Ohio

In an improved system for holographic vibration testing, holographic interferograms that indicate the shapes of vibrational modes are recorded by a video camera under computer control. This system makes results available almost immediately, and the images can be distributed simultaneously to multiple computer terminals connected to the vibration-testing computer via a local-area network.

This system was designed to replace a prior photography-based system for identifying natural vibrational modes of propfan blades, and obviously could be adapted to similar vibration testing of other objects. The prior system yielded results more slowly because it involved photographic recording of the interferograms and thus took more time for photographic processing. Moreover, because the results were not in electronic form, they were not available simultaneously to multiple users. Yet another advantage of the improved system is that the digital image data can be stored and processed conveniently, and there is no need to store photographs.

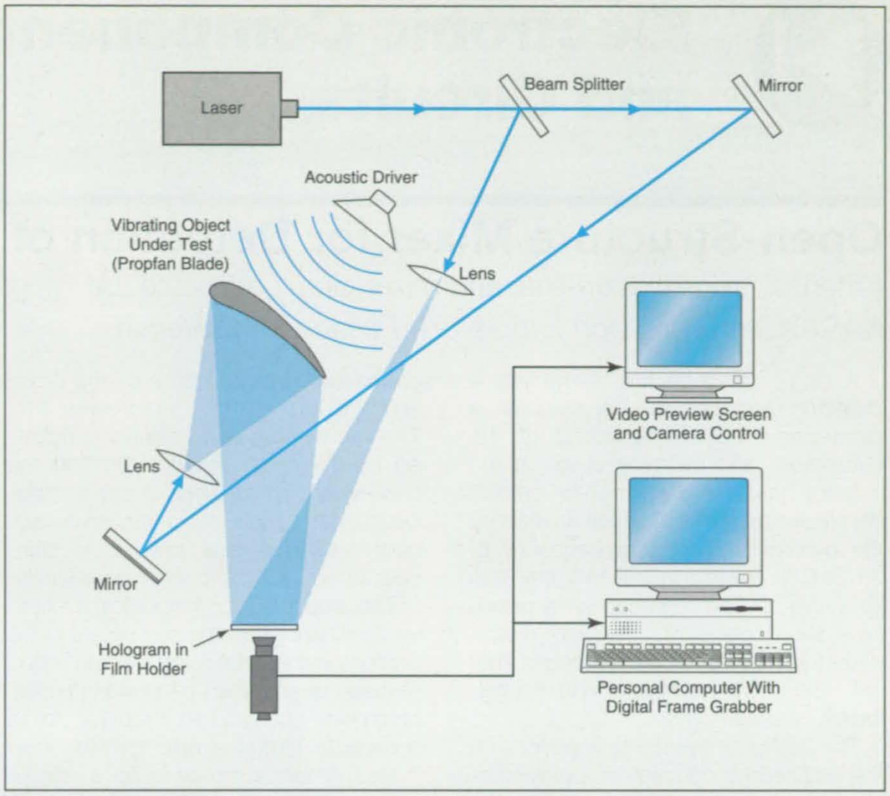
The figure schematically illustrates the present improved system. In holographic vibration testing using either the prior or the present system, the first step is to make a conventional photographic reference hologram of the object to be tested while the object is not vibrating. After photographic development, the reference hologram is once again placed in the mount in which it was recorded. During a subsequent vibration test, the vibrating object is illuminated with the same laser beam used to make the reference hologram; the laser light reflected from the vibrating object interferes with the light in the reference holographic image, producing interference fringes indicative of the local vibrational displacement of the surface of the object from the stationary position represented by the reference image.

During a vibration test in the original propfan application, the vibrations of the propfan blade are excited by use of a nearby acoustic driver. A technician adjusts the driving frequency while watching a video image of the holographic interferogram of the propfan blade to look for clear vibration-mode shapes. Once a mode has been found, a computer commands a video frame grabber to acquire the video image of the holographic interferogram. The frame grabber digitizes the image (which is monochrome) to 512 by 480 pixels with 256 gray levels per pixel; this amounts to 245,760 8-bit bytes.

The digitized image data are passed on to the computer, where they are processed to increase contrast and bring out important details. To reduce data-storage requirements, the image data are compressed to 6,000 bytes per frame by use of the Joint Photographic Experts Group (JPEG) compression scheme with a quality factor (Q) of 25. Although the JPEG scheme at Q = 25 is slightly lossy, the loss in image quality is imperceptible to a human observer when an image is printed by a 300-dpi (118-dot/cm) laser printer.

This work was done by Christopher J. Miller of **Lewis Research Center.** *For further information,* ***write in 74*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Lewis Research Center; (216) 433-2320. Refer to LEW-16210.



Video Images of Interferograms are digitized and processed for enhancement and compression. The enhanced, compressed image data can be made available via a local-area network, and paper copies can be produced easily by use of a laser printer.

Ultrasonic-Transmission Testing Device

Marshall Space Flight Center, Alabama

An ultrasonic-testing apparatus measures transmission through a component under inspection. The apparatus includes a hand-held ultrasonic transmitter that is placed on one side of the component and an ultrasonic receiver that is placed on the other side. However, there is no need to hold or manually align the receiving transducer after initial setup. The transmitter is loosely inserted in a magnetic assembly on one side, while the receiver is placed in another magnetic assembly on the other side. The magnetic coupling keeps the transmitter and receiver assemblies pressed against the component and keeps the receiver aligned with the transmitter as the transmitter is scanned across the surface of the component. The receiver can thus be moved to locations that might otherwise be inaccessible.

This work was done by Victor Ray Atkins and Carl Bouvier of Martin Marietta for **Marshall Space Flight Center**. *For further information,* ***write in 1*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center; (205) 544-0021. Refer to MFS-31007.

Apparatus To Test Solvent Stress Crazing of Polymer Sheets

Marshall Space Flight Center, Alabama

An apparatus that is simple to make, operate, and maintain can be used to determine the abilities of transparent polymeric seal materials to resist stress crazing when exposed to various cleaning solvents. The apparatus includes pulleys, a cable, and weights to apply a constant tension to a specimen sheet immersed in the test fluid in a glass vessel. The specimen can be observed through the wall of the vessel at any time during the test. The level of applied tension is chosen to stress the specimen at a given percentage of the ultimate tensile strength of the specimen material. The specimen is observed at intervals to determine whether it has begun to craze, and the time for onset of crazing is plotted as a function of the applied stress. The test is terminated if no crazing is observed after 24 hours. The design of the apparatus provides for visual observation of the specimen at any time during the test and for ease of removal of fluid via a drain port at the bottom of the glass vessel.

This work was done by Gareth L. Simpson and William S. Hoult of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information,* ***write in 53*** *on the TSP Request Card. MFS-30075*

Open-Structure Mixer for Detection of Hydroxyl

Antenna, transmission-line, and mixer circuit elements are integrated.

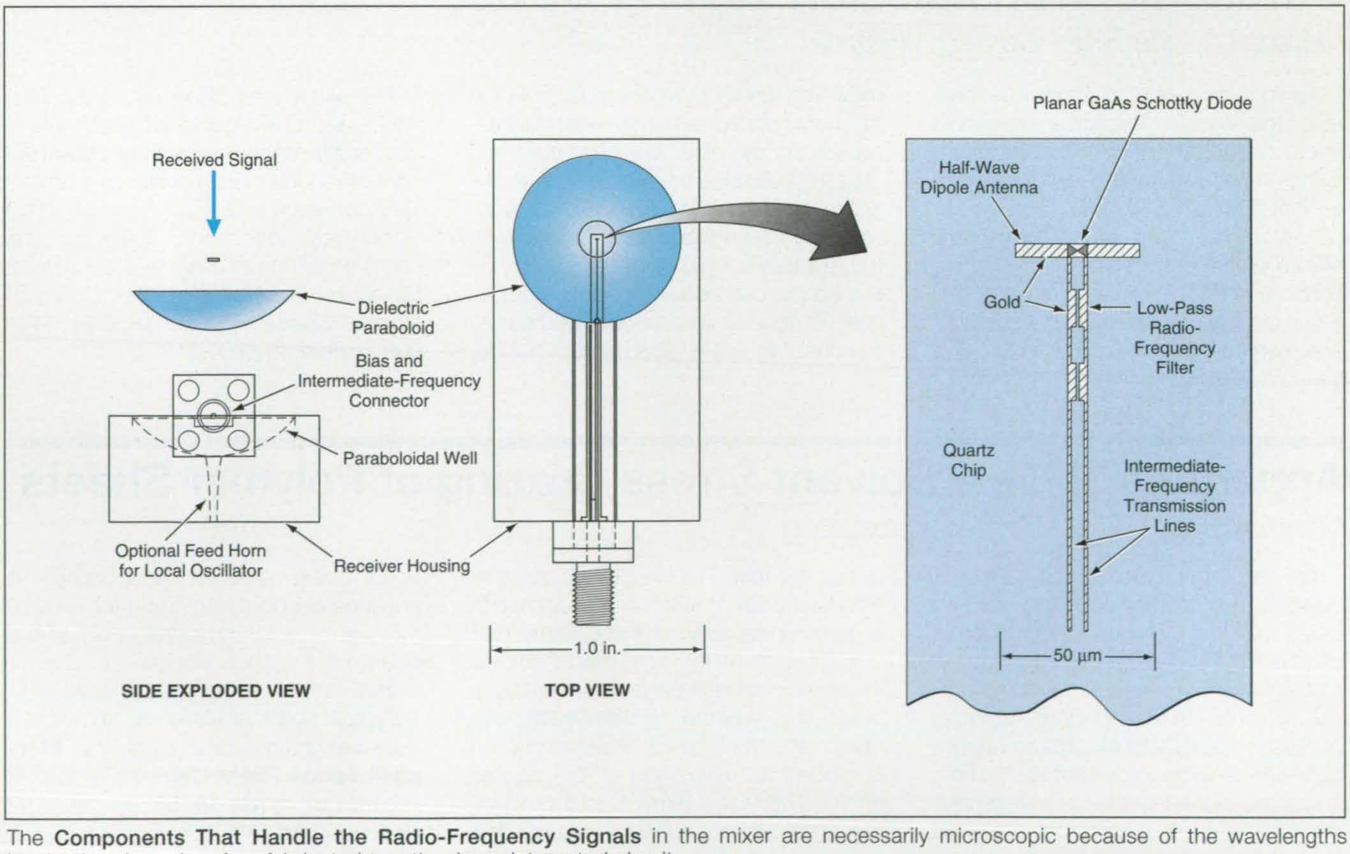
NASA's Jet Propulsion Laboratory, Pasadena, California

A single structure that comprises a dielectric-filled paraboloidal reflector, a dipole antenna at the focus of the paraboloid, and a mixing circuit at the antenna has been developed for detecting electromagnetic radiation emitted by the hydroxyl radical at a frequency of 2,520 GHz (wavelength of 119 μm). This structure can be regarded as a prototype for a class of improved direct-detector and heterodyne circuits that will operate at millimeter and submillimeter wavelengths.

The design of this mixer combines (1) the established concept of a dielectric-filled paraboloidal reflector with the flat surface of the dielectric located in the focal plane of the paraboloid and a dipole antenna mounted on the dielectric at the focus with (2) the use of a novel combination of techniques to fabricate the antenna as part of an integrated circuit along with a mixing diode and the associated transmission line. The use of integrated circuitry is dictated by the small wavelengths and the consequent small sizes of the components that handle radio-frequency signals; there is no practical way to fabricate such small components individually.

The dielectric-filled paraboloidal reflector is made by grinding and polishing the paraboloidal and flat surfaces onto a slug of fused quartz, then de-positing nickel, chromium, and gold on the paraboloidal surface to form the reflector. The integrated circuit is mounted on a narrow rectangular quartz chip that is, in turn, mounted on the focal-plane surface of the fused quartz (see figure). The integrated circuit includes the dipole antenna, a planar GaAs Schottky-barrier diode, an intermediate-frequency transmission line that also supplies dc bias to the diode, and a radio-frequency filter that prevents the local-oscillator and received signals from going out on the transmission line, along with the intermediate-frequency signal, to the external receiver circuits.

To solve an earlier problem associated with device yield, the integrated circuit is fabricated as one in an array of many identical devices on a single wafer, which is then diced to obtain the individual integrated circuits. The diode and all associated signal-handling circuit elements are fabricated by use of electron-beam lithography on GaAs wafers grown by molecular-beam epitaxy. The antenna is a simple half-wave dipole made of evaporated gold, and the Schottky diode is formed at the mid-length of the antenna. The radio-frequency filter is composed of alternating high- and low-impedance sec-



The **Components That Handle the Radio-Frequency Signals** in the mixer are necessarily microscopic because of the wavelengths involved and are therefore fabricated together in an integrated circuit.

tions of the coplanar transmission line.

By use of a liftoff technique, the top few microns of GaAs containing the array of devices is transferred, device-side down, to a quartz wafer. The array is bonded to this substrate by use of an ultraviolet-curable optical cement. Then the GaAs around the diodes is masked and all the remaining GaAs (now on top of the antenna and intermediate-frequency transmission lines) is etched away. This leaves the original metal film of the antenna and intermediate-frequency circuitry exposed. DC contact can then be made through bonding pads at the edge of the wafer. The wafer can then be diced into individual rectangular integrated-circuit chips.

One of the separated chips is then positioned on the focal-plane surface of the quartz, with the diode (which is at the middle of the dipole) at the focal point. The chip is bonded in place by use of the ultraviolet-curable optical cement. Connections to the dc-bias lines are made via bond wires at the one edge of the chip that coincides with the edge of the fused-quartz dielectric.

A balun transformer converts the mode of propagation of the intermediate-frequency signal from that of the coplanar balanced line on the antenna wafer to that of the unbalanced coaxial line. It also transforms the 200-Ω impedance re-quired for matching the diode to the 50-Ω impedance of an external coaxial transmission line. Wire bonds are used to connect the balun to the quartz wafer on one side and to a coaxial panel mount connector on the other.

In operation, the received and local-oscillator signals can be coupled into the reflector and antenna via a conventional beam splitter or interferometric diplexer. Optionally, the local-oscillator signal can be coupled in via a small conical feed horn and a hole in the reflective coat at the apex of the paraboloid. The paraboloidal reflector focuses the signals onto the dipole antenna, where they are directly coupled to the diode. The intermediate-frequency signal is coupled out via the coplanar lines and balun transformer.

This work was done by Peter H. Siegel of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 14*** *on the TSP Request Card.* *NPO-19267*

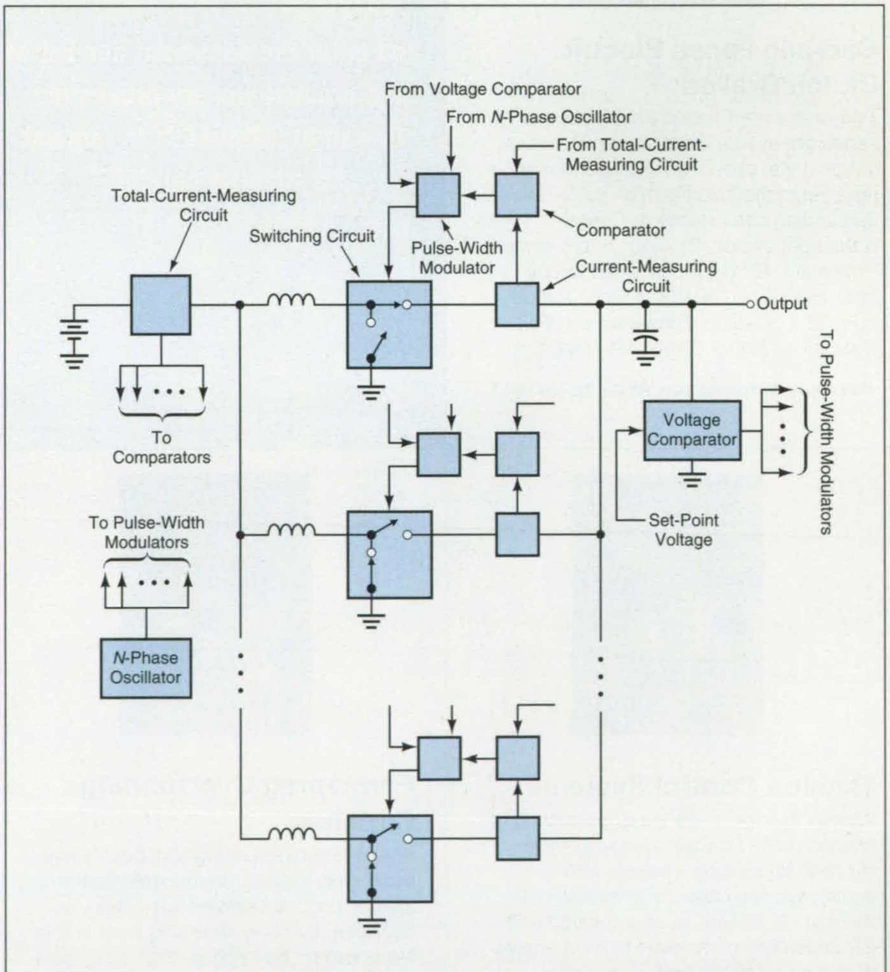
Current-Sharing Control in a Multisection Power Converter

Imbalances among currents in different sections are suppressed.

Lewis Research Center, Cleveland, Ohio

A current-sharing control scheme suppresses imbalances among the currents flowing in different sections of a multiple-section power converter. The imbalance problem arises because power converters that handle more than a few kilowatts are frequently divided into several sections called "slices"; each section of such a converter supplies a portion of the overall load current. If a condition such as slightly higher susceptibility to saturation of an inductor exists in one slice, regenerative effects can cause that section to carry a larger share of the load current than the other slices do. The result of this imbalance can be decreased conversion efficiency, overstressed components, and/or saturation of an inductor.

The current-sharing control scheme can be applied to a power converter in which the raw input power to each of N slices is switched on and off in pulses that are interleaved under timing control by an N-phase oscillator so that each slice nominally carries $1/N$ of the total current (see figure). The pulses in all the slices are of the same duration, which is adjusted by a current- or voltage-feedback control circuit to maintain the total output current or voltage, averaged over one or a few oscillator cycle(s), at the desired value. In the absence of current-sharing control, no attempt is made to measure or control the currents in individual slices, even though the currents can become imbalanced.



Current-Feedback Loops are added to the individual slices (phases) in an N-slice (N-phase) power converter to equalize the shares of the total current carried by the slices.

In the current-sharing control scheme, an additional current-feedback control loop is added to each slice. The actual current in each slice is compared with the average value *I/N* (where *I* denotes the total current contributed by all slices). The comparison yields an error voltage proportional to the difference between the actual and average values. The error voltage is added to a ramp voltage in the pulse-width modulator in the slice to adjust the duration of the pulses to remove the imbalance.

This work was done by Stan Canter and Ronald J. Lenk of Space Systems/Loral for **Lewis Research Center**. *For further information,* ***write in 84*** *on the TSP Request Card.* LEW-15707

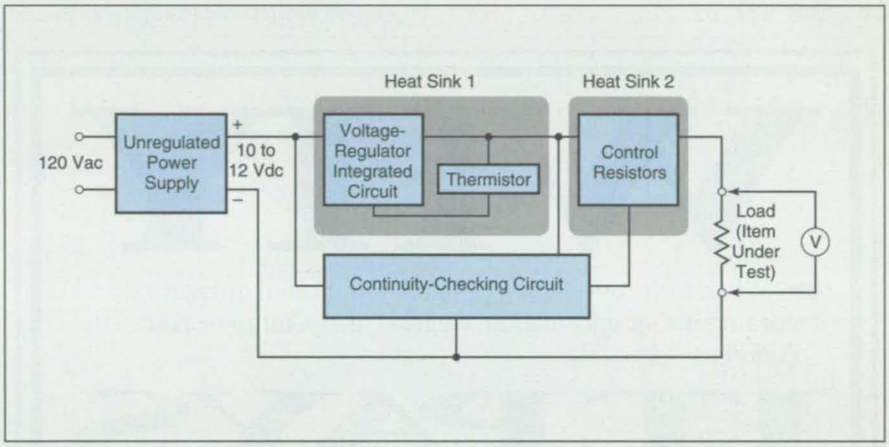
Constant-Current Source for Measuring Low Resistances

At a current of 1 A, resistances are indicated directly as voltages.

NASA's Jet Propulsion Laboratory, Pasadena, California

A constant-current source has been constructed for measuring electrical resistances up to a few ohms in power-supply equipment. By setting the current at 1 A and measuring the resulting voltage drop across an item under test, one obtains a voltage reading that is numerically equal to the resistance in ohms.

The constant-current source (see figure) includes an unregulated power supply of 10 to 12 Vdc, the specific design of which was chosen to minimize dissipation of power, to minimize arcing upon connection to a low-resistance load, and to be capable of supplying a steady output current of 1 A to a load of ≤ 5 Ω. The circuit also includes a commercial voltage-regulator integrated circuit connected to provide a constant current. This integrated circuit is mounted on a heat sink. The output current is manually adjusted to the desired constant value (e.g., 1 A) by use of a variable-control resistor mounted on a second heat sink. Both heat sinks are as large as is feasible and are thermally isolated from each other. A thermistor with negative temperature coefficient, mounted on the same heat sink as that of the voltage-regulator integrated circuit, enhances the stability of the output current.



The **Load Current Is Maintained at 1 A** (provided that the resistance of the load is ≤ 5 Ω), so that the voltage across the load equals its resistance in ohms. The voltage is best measured by use of an autoranging, high-resolution digital voltmeter. Load resistances as small as 1 μΩ can be measured in this way.

This work was done by Robert L. Toomath of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 80*** *on the TSP Request Card.* NPO-19337

SNS Devices With Pinhole-Defined Active Regions

Junction resistances and maximum junction voltages are expected to be increased.

NASA's Jet Propulsion Laboratory, Pasadena, California

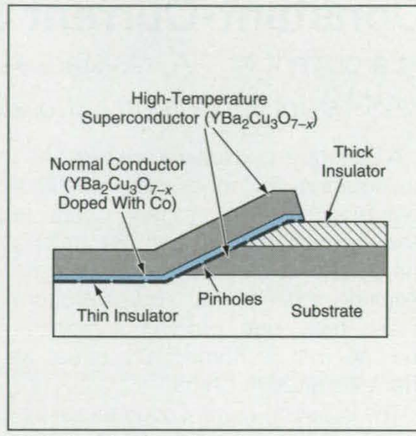
Superconductor/normal conductor/superconductor (SNS) microbridge devices with pinhole-defined active regions are undergoing development. (SNS microbridges are also known, variously, as SNS weak links and as Josephson junctions.) A device of the present type includes a thin, electrically insulating layer deposited epitaxially, with controlled formation of pinholes, on one of the two superconducting layers. The normally conducting metal is deposited epitaxially in the pinholes and on the insulating layer, forming the electrical contact between the two superconducting layers. The pinholes thus define the microbridges — the narrow, normally conductive active regions that collectively constitute the desired normally conducting "weak link." The average current density through the weak link is determined partly by the total pinhole area and the thickness of the normally conducting metal layer.

The major purpose of this development effort is to enhance performance as quantified by two figures of merit; a junction electrical resistance R_n associated with normal conduction in the microbridge(s) and a maximum junction voltage defined as I_cR_n, where I_c denotes the critical current above which superconductivity breaks down. The R_n of a typical photolithographically defined SNS device now available is < 1 Ω; it would be desirable to increase R_n to about 50 Ω to match the impedances of typical external circuits for efficient transfer of power. For complex reasons that exceed the scope of this article, previous approaches taken to increase R_n have been problematic and, in particular, have lead to reduced values of I_cR_n.

The practical basis for the present approach is the notion that the insulating layer in an SNS device would contain pinholes if it were made thin enough and grown under the proper conditions. If the local thickness of the insulator layer were sufficient to prevent measurable quantum-mechanical tunneling (greater than approximately 30 Å), conduction through the device would be dominated by current transport in the pinholes, and the effective active cross-sectional area of the device would then be reduced to the total pinhole area. The total pinhole area could be much smaller than the nominal area encompassed by the outline of the device, resulting in a large value of R_n.

Reducing the effective area of the device should also help solve the problems that limit the I_cR_n values of prior SNS devices. The use of a thin insulating layer with pinholes may also enable the use of a thinner layer of normally conducting metal while reducing the problems associated with nonuniform conduction through such layers.

The first attempts to fabricate SNS devices with pinhole-defined active regions are expected to involve edge-geometry SNS devices like that shown in schematic cross section in the figure. The thin pinhole insulator layer would be grown on the edge of the superconducting base electrode. The advantages of the edge-junction approach include that (1) current would flow along the high-current-density direction of the $YBa_2Cu_3O_{7-x}$ throughout the device; (2) the interfaces between the normally conducting metal and the superconductors would be formed on the longer-coherence-length surfaces perpendicular to the *a-b* planes of the $YBa_2Cu_3O_{7-x}$; and (3) very short, small-area devices could be fabricated by use of conventional optical lithography.



Pinholes in the Thin Insulator define the normally conducting microbridges.

The pinhole-insulator approach should also work just as well with the insulator grown on top of the normally conducting metal, rather than below it. Presumably, in either case, the density of pinholes could be controlled reproducibly by simply varying the nominal average thickness of the insulator, and by varying such conditions as the temperature and the background pressure of oxygen during the deposition of the insulating material. A thin insulating layer is expected to contain pinholes because many deposited materials grow in a three-dimensional fashion, starting as islands that meet and coalesce as more material is deposited.

The superconducting electrodes in the initial experiments are expected to be made of the high-temperature superconductor $YBa_2Cu_3O_{7-x}$. The normally conducting material is expected to be $YBa_2Cu_3O_{7-x}$ doped with Co. The insulating material is expected to be Sr_2AlTaO_6. This insulating material is chosen because its relative permittivity (≈25) is smaller than that of other candidate insulating materials; smaller permittivity results in smaller junction capacitances and thus higher limits on achievable operating frequencies.

This work was done by Brian D. Hunt and Jeffrey B. Barner of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 83*** *on the TSP Request Card. NPO-19475*

Micromachined Ion Accelerators

Advantages would include small size and weight, modularity, and compatibility with integrated circuits.

NASA's Jet Propulsion Laboratory, Pasadena, California

Proposed ion accelerators an order of magnitude smaller than the smallest now in use would be made by micromachining techniques like those now used to fabricate integrated circuits. Originally intended for use as thrusters aboard small spacecraft (the concept of "ion thruster on a chip"), these ion accelerators could also be used as sources of ion beams for industrial processes. An ion accelerator of this type could be combined with integrated electronic control and power circuitry, plus similarly miniaturized valves and other mechanisms for regulating the flow of gas used to generate the ions — all micromachined on a single chip. The resulting combination of small size and modularity would provide flexibility for tailoring characteristics of ion sources for specific applications; for example, one could construct an array of many such devices to obtain a large ion source or could position multiple devices to obtain a desired ion-beam pattern in a processing chamber.

A micromachined ion accelerator (see figure) would be built up on a substrate, using alternating layers of electrically conducting and electrically insulating materials. Typically, the overall thickness of the device, including the substrate, would be a few millimeters. The substructure containing the ion-accelerating electrodes and the discharge chamber(s) for generating the ions would be only about 300 μm thick. The long dimension of the discharge chambers in the accelerator could be any length, but would be typically several centimeters. Although the figure shows only two side-by-side linear discharge chambers, each about 100 μm wide, an accelerator could contain more such chambers, so that its width could be comparable to its length.

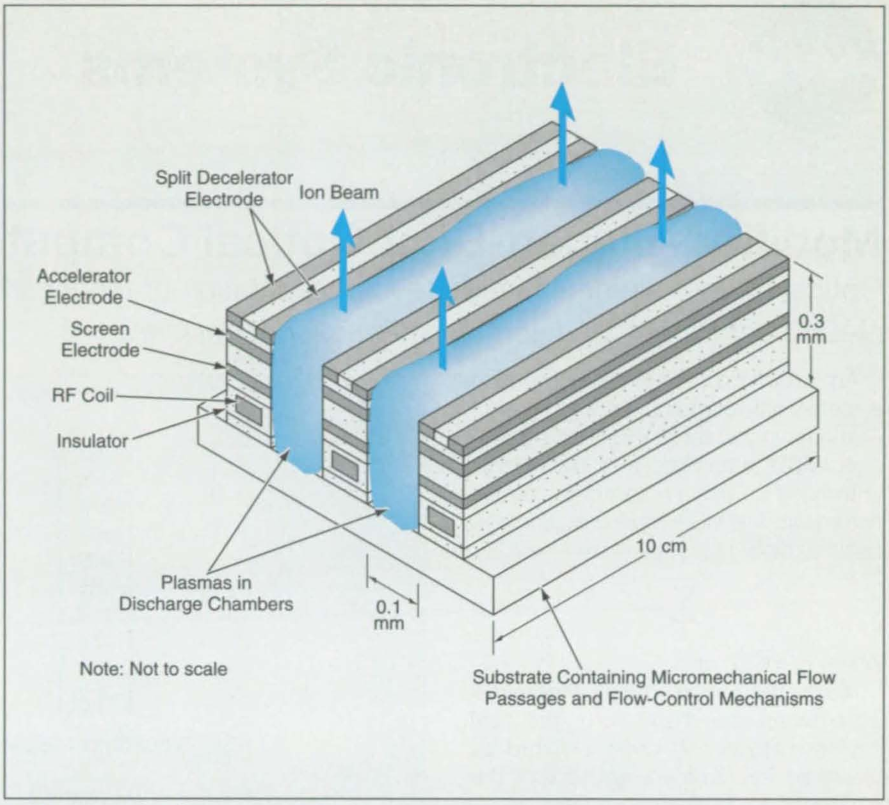
The device would include screen, accelerator, and decelerator electrodes separated by layers of spray-coated aluminum oxide thick enough to stand off the high voltages applied between the electrodes. The accelerator electrodes would perform the same function as that of the similarly named grids in conventional ion accelerators. The screen electrodes would collect electrons stripped from the gas in the ionization process, and an external neutralizer (not shown in the figure) would inject the collected electrons into the ion beam. The decelerator grid would be split into two pieces so that different voltages could be applied to the pieces to steer the ion beam.

The substrate would contain integral micromachined passages that would distribute the flow of gas to the discharge chamber(s), high-voltage isolators to prevent undesired discharges elsewhere than in the discharge chamber(s), and the integral micromachined flow-control mechanisms mentioned above. Of course, the gas would still have to be supplied from an external pressure vessel.

Two alternative discharge concepts are under consideration. In the device shown in the figure, the discharge would be energized by radio-frequency (RF) induction via the micromachined equivalent of a single-turn RF coil wrapped around each discharge chamber and insulated with aluminum oxide. In operation, the RF excitation in the coil would inductively couple an alternating electric field into the chamber, generating a plasma; the RF electric field would accelerate the plasma electrons to energies sufficient to ionize the gas molecules or atoms.

The other discharge concept is that of a dc discharge initiated via one or more micromachined cold-cathode emitter(s) in each discharge chamber. The leading candidate cold-cathode emitter is diamond film doped to form a forward-biased p/n junction, with boron as the p dopant and C^+ ions as the n dopant.

This work was done by John Brophy, Juergen Mueller, James Polk, and John Blandino of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 19*** *on the TSP Request Card. NPO-19652*



A **Micromachined Ion Accelerator** (an "ion thruster on a chip") would be much smaller than ion accelerators now in use. The dimensions shown here are order-of-magnitude figures for example only; dimensions could be chosen to suit specific applications.

Modified-Signed-Digit Optical Computing Using Fan-Out

Optical fan-out elements facilitate implementation of trinary arithmetic and logic.

NASA's Jet Propulsion Laboratory, Pasadena, California

An experimental optical computing system that contains optical fan-out elements implements modified signed-digit (MSD) arithmetic and logic. MSD arithmetic partly resembles binary arithmetic: the MSD representation of a decimal digit, D_d, is given by

$$D_{d} = \sum_{i} c_i 2^i$$

where $c_i = \bar{1}$, 0, or 1.

MSD computing offers theoretical advantages, but heretofore, practical implementation has been inhibited by the need for complex optics and the smallness of achievable spatial-bandwidth products. The optical fan-out elements in this system enable discrete correlation and multiple imaging, which facilitate the implementation of MSD arithmetic and logic. In comparison with previous optical implementations of MSD arithmetic, this one is characterized by larger throughput, greater flexibility, and simpler optics.

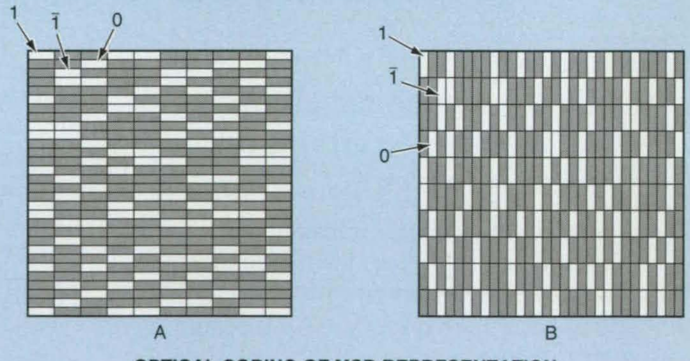
In this system, each signed digit is associated with a square or rectangular picture element that is subdivided into three equal areas, and the value of the signed digit ($\bar{1}$, 0, or 1) is represented by illumination in one of the subdivisions, the other two remaining dark (see Figure 1). In an MSD arithmetic operation, the input digits are processed into output digits according to a set of transformation rules, which, in the optical implementation of the present system, cause bright spots to be shifted among picture elements and their trinary subdivisions.

$$A = \begin{bmatrix} 329 \\ -178 \\ -679 \\ 689 \\ -89 \\ -455 \\ 613 \\ 166 \\ 310 \\ -479 \end{bmatrix}_D \qquad B = \begin{bmatrix} 500 \\ -319 \\ -402 \\ 375 \\ 618 \\ 214 \\ -213 \\ 886 \\ 341 \\ -819 \end{bmatrix}_D$$

VECTORS IN DECIMAL REPRESENTATION

$$A = \begin{bmatrix} 1 & \bar{1} & 0 & 1 & 1 & \bar{1} & \bar{1} & 0 & 0 & 1 \\ \bar{1} & 1 & 1 & \bar{1} & 0 & 1 & 0 & \bar{1} & 1 & 0 \\ \bar{1} & \bar{1} & 0 & 1 & 1 & 0 & \bar{1} & 0 & 1 & \bar{1} \\ 1 & 1 & 0 & \bar{1} & \bar{1} & 1 & 0 & 1 & \bar{1} & \bar{1} \\ 0 & \bar{1} & 1 & 0 & 1 & 1 & \bar{1} & \bar{1} & 1 & 1 \\ \bar{1} & 0 & 0 & \bar{1} & 1 & 0 & \bar{0} & 1 & 1 & 1 \\ 1 & 0 & 0 & 1 & 1 & 0 & 0 & 1 & 1 & \bar{1} \\ 0 & 1 & 0 & \bar{1} & 0 & \bar{1} & \bar{1} & 0 & \bar{1} & 0 \\ 1 & \bar{1} & 1 & \bar{1} & 0 & \bar{1} & 0 & 1 & 1 & 0 \\ \bar{1} & 0 & 1 & \bar{1} & \bar{1} & 0 & 0 & 1 & \bar{1} & \bar{1} \end{bmatrix} \qquad B = \begin{bmatrix} 1 & 1 & \bar{1} & \bar{1} & \bar{1} & 0 & 0 & 1 & 1 & 0 \\ \bar{1} & 1 & \bar{1} & 1 & 0 & 0 & 1 & \bar{1} & \bar{1} & \bar{1} \\ \bar{1} & 0 & 0 & 1 & 1 & 1 & 0 & \bar{1} & \bar{1} & 0 \\ 0 & 1 & 1 & 0 & \bar{1} & 1 & 1 & 0 & 0 & \bar{1} \\ 1 & 1 & \bar{1} & 0 & \bar{1} & 0 & 1 & 0 & 1 & 0 \\ 1 & \bar{1} & \bar{1} & 1 & 0 & 1 & 0 & 1 & 1 & 0 \\ 0 & 0 & \bar{1} & \bar{1} & 0 & \bar{1} & \bar{1} & 0 & 1 & 1 \\ 1 & 1 & 1 & 0 & 0 & 0 & \bar{1} & 0 & \bar{1} & 0 \\ 0 & 1 & 1 & 0 & \bar{1} & \bar{1} & 0 & 1 & 0 & 1 \\ \bar{1} & \bar{1} & 0 & \bar{1} & 0 & 1 & \bar{1} & 1 & 0 & 1 \end{bmatrix}$$

VECTORS IN MSD REPRESENTATION



OPTICAL CODING OF MSD REPRESENTATION

Figure 1. The **Value of a Signed Digit** ($\bar{1}$, 0, or 1) is represented optically by a bright spot in one of the 3 subdivisions of each square picture element: In vector A, top = 1, middle = 0, bottom = $\bar{1}$; in vector B, left = 1, middle = 0, right = $\bar{1}$.

Figure 2 schematically illustrates the optical system. A collimated laser beam is incident on overlapped masks A and B, which contain the input numbers. The axis of position coding of the signed digits in mask A is perpendicular to that in mask B, as in Figure 1. Now carrying the spatial input signal, the beam passes through a Dammann grating, which serves as the optical fan-out element. The grating generates 3 × 3 angularly multiplexed copies of the input signal. Following this, the beam is split into three subbeams on different paths by use of standard beam splitters.

On these three paths, the subbeams are Fourier-transformed and made to pass through Kernel filters (K1, K2, and K3, respectively) located in the Fourier plane of the Dammann grating. The Kernel filters are masks that contain 3 × 3 square patterns of transparent and opaque subdivisions that encode parts of the transformation rules. Physically, these filters act as spatial filters, selecting specific angular copies of the input signal. The spatially filtered subbeams then propagate through decoding masks (D1, D2, and D3, respectively). The optical processing of each subbeam effects part of the

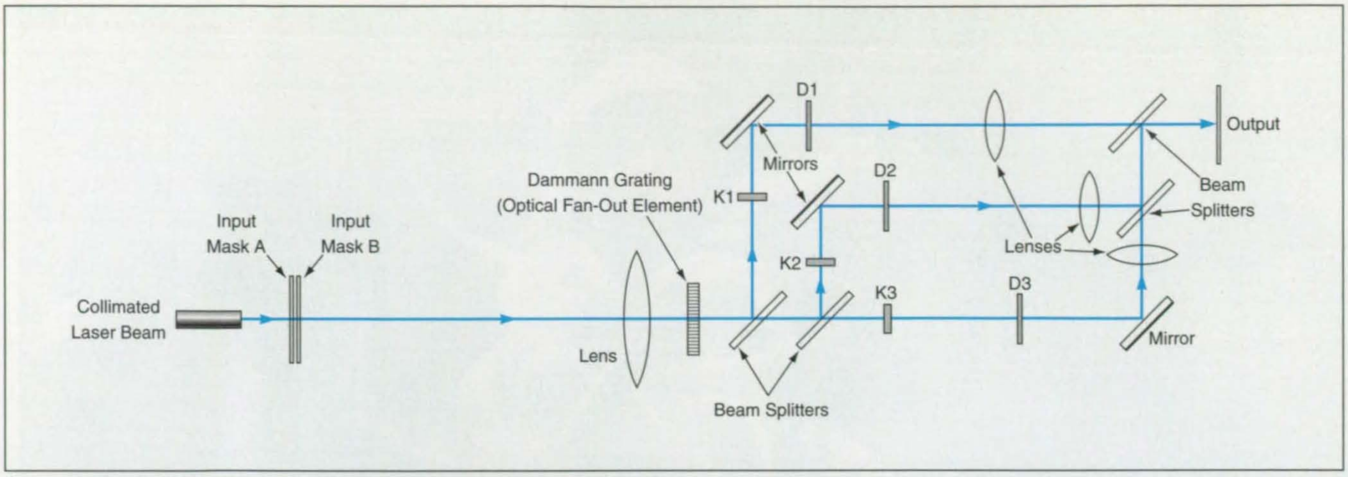


Figure 2. **Spatial Filtering** by the various optical elements of this system processes the input images of masks A and B into an output image in such a way as to implement a transformation rule of MSD arithmetic.

transformation. By use of beam splitters, the three subbeams are combined into an output beam bearing the complete transformation; that is, the pattern of bright spots in the output beam represents the MSD digits obtained in the arithmetic operation corresponding to the transformation rule.

This work was done by Hua-Kuang Liu of Caltech and Shaomin Zhou and Pochi Yeh of the University of California at Santa Barbara for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 29*** *on the TSP Request Card. NPO-19032*

Dynamically Reconfigurable Optical Morphological Processor

Reconfigurability affords an advantage over correlator-based morphological processors with fixed holographic filters.

NASA's Jet Propulsion Laboratory, Pasadena, California

An experimental optical/electronic image-processing system performs morphological processing in the optical domain. Because of the inherent parallel nature of optical processing (simultaneous processing of all parts of an image), this system operates at high speed. This system is also dynamically reconfigurable, so that it can be switched rapidly among all forms of morphological processing. Reconfigurability affords a major advantage over correlator-based optical morphological processors in which the morphological operations are governed by fixed holographic filters.

"Morphological" as used here does not have its customary meaning. In image processing, "morphological" characterizes an operation, on each pixel of an image, that involves data from only that pixel and a few other pixels in its neighborhood. A morphological operator could also be regarded as a few-point discrete convolution over a pixel and its nearest neighbors. For example, two morphological operations that are commonly performed on binary images are called "erosion" and "dilation" (see Figure 1). Two other common operations are called "opening" (consisting of erosion followed by dilation) and "closing" (consisting of dilation followed by erosion). Opening followed by closing is useful for removing salt-and-pepper noise (isolated single black and isolated single white pixels) from a binary image.

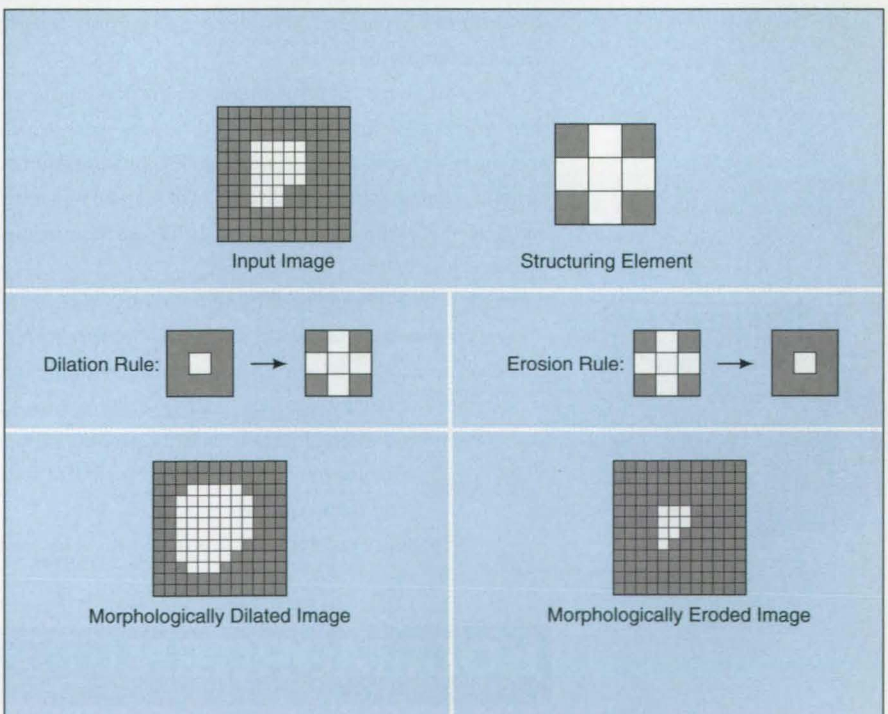


Figure 1. **Dilation and Erosion** are morphological operations that can be defined by use of structuring elements (in effect, few-point discrete-convolution kernels) for each pixel and its four nearest neighbors.

Figure 2 schematically illustrates the present image-processing system. The input image to be processed is generated electronically by a computer, then transferred to a frame grabber, then displayed on a cathode-ray tube coupled via a fiber-optic face plate to a liquid-crystal light valve (LCLV). Thus, the LCLV is made to act as a spatial light modulator (SLM) that converts the input image into the optical domain. The input image consists of an $N \times N$ array of pixels.

A pair of lenses performs Fourier transformations between the input and the output planes. A Dammann grating between lens 1 and the Fourier-transform plane splits the impinging beams of light into an $N \times N$ array. Upon reaching the Fourier-transform plane these beams form an $N \times N$ array of Fourier spectra of the input image. An aperture pattern that represents the kernel of the desired morphological operation is placed in the Fourier-transform plane. This pattern could be, for example an opening in a central pixel and its four nearest neighbors, as in the erosion and dilation kernels of Figure 1. To enable dynamic reconfiguration, a shutter SLM is placed in the Fourier-transform plane and used to generate the pattern under computer control.

It is worth noting that since this is a parallel-processing system, every pixel in the input image is replaced, in the output image, with the pattern impressed on the shutter SLM. The output image is received by a planar array of photodetectors and thresholded. The thresholded image is displayed as output and/or sent back to the input SLM for the next iteration of processing.

The process shown in Figure 2 is a dilation of a single pixel. Erosion would be performed similarly, except that the input LCLV SLM would be operated in its contrast-reversal mode. Because the system contains a feedback loop, more complex processes like opening, closing, and removal of salt-and-pepper noise can be achieved by iteratively executing a series of dilation and erosion operations. Required operations, including contrast reversal, dynamic reconfiguration, and feedback, can be accomplished via computer control.

Although the system as described thus far is designed to process binary images, the basic principle of operation can be extended to gray-scale morphological processing. The key is to utilize the thresholding decomposition technique, in which a thresholding operation is repetitively applied to a gray-scale image with a different threshold level during each successive operation. As a result, the gray-scale image would be decomposed into multiple binary images ("slices"). Each binary slice would then be processed as in the present system. All the processed binary slices would then be superposed to construct the output gray-scale image.

This work was done by Tien-Hsin Chao of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 37*** *on the TSP Request Card. NPO-19120*

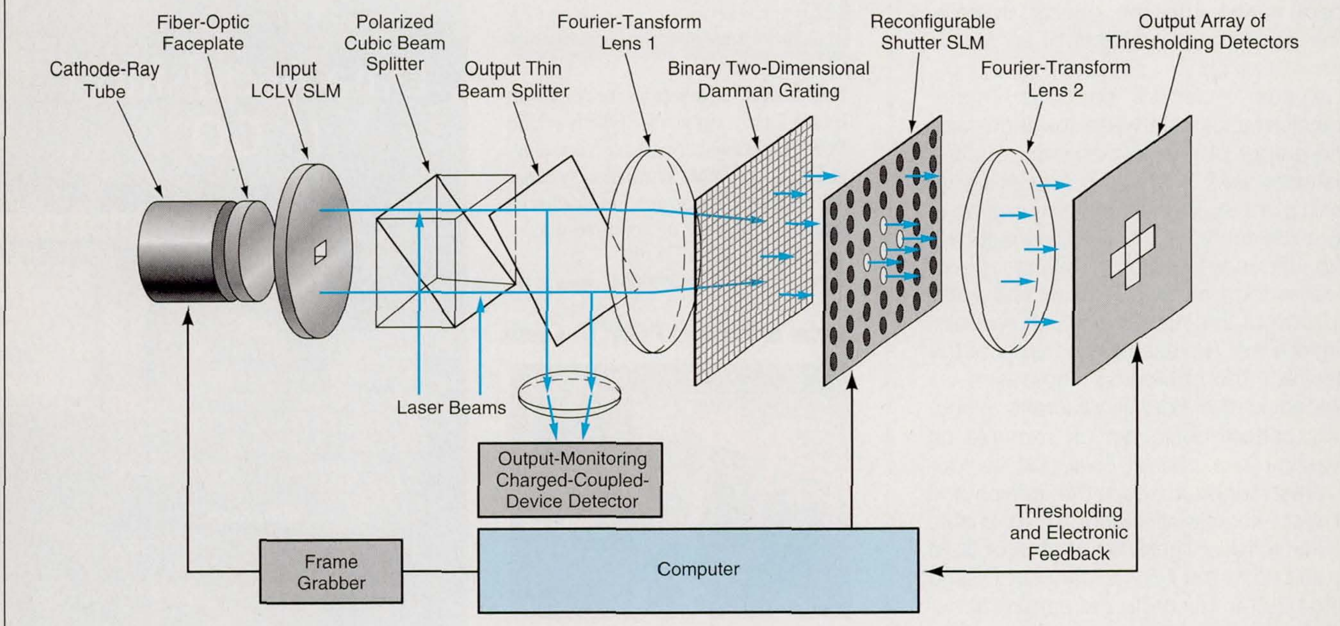


Figure 2. The **Dynamically Reconfigurable Optical Morphological Processor** is implemented with optical, electro-optical, and optoelectronic components, with computer-controlled input and feedback.

Higher-Order Neural Networks Recognize Patterns

Invariance under translation, scale, and orientation can be built into a network.

Ames Research Center, Moffett Field, California

In comparison with electronic neural networks of first order, networks of higher order have enhanced capabilities to distinguish between different two-dimensional patterns and to recognize those patterns. The higher-order neural networks also have enhanced capabilities to "learn" the patterns to be recognized: they can be "trained" with far fewer examples and, therefore, in less time than is necessary to train comparable first-order neural networks.

The output of the ith output node of general neural networks is given by

$$y_i = \theta(\Sigma_j w_{ij}x_j + \Sigma_j \Sigma_k w_{ijk}x_jx_k + \Sigma_j \Sigma_k \Sigma_l w_{ijkl}x_jx_kx_l + \ldots)$$

where θ denotes a nonlinear threshold function; the ws are known variously as synaptic weights, interconnection strengths, and the like; and x_j denotes the excitation applied to the jth input node (e.g., the brightness of the jth picture element of an imaging detector onto which a pattern is projected). The order of the network is the highest order of input-excitation products included in the series; for example, if the series stops at $\Sigma_j \Sigma_k w_{ijk}x_jx_k$, then the network is of second order (see Figure 1).

A network is "trained" by an iterative process of exposing it to training sets of the pattern(s) to be recognized and adjusting the interconnection strengths until the desired outputs are obtained. Typically, for a first-order network, the process must be repeated many times with different combinations and versions of the patterns.

The great advantage of higher-order neural networks is that geometrical invariances can be built into them by use of information about the expected relationships between picture elements. In particular, a second-order neural network can be given the ability to recognize the same pattern at different locations and magnifications by imposing appropriate functional forms on the w_{ijk}. Similarly, a third-order network can be made to recognize the same pattern at different locations, magnifications, and orientations by suitable choices of the w_{ijkl}. In principle, it is not necessary to "train" such a network with differently located, magnified, and oriented versions of the same pattern (provided that the spatial resolution of the input nodes is sufficiently high): The geometrical invariances are inherent in the advance choice of constraints on the connection strengths.

These concepts were verified by computer simulations of the ability of a second-order and a third-order neural network to recognize the letters "C" and "T." The second-order network consisted of a 16 × 16 array of picture-element input nodes fully interconnected to a single output node. The third-order network was a 9 × 9 array of picture-element input nodes fully interconnected to a single output node. The interconnection strengths were constrained to provide the geometrical invariances. The second-order network learned to recognize both letters at various sizes and positions after only 10 training iterations on one example (one size at one position of each letter). Similarly, the third-order network was able to recognize both letters at various positions, sizes, and orientations after only 20 iterations on one example of each (see Figure 2).

This work was done by Max B. Reid, Lilly Spirkovska, and Ellen Ochoa of **Ames Research Center**. *For further information,* ***write in 20*** *on the TSP Request Card.*

This invention has been patented by NASA (U.S. Patent No. 5,333,210). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Ames Research Center; (415) 604-5104. Refer to ARC-11961.

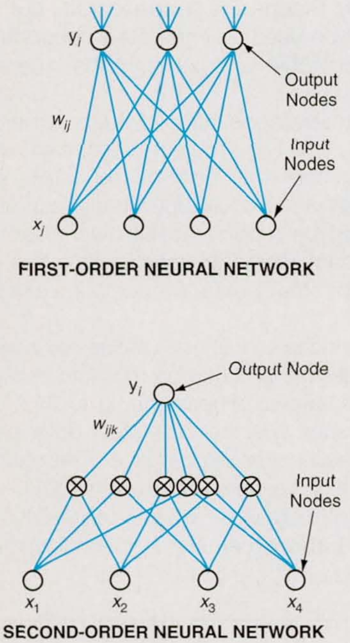


Figure 1. In a **Second-Order Neural Network**, excitations are multiplied in weighted pairs, then summed at the input side of the output node. In a first-order network, each excitation is weighted and added individually.

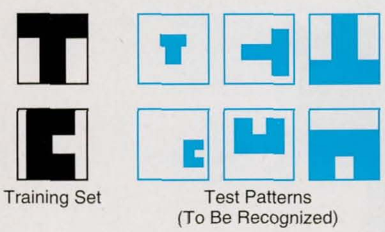


Figure 2. **Differently Located, Magnified, and Orientated** versions of the letters C and T were recognized by a third-order neural network after 20 training exposures to only one example of each letter.

Robot for Infrared Mapping of a Large Assembly in a Vacuum

Thermal images can be recorded from almost any direction.

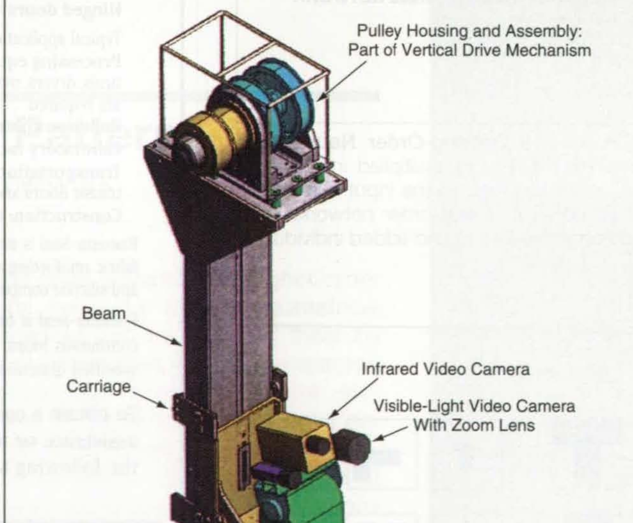
NASA's Jet Propulsion Laboratory, Pasadena, California

A robotic system has been devised for use in infrared (thermal) mapping of a large assembly of equipment under test in a vacuum chamber. In the original intended application, the assembly to be thermally mapped is a spacecraft, but the system could just as well be used on integrated-circuit-fabrication equipment or other industrial equipment that operates in a vacuum.

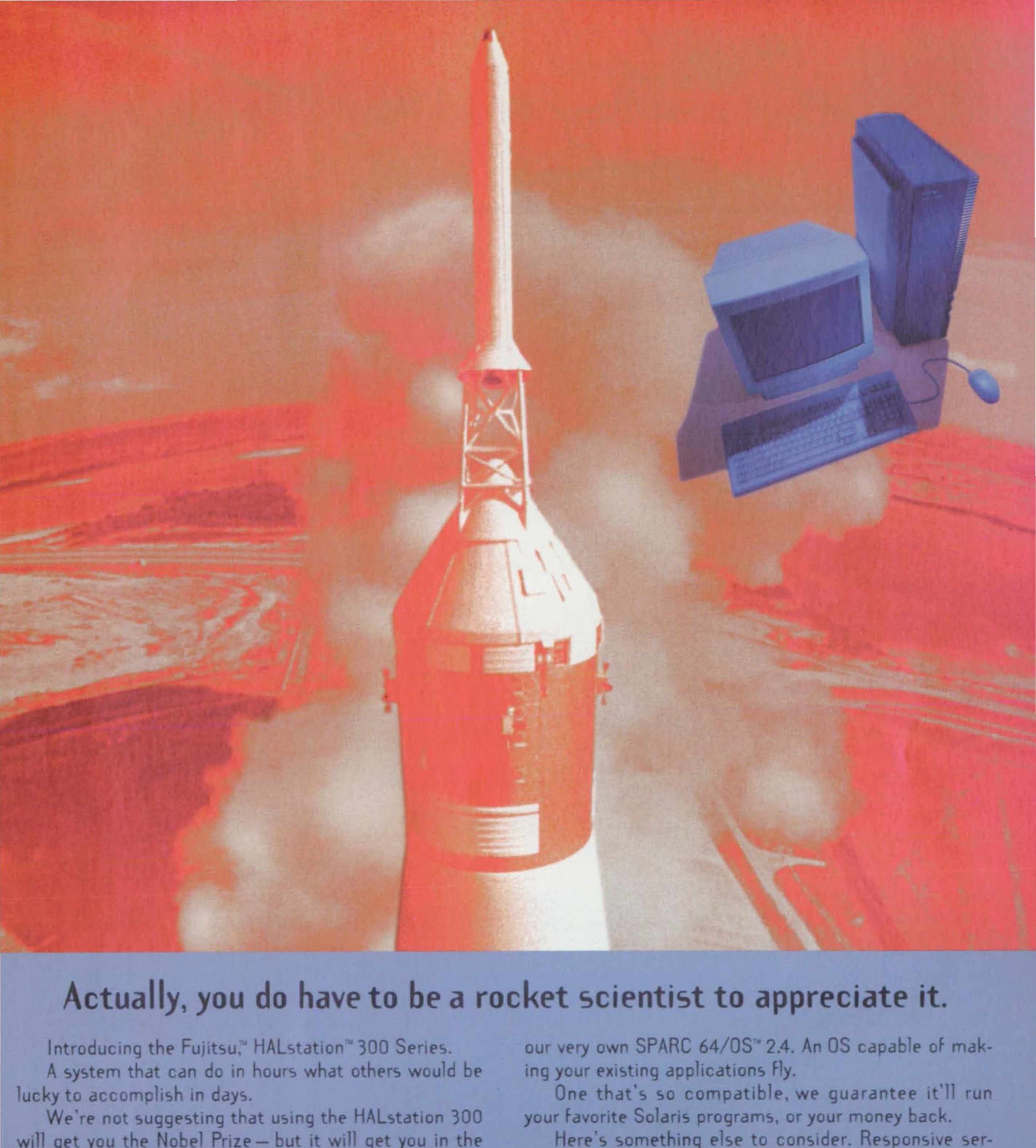
The system includes an advanced infrared video camera, a controlled source of light, and two vacuum-rated, high-resolution, visible-light, video cameras. One of the visible-light cameras is equipped with a remotely operated zoom lens. The cameras are mounted on a pan-and-tilt mechanism on a carriage on a vertical beam in a gantry (see figure); thus, the cameras can be aimed from many different positions at many different angles.

The vertical-axis drive mechanism is of a unique lubrication-free, clean-room quality design, and can be modified easily to fit vacuum chambers with vertical dimensions up to 25 ft (7.7 m). This mechanism includes two stainless-steel drive belts, which are used to raise and lower the carriage. The mechanism can be operated in high vacuum and extreme cold.

This work was done by Douglas A. McAffee of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 35*** *on the TSP Request Card. NPO-19578*



The **Vertical-Axis Assembly of the Infrared-Mapping Robot** contains an infrared video camera and two visible-light video cameras that can be oriented to provide stereoscopic views with scalable depth of field. The video and thermal images can be viewed, captured, and processed at a remote operator station.



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Measuring High Temperatures in Ceramic-Fiber Blankets

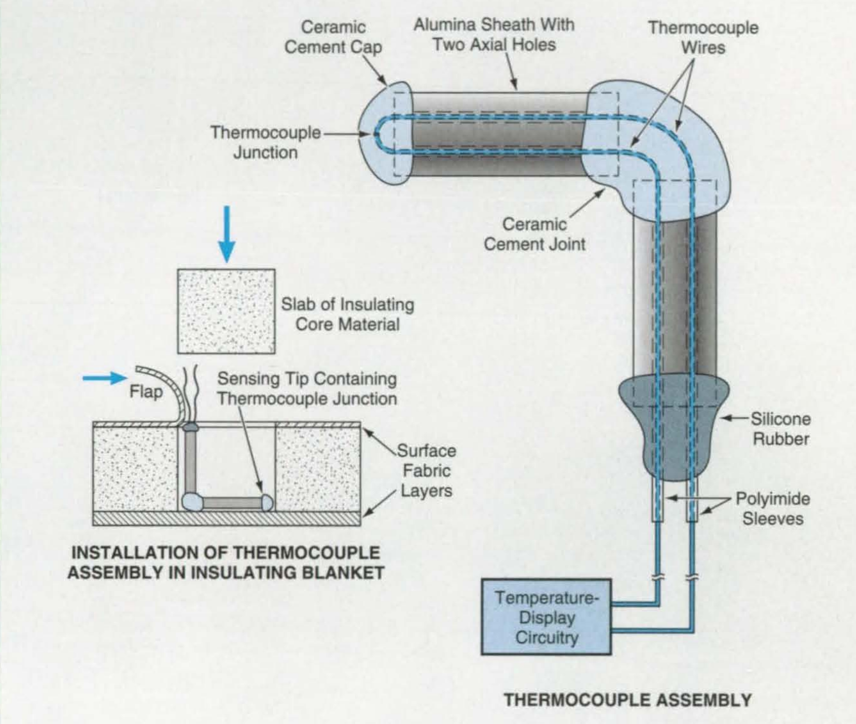
Thermocouple wire is protected from an oxidizing atmosphere.

Ames Research Center, Moffett Field, California

Thermocouple assemblies have been devised specifically for measuring temperatures at fixed locations within insulating blankets made of such ceramic fibers as alumina, silicon carbide, and/or aluminoborosilicate. The thermocouples in these assemblies can measure temperatures from 100 to 3,200 °F (38 to 1,760 °C) in oxidizing atmospheres.

A thermocouple assembly of this type is L-shaped. It includes a type-R thermocouple — a platinum wire welded at the sensing tip to a wire of platinum alloyed with 13 percent rhodium. The wires are enclosed in an alumina sheath for protection against hot oxidation and mechanical damage (see figure).

Typically, the thermocouple assembly is installed in an insulating blanket to measure the temperature just inside one of the surface fabric layers. First, a flap is cut to make a hole in the opposite fabric surface layer, then a slab of insulating core material is removed to make room for the thermocouple assembly. The assembly is inserted in the hole with the thermocouple wire leads trailing, and the sensing tip is placed in contact with the inner face of the desired surface layer. The assembly is bonded in place by use of ceramic cement. The slab of insulating core material is then reinserted, the flap is closed, and the edges of the flap are fastened in place by use of room-temperature-vulcanizing silicone-rubber cement. The thermocouple wires extending from the flap are then connected to the external circuitry that generates a temperature display from the thermocouple reading.



Refractory Materials protect and support the thermocouple wires in the hot measurement region.

This work was done by Demetrius A. Kourtides of **Ames Research Center.** *For further information,* ***write in 41*** *on the TSP Request Card.*

This invention has been patented by NASA (U.S. Patent No. 5,399,019). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Ames Research Center; (415) 604-5104. Refer to ARC-11984.

Simultaneous Use of Zr and Mg Anodes in XPS

Previously unresolvable peaks of the electron-energy spectrum become resolvable.

Marshall Space Flight Center, Alabama

An improved x-ray source for x-ray photoelectron spectroscopy (XPS) contains both a zirconium anode with a beryllium window and a magnesium anode with an aluminum window. This x-ray source makes it possible to analyze electron-energy peaks that cannot usually be resolved when using a conventional x-ray source that contains an aluminum or magnesium anode. This source was developed specifically for use in analyzing the distributions of chemical constituents in the surface layers of specimens of 2219 aluminum alloy and, more specifically, in determining the depths of surface oxide layers and the relative proportions of aluminum and oxide in the layers. The improved x-ray source could also be used to study chemical constituents of surface layers in other material

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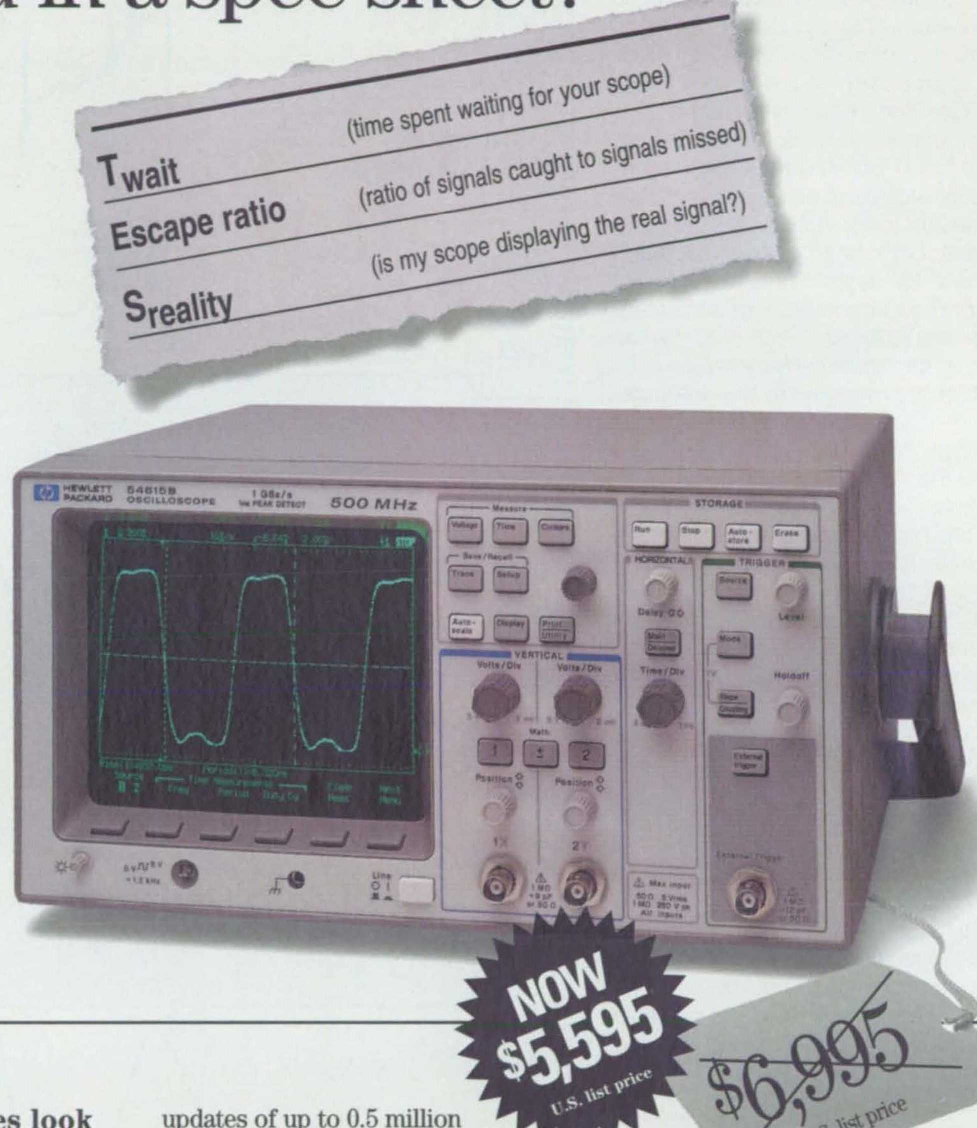

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systems — for example, thin oxide films on silicon-based semiconductor devices, oxide films on alloys, and surface layers that affect the adhesion of paints or bonding materials.

Both anodes of the improved x-ray source are operated simultaneously at a potential of 15 kV and a power of 250 W each. The x-radiation from the zirconium anode includes a spectral peak at an energy of 2,042.4 eV, while that from the magnesium anode includes a spectral peak at 1,253.6 eV. Unlike the radiation from a conventional aluminum or a conventional magnesium (only) anode, this radiation provides both energy and resolution sufficient for quantitative analysis of the small concentration of aluminum metal (as little as 1/50 that of the oxide) in an oxide surface layer.

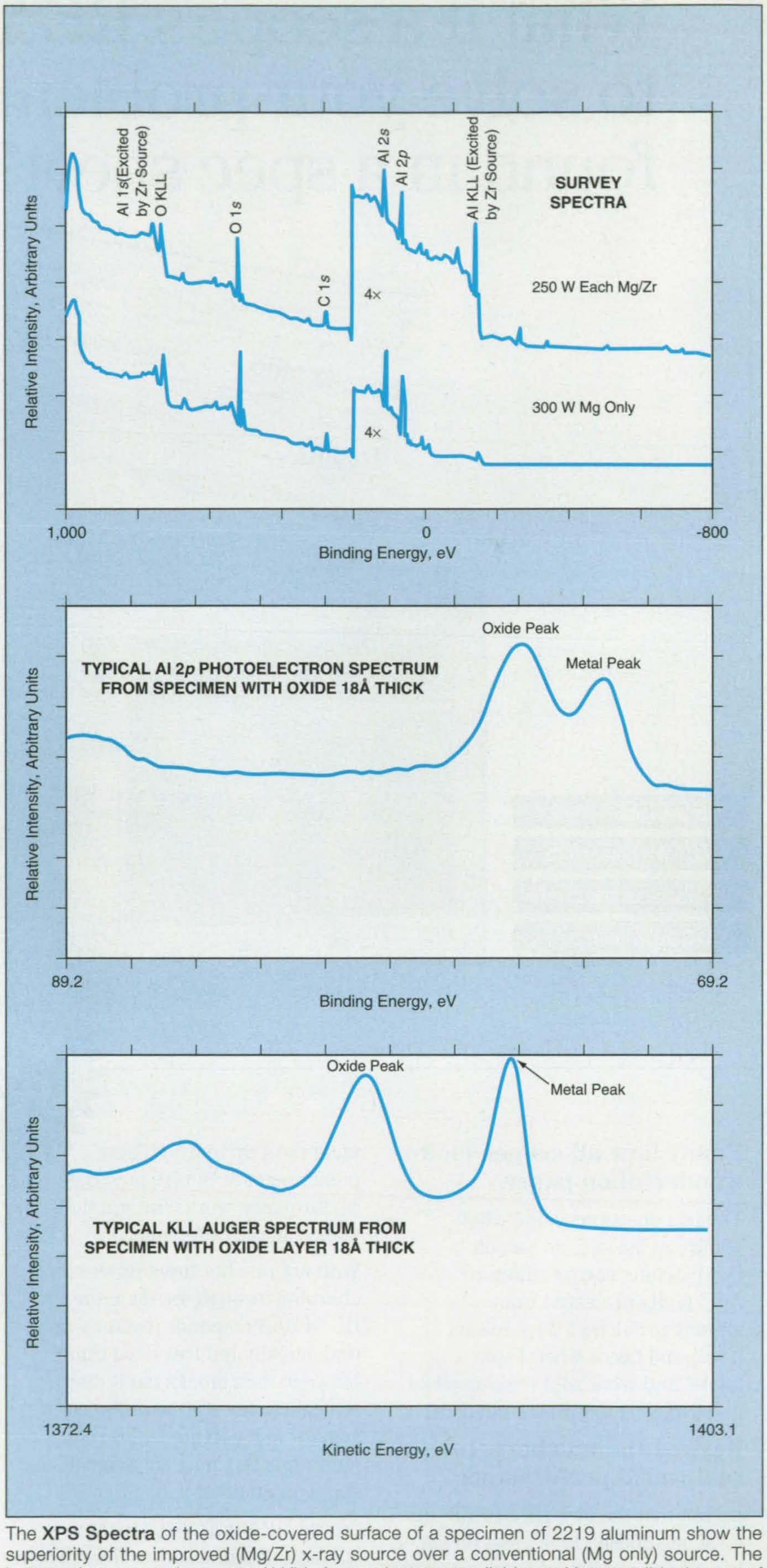
One of the reasons for this enhancement of capability is that the radiation from the improved x-ray source excites the aluminum KLL Auger spectral peaks much more effectively than does the radiation from a conventional source. The KLL Auger peaks of the metal and the oxide are separated by about 6 eV and have half-maximum widths of less than 2.5 eV: in contrast, the 2*s* and 2*p* photoelectron peaks of the metal and oxide, which are used in analysis with a conventional x-ray source, are separated by only 2 eV and have widths of almost 2 eV (see figure). Thus, the KLL Auger peaks made available by the improved x-ray source can be distinguished from each other more easily, with less subjectivity involved in interpretation of the XPS measurements.

The improved source confers an additional benefit by making it possible to determine the depth of the oxide layer from the XPS measurements. The equation for the depth is

$$d = \lambda_o \sin(\theta)\, \ell_n\left(\frac{N_m \lambda_m l_o}{N_o \lambda_o l_m} + 1\right)$$

where d is the depth, l_o and l_m are the inelastic mean free paths of the KLL Auger transitions in the oxide and the metal, respectively; N_m and N_o are the volume densities (which are known properties) of the metal and oxide, respectively; and θ is the takeoff angle relative to the sample plane (this angle is a known parameter of the XPS apparatus).

This work was done by D. F. Allgeyer and E. H. Pratz of Martin Marietta Corp. for **Marshall Space Flight Center.** *For further information,* ***write in 9*** *on the TSP Request Card. MFS-28831*



The **XPS Spectra** of the oxide-covered surface of a specimen of 2219 aluminum show the superiority of the improved (Mg/Zr) x-ray source over a conventional (Mg only) source. The improved source makes more Al KLL Auger electrons available, making possible the use of the KLL Auger metal and oxide peaks instead of (or in addition to) the Al 2*s* and 2*p* photoelectron peaks, the interpretation of which is more difficult and entails more subjectivity.

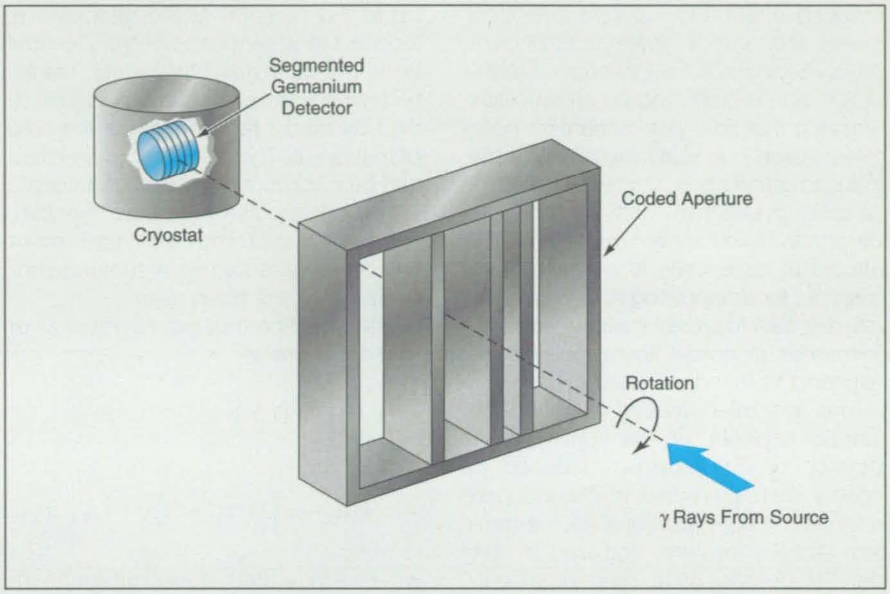
Gamma-Ray Imager With High Spatial and Spectral Resolution

An externally segmented germanium detector is rotated in synchronism with a segmented aperture.

NASA's Jet Propulsion Laboratory, Pasadena, California

A γ-ray instrument has been developed to enable both (1) two-dimensional imaging at relatively high spatial resolution and (2) spectroscopy at a fractional-photon-energy resolution of about 10^{-3} in the photon-energy range from 10 keV to >10 MeV. In its spectroscopic aspect, the instrument enables identification of both narrow and weak γ-ray spectral peaks.

Heretofore, two-dimensional γ-ray imaging was possible, but only with relatively coarse energy resolution; a typical resolution would be 7 percent at a photon energy of 662 keV, and this is insufficient for spectroscopy of γ-ray spectral peaks and for detection of weak γ-ray spectral peaks. Prior to the development of the present instrument, it has not been possible to perform two-dimensional γ-ray imaging simultaneously with fine energy spectroscopy at photon energies above 10 keV.



The **Segmented Detector and Segmented Aperture** are rotated in synchronism to acquire one-dimensional image data at a suitably large number of rotational positions. Deconvolution of these data yields a two-dimensional image.

The instrument (see figure) includes a large-volume germanium detector with an external electrode segmented into N distinct charge-collection regions (such detectors are manufactured with $5 \leq N \leq 12$). This detector is mounted in a cryostat and is used in conjunction with a segmented, linearly coded rectangular aperture that is placed between the detector and the γ-ray source. The widths of the detector segments equal those of the aperture segments, and the detector and aperture segments are aligned with each other, forming a one-dimensional imaging system.

To obtain data for two-dimensional imaging, the detector and aperture are rotated in synchronism (maintaining alignment) 180° about the line of sight, and detector readings are taken at multiple rotational positions along the way. The γ-ray image is then reconstructed by use of a computer to deconvolve the detector readings. Spatial resolution can be increased by increasing the distance between the aperture and the detector or by increasing the number of rotational positions where readings are taken. Both point and spatially extended γ-ray sources can be imaged. Large fields of view are possible if multiple detectors are used.

This work was done by John L. Callas, Larry S. Varnell, William A. Wheaton, and William A. Mahoney of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 78*** *on the TSP Request Card.* NPO-19140

Electrochemical Apparatus Simulates Corrosion in Crevices

Marshall Space Flight Center, Alabama

A method of testing metal specimens for susceptibility to galvanic corrosion in crevices involves the use of a relatively simple electrochemical apparatus. By following this method, one can quantify the rates of corrosion of dissimilar-metal couples exposed to various etchants or other corrosive solutions. The apparatus includes a crevice cell, in which disk specimens of the metals of interest are mounted, separated by a polytetrafluoroethylene washer with radial channels that simulate crevices. The cell is filled with the corrosive solution of interest, which enters the channels. Galvanic currents are measured by electrically coupling the two metals together through a zero-resistance ammeter circuit. Rates of galvanic corrosion, which are proportional to galvanic currents, are measured and recorded for each metal couple. The apparatus was used to study the nickel/braze and braze/A286 stainless-steel couples as part of an investigation into the corrosion of nickel-plated A286 nozzle-coolant tubes in the main engine of the space shuttle. It was found that corrosion had been caused, in part, by acid etchants used during manufacturing of nozzles. The apparatus was also used to evaluate corrosion after treatment with corrosion inhibitors.

This work was done by S. Rachel Khoshbin, S. L. Jeanjaquet, and Jesse B. Lumsden of Rockwell International Corp. for **Marshall Space Flight Center.** *For further information,* ***write in 76*** *on the TSP Request Card.* MFS-30101

Theory of Radiation-Induced Attenuation in Optical Fibers

An improved mathematical model accounts for the effects of dose rates.

NASA's Jet Propulsion Laboratory, Pasadena, California

An improved theory of radiation-induced attenuation of light in optical fibers accounts for the effects of dose rates. Previously, radiation-induced attenuation was represented by an empirical equation that does not account for dose rates; namely, $A = aD^b$, where A is the induced attenuation, D is the total dose of ionizing radiation, and a and b are constants. Accurate accounting for the effects of dose rates is necessary, for example, for extrapolating from high-dose-rate test data to predict the long-term performances of optical fibers that will be exposed to low dose rates in use.

The improved theory is based on kinetic aspects of the fundamental physics of color centers induced in optical fibers by radiation. The induced attenuation is proportional to the density of color centers, and part of this density decays by a thermal-annealing/recombination process after irradiation. Thus, once irradiation stops, there can be a partial recovery from the maximum induced attenuation.

The improved theory is based on a simple linear-superposition principle: the attenuation at any given time is considered to be the sum, over all time up to the present, of the attenuations induced in a sequence of infinitesimal and/or finite irradiation events, the attenuation from each event being modified by partial recovery since the time of that event. The partial-recovery effect can be incorporated into what amounts to a unit-impulse-response function, and the radiation impulse in each event can be represented as a stimulus proportional to the dose rate.

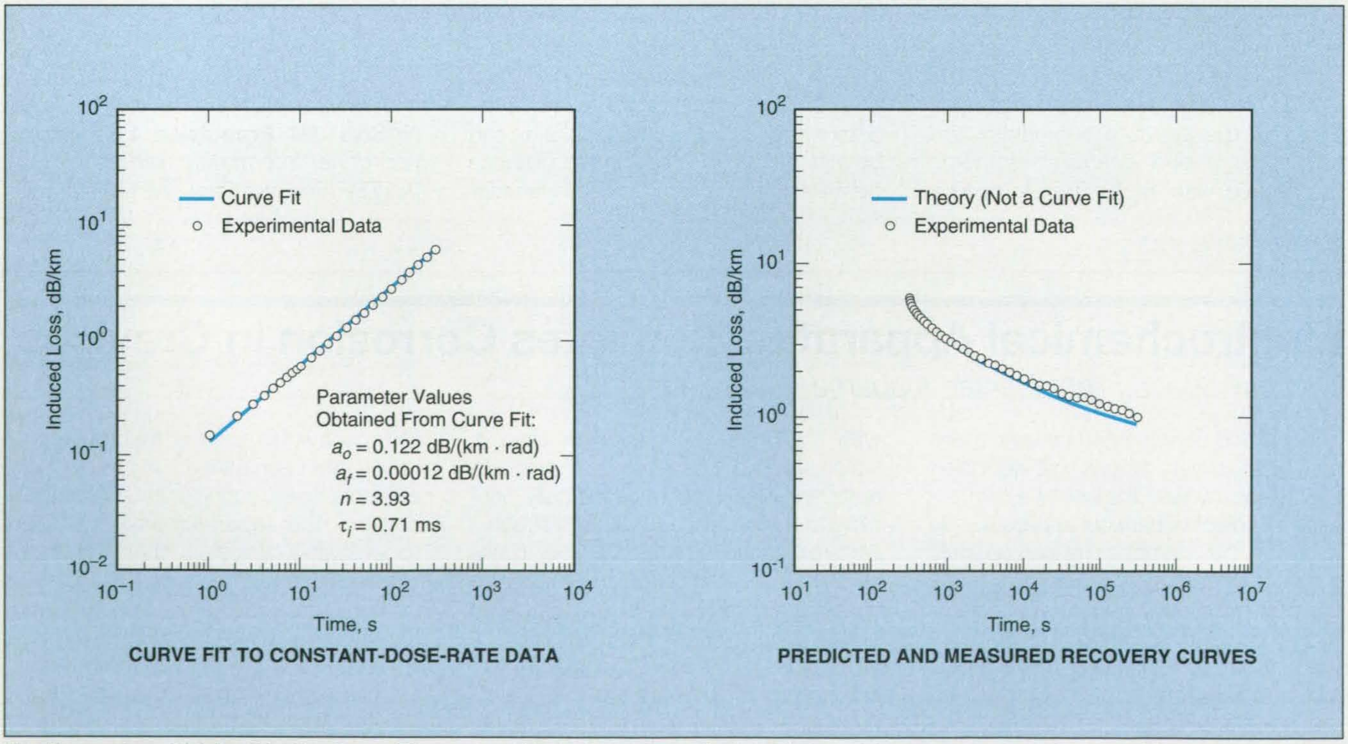
The equation that incorporates all of these effects is

$$A(t) = \int_0^t D'(t') \left\{ (a_0 - a_f)\left[1 + c_i(t - t')\right]^{\frac{-1}{n-1}} + a_f \right\} dt'$$

where $A(t)$ is the induced attenuation; t is time; $D'(t')$ is the time-dependent dose rate; a_0 is a coefficient that corresponds to the attenuation immediately after irradiation; a_f is a coefficient that corresponds to the final attenuation after long recovery; and $c \equiv (1/\tau)(2^{n-1} - 1)$, where τ is the half-height lifetime of the recovery process and n is the material-dependent order of the recovery kinetics. The terms in braces constitute the unit-impulse-response function. The coefficients in this equation can be obtained by fitting the equation to experimental data. Then, the equation can be used to predict subsequent behavior under different conditions.

In an experimental test of the theory (see figure), a multimode optical fiber was bombarded by radiation from Co^{60} at a constant dose rate of 15.5 rad/s at a temperature of 21 °C and the induced attenuation was measured as a function of time. Then, the irradiation was stopped and the measurements continued. The coefficients of the equation were obtained from a curve fit of the equation to the constant-dose-rate measurements, then the coefficients were inserted in the equation, which was used to calculate the post-irradiation recovery curve.

This work was done by Tsuen-Hsi Liu and Alan R. Johnston of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 27*** *on the TSP Request Card. NPO-19334*



The **Parameters Obtained in the Curve Fit** were used to obtain a theoretical prediction of the recovery curve for comparison with the experimental recovery data.

Compact Color Schlieren Optical System

All of the lenses are stock items.

Lewis Research Center, Cleveland, Ohio

A compact, rugged optical system has been developed for use in rainbow schlieren deflectometry. The system features an unobscured telescope with a focal-length/aperture-width ratio of 30. It is made of carefully selected but relatively inexpensive parts.

Figure 1 shows a conventional gray-scale schlieren system. Light from a source is focused by a condensing lens on an aperture, which could be a pinhole or slit. Light diverging from this aperture is collected and collimated by a mirror and then passes through a test section, which contains a transparent medium, the spatial variations of the index of refraction of which are to be imaged and/or measured. (For example, if the medium is a fluid, the spatial variations in the index of refraction can be caused by gradients of temperature and/or density associated with flow of the medium.)

These spatial variations locally alter the phase of the optical wavefront (less precisely but more intuitively comprehensibly, they cause the light rays to bend). A decollimating mirror then forms a Fourier transform of the complex-amplitude transmittance of the medium in its back focal plane (makes the remaining collimated rays converge on a focal point, while it makes the bent rays

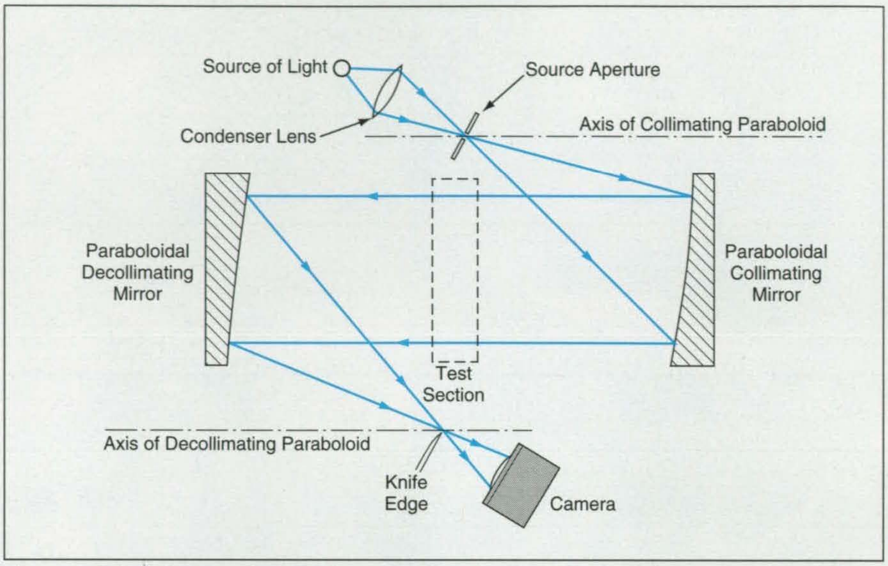


Figure 1. This **Schlieren System** has one of several common configurations of conventional gray-scale schlieren systems. In this case, the collimating and decollimating mirrors are off-axis-machined paraboloids.

strike the focal plane near, but not at, the focal point). A knife edge at or close to the focal point intercepts the amplitude and half of the phase information in the Fourier plane (the bent rays that strike the knife are prevented from reaching the camera). As a result, the image of the section projected into the camera is a pattern of light and dark areas that correspond to lateral (with respect to the line of sight) variations in the index of refraction of the medium.

A rainbow schlieren system differs from a gray-scale schlieren system in that the knife edge is replaced by either a color filter that changes linearly in hue from one side to the other or by one that changes radially in hue. A rainbow schlieren system offers sensitivity equal to that obtained with interferometry. It also offers the potential for quantification of the schlieren-image data, provided that the focal length of the optics and the relationship between the optics and the medium of interest in the test section are unambiguously known. Therefore, correction of astigmatism is desirable.

Figure 2 shows the layout of the optical system that was developed for use in a rainbow schlieren system. More specifically, it shows an optical subsystem and a half length of the test section; this optical subsystem can be used for decollimation, and a similar optical subsystem at the other end of the test section can be used for collimation.

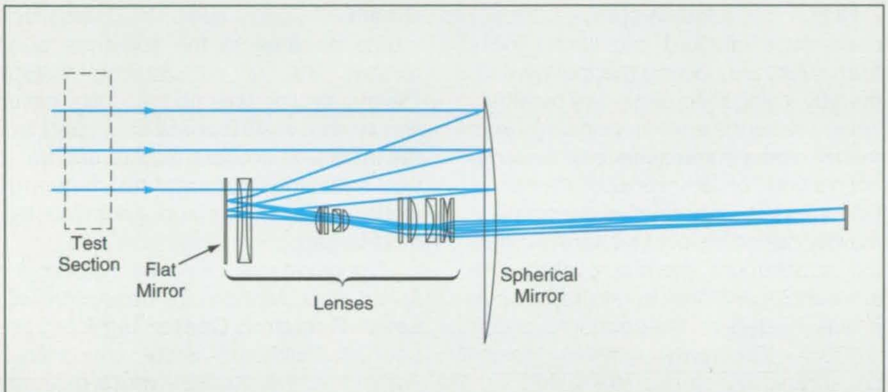


Figure 2. This **Optical System** is particularly well suited for use as a decollimating (as shown here) or as a collimating subsystem of a rainbow schlieren system.

To minimize the cost, the design of the subsystem deliberately avoids aspherical lenses and off-axis-figured aspherical mirrors, which are expensive and difficult to make. The optics are nevertheless highly corrected by use of multiple carefully selected and carefully placed spherical reflecting and refracting optics: the subsystem is assembled from stock lenses, a spherical mirror, and a flat mirror.

An intentional by-product of the design is an optical system with loose tolerances on interlens spacing. One of the resulting advantages is insensitivity to errors in the fabrication of optomechanical mounts. Another advantage is the ability to compensate for some of the unit-to-unit variations inherent in stock lenses.

This work was done by Donald R. Buchele of ADF, Inc., and DeVon W. Griffin of Sverdrup Technology, Inc., for **Lewis Research Center**. *For further information,* ***write in 79*** *on the TSP Request Card. LEW-15987*

Coating Silicon-Based Ceramics With Durable Mullite

Elimination of the amorphous phase eliminates extensive cracking and debonding.

Lewis Research Center, Cleveland, Ohio

An improved plasma-spraying process deposits mullite (aluminum silicate) on silicon carbide substrates. The process is also expected to be useful in depositing mullite on substrates made of other silicon-based ceramics (e.g., Si_3N_4 and SiC/Si_3N_4 composites) and other ceramic substrates (e.g., AlN) that have coefficients of thermal expansion similar to those of mullite.

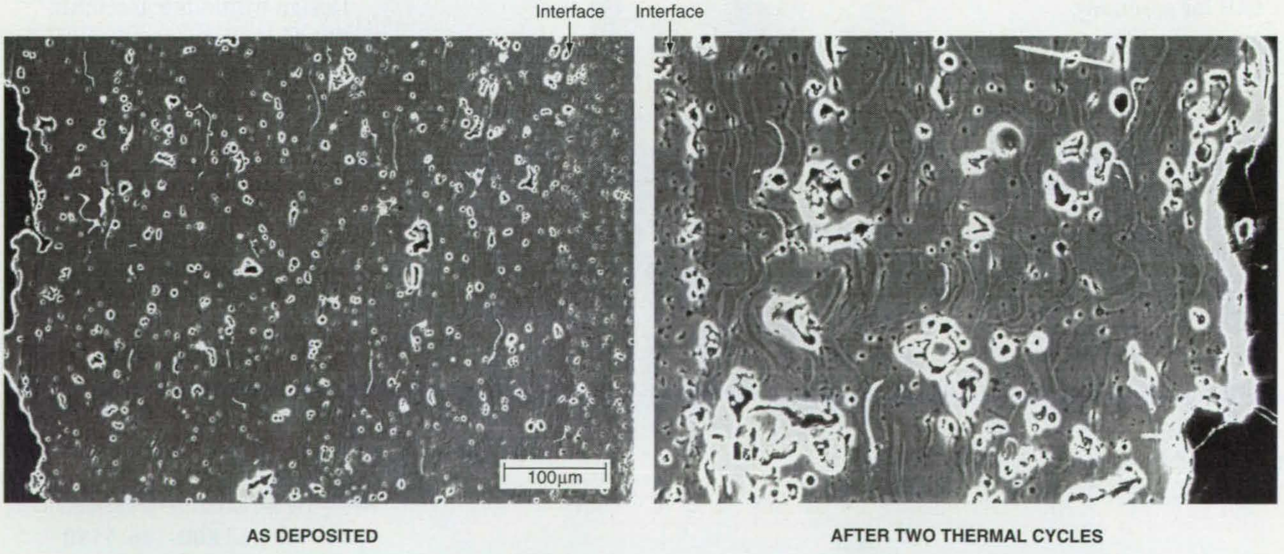
Mullite coats are highly desirable for silicon-based ceramic structural components of heat exchangers, gas turbine engines, and advanced internal-combustion engines. Mullite exhibits high chemical stability, low thermal conductivity, and a coefficient of thermal expansion approximately equal to those of silicon-based ceramics. Therefore, an adherent coat of mullite could serve as both a chemical and a thermal barrier that would protect the underlying ceramic against high-temperature chemical attack. In addition, overlayers of such other refractory oxides as alumina, yttria-based zirconia, or yttria could be applied to the base coats of mullite.

Until now, plasma-sprayed mullite coats have cracked and flaked away from substrates during thermal cycling, thereby losing their protective qualities. This cracking and debonding was found to be a consequence of the large proportion of amorphous (noncrystalline) mullite that formed during plasma deposition on cold substrates: during subsequent thermal cycling, the amorphous material crystallized when it was heated to temperatures above 1,000 °C. The newly crystallized material shrank, giving rise to cracks.

The improved process prevents the formation of amorphous mullite by maintaining high temperature of the sprayed deposit to allow crystallization to occur. For this purpose, the plasma spraying of mullite is done in a furnace that heats the substrate to about 1,000 °C. Once the substrate has reached the desired temperature, mullite powder is introduced into an argon-40-percent-helium plasma in a stream of argon gas. The deposited mullite adheres to the substrate and exhibits little or no cracking during thermal cycling (see figure). Tests have shown that mullite coats deposited by the improved process adhere and provide substantially greater resistance to oxidation in dry air and corrosion by molten salt.

This work was done by Robert A. Miller and Nathan S. Jacobson of **Lewis Research Center** *and Kang N. Lee of Cleveland State University. For further information,* ***write in 2*** *on the TSP Request Card.*

This invention has been patented by NASA (U.S. Patent No. 5,391,404). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Lewis Research Center; (216) 433-2320. Refer to LEW-15561.



This **Specimen of Mullite Coat on a Silicon Carbide Substrate** contained no interconnected cracks and could thus protect the substrate against chemical attack, even after two thermal cycles. In each cycle, the specimen was suddenly heated to 1,000 °C, kept at that temperature for 24 h, and quenched in air to room temperature.

Extruded Self-Lubricating Solid for High-Temperature Use

Properties equal or exceed those of a powder-metallurgy version of this material.

Lewis Research Center, Cleveland, Ohio

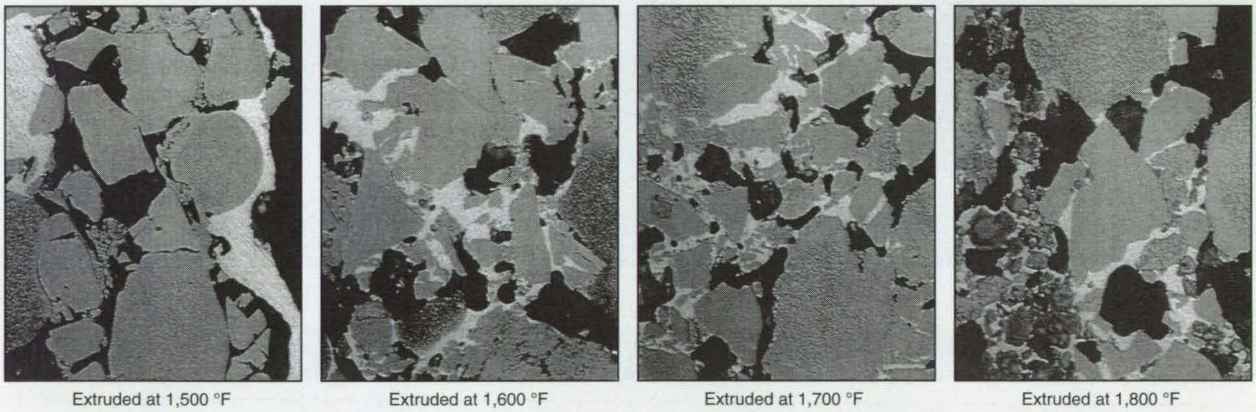
"EX-212" denotes a high-density extruded form of a composite solid material that is self-lubricating over a wide range of temperatures. The material has been developed for use in advanced engines at high temperatures at which ordinary lubricants are destroyed. An older form of the material, made by plasma spraying, is called "PS-212"; another older form of the material, made by powder metallurgy, is called "PM-212." All three forms of the material have the same chemical composition: they are made from powders of chromium carbide with a nickel-based binder (70 percent) combined with silver (15 percent) and with a eutectic mixture of barium and calcium fluorides (15 percent).

EX-212 was added to the "212" product line in an effort to enhance its commercial potential. Experiments were conducted to investigate the properties of "212" extruded at various temperatures. PS-212 powder for use in the extrusion experiments was prepared by blending the constituent powders. Then the powder was extruded into bars, at an area-reduction ratio of 16:1, at temperatures of 1,400 °F (760 °C), 1,500 °F (816 °C), 1,600 °F (871 °C), 1,700 °F (927 °C), and 1,800 °F (982 °C). Measurements of frictional and strength properties of the bars indicated that the tribological and other physical properties of EX-212 equal or exceed those of PM-212. Overall results of the experiments indicated that extrusion temperatures are not critical for densification, but other properties depend on extrusion temperatures.

X-ray images of the bars showed relatively uniform, continuous extrusions with no bursts or discontinuities. Specimens made from the bars were inspected further by use of x rays and surface fluorescence and found to be generally porous. The amount of porosity was greatest in the bars extruded at lower temperatures and least in the bars extruded at the maximum temperature of 1,800 °F (982 °C).

Specimens made from the bars were subjected to tensile tests at room temperature, 800 °F (427 °C), 1,200 °F (649 °C), 1,400 °F (760 °C), and 1,600 °F (871 °C). For the most part, tests consisted of measurements of ultimate tensile strengths in a controlled-strain-rate testing machine. Generally, the bars extruded at lower temperatures exhibited greater tensile strengths at test temperatures from ambient to 1,200 °F (649 °C), whereas the bars extruded at higher temperatures exhibited greater strengths at 1,400 °F (760 °C), and 1,600 °F (871 °C). In all cases, elongation was less than 3 percent. The bars extruded at the lower temperatures exhibited the least ductility as measured in terms of tensile elongation.

This work was done by H. E. Sliney of **Lewis Research Center**, *W. J. Waters of Sverdrup Technology, Inc., R. F. Soltis of Omni, Inc., and K. Bemis of Case Western Reserve University. For further information,* ***write in 95*** *on the TSP Request Card. LEW-15936*



These **Magnified Views of Etched Specimens** of EX-212 all show porosity. Note that the pores are smallest in the specimen extruded at the highest temperature.

Improved Synthesis of Potassium ß″-Alumina

The ß″ phase can be synthesized from alternative formulations.

NASA's Jet Propulsion Laboratory, Pasadena, California

Improved formulations of precursor materials have made it possible to synthesize nearly-phase-pure potassium ß″-alumina solid electrolyte (K-BASE) powder. The precursor materials in question are microhomogeneous powders (or, alternatively, gels) that contain K^{+}, Mg^{2+}, and Al^{3+}. Conversion of these materials to K-BASE is effected by heating them in air at temperatures between 1,373 and 1,773 K. K-BASE powder thus produced can be used in potassium-working-fluid alkali-metal thermal-to-electric conversion (K-AMTEC), in which the heat-input and heat-rejection temperatures are lower than those of sodium-working-fluid AMTEC (Na-AMTEC). An additional potential use lies in the purification of potassium by removal of sodium and calcium.

High-quality potassium ß″-alumina powder is necessary for making high-quality potassium ß″-alumina ceramics needed in K-AMTEC cells. Difficulties were encountered in previous attempts to synthesize potassium ß″-alumina by direct solid-state chemical reactions among oxides because the temperatures needed for formation of the ß″-alumina phase are high enough to cause escape of K_2O and thus loss of potassium from the ß″-alumina. Liquid-phase synthesis has also proven difficult because it involves still higher temperatures at which the ß″ phase is crystallographically unstable.

One class of improved precursor materials comprises gels made by hydrolysis of solutions of alkoxides of K^+, Mg^{2+}, and Al^{3+}; isopropoxides, ethoxides, *t*-butoxides, and *n*-butoxides have been used. An alternative class of precursor materials comprises polymeric oxalate salts of the three metals in the appropriate ratios. Mg^{2+} ions are included in the formulations because they stabilize the ß″ phase. (Prior to the development of these precursor materials, stabilizing ions were not included.) In experiments, the improved precursor materials were fired at temperatures from 1,373 K to 1,773 K to obtain crystalline potassium ß″-alumina.

This work was done by Roger M. Williams, Barbara Jeffries-Nakamura, Margaret A. Ryan, Dennis E. O'Connor, Adam Kisor, and Mark Underwood of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 64*** *on the TSP Request Card. NPO-19210*

Iridium Aluminide Coats for Protection Against Oxidation

Iridium aluminide protects as well as platinum does at temperatures up to 1,600 °C.

Lewis Research Center, Cleveland, Ohio

Iridium aluminide coats have been investigated for use in protecting some metallic substrates against oxidation at high temperatures. The investigation was prompted by the need for cost-effective anti-oxidation coats for the walls of combustion chambers in rocket engines. Iridium aluminide coats may also prove useful in special terrestrial applications like laboratory combustion chambers and some chemical-processing chambers.

In the investigation, an iridium aluminide coat was formed by chemical vapor deposition from iridium carbonyl and tri-isobutyl aluminum precursors. The substrate was a water-cooled part of a center body for use in a cylindrical thrust chamber. Metallographic analysis showed the coat to be a dense mixture of iridium/aluminum compounds and elemental iridium.

The coated substrate was tested by subjecting it to simulated thruster-firing cycles in which the temperature at the interface between the coat and the substrate reached various peak values from 430 to 2,000 °C. At 2,000 °C, the iridium aluminide coat was found to be as protective as a pure iridium coat. At temperatures up to about 1,600 °C, the iridium aluminide coat was found to be as protective as a platinum coat; that is, the rate of oxidation with the iridium aluminide coat was found to be the same as that with a platinum coat — of the order of a hundredth the rate of oxidation with a pure iridium coat.

Not only does iridium aluminide provide superior protection against oxidation, it also costs about half as much as iridium and platinum do. In addition, iridium aluminide protects against oxidation at temperatures equal to or greater than those for pure iridium. Iridium aluminide may not be suitable for use on some substrates; for example, at temperatures near and above 2,000 °C, low-melting-temperature iridium/niobium compounds can form, with resultant degradation of both coats and substrates. It may be necessary to use intermediate diffusion-barrier coats in such cases. Further investigation will be necessary to understand process kinetics and optimize process parameters.

This work was done by Richard B. Kaplan, Robert H. Tuffias, Raffaele La Ferla, and Qin Jang of Ultramet for **Lewis Research Center**. *For further information,* ***write in 54*** *on the TSP Request Card. LEW-15645*

Lightweight, Thermally Insulating Structural Panels

Thermal conductivities are smaller than those of the best commercial insulating materials.

NASA's Jet Propulsion Laboratory, Pasadena, California

Lightweight, thermally insulating panels that also serve as structural members have been developed. In the original intended application, the panels would be used to house electronic circuitry aboard a vehicle that would explore the surface of Mars. On Earth, panels of this type would be especially suitable for use in low-air-pressure environments in which lightweight, compact, structurally supporting insulation is needed; for example, aboard high-altitude aircraft or in partially evacuated panels in refrigerators.

A panel of this type (see Figure 1) is a low-thermal-conductivity composite-material honeycomb-core/sandwich that affords thermal insulation over wide pressure and temperature ranges. The convective transfer of heat in an ordinary honeycomb core would be significant at pressures down to 1 torr (about 130 Pa). The core is filled with a silica aerogel. This filling eliminates the convective transfer of heat; it also exhibits very low thermal conductivity. Furthermore, this aerogel is opacified with 15-weight-percent Al particles smaller than 2 μm to minimize radiative heat transfer.

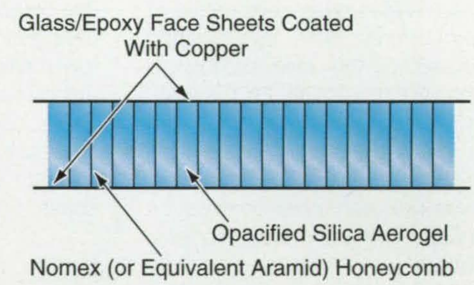


Figure 1. A **Honeycomb-Core Panel** of low thermal conductivity is filled with a low-thermal-conductivity, opacified silica aerogel that prevents convection and minimizes internal radiation. The copper coating on the face sheets reduces radiation.

Thermal conduction through the thickness of the panel via the honeycomb walls is minimized by making the honeycomb walls as thin as possible (in this case, occupying only 3.4 percent of the cross-sectional area) while still providing adequate structural support. The honeycomb is made of Nomex (or equivalent aramid), which offers the required strength and rigidity, plus a thermal conductivity lower than that of other available composite-core materials. The face sheets are made of low-thermal-conductivity glass/epoxy composites. They are coated with copper to obtain low emissivity and thereby to further reduce transfer of heat by radiation.

The effective overall thermal conductivities of a panel of this type and several other types were measured at representative temperatures in a carbon dioxide atmosphere at a pressure of 10 torr (1.3 kPa). The results of some of these measurements are plotted in Figure 2, which shows clearly that the effective overall thermal conductivities of the developmental panels are smaller than those of state-of-the-art commercial non-structurally-supporting foam and fibrous insulations.

This work was done by Howard J. Eisen, Gregory Hickey, Liang-Chi Wen, William E. Layman, Richard A. Rainen, and Gajanana C. Birur of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 26*** *on the TSP Request Card. NPO-19382*

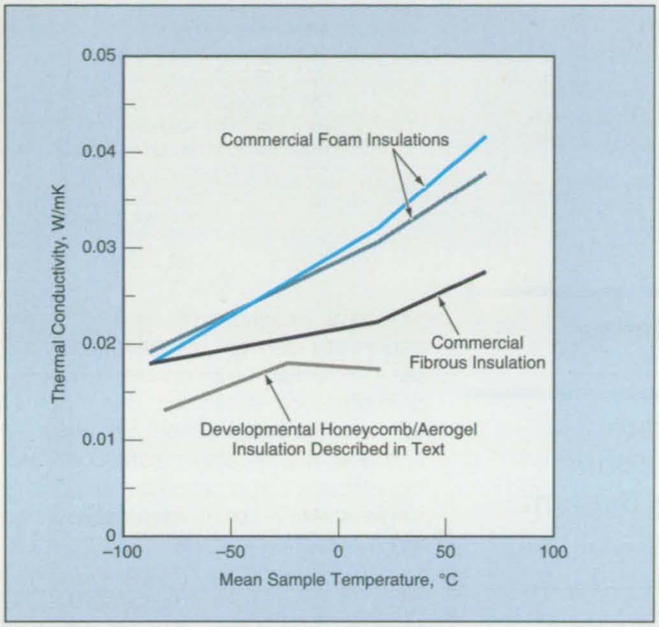


Figure 2. These **Thermal Conductivities Were Measured** in a 10-torr carbon dioxide atmosphere.

Advanced Polymer for Multilayer Insulating Blankets

This polymer resists degradation by monatomic oxygen.

Marshall Space Flight Center, Alabama

A polymer that resists degradation by monatomic oxygen has been invented by scientists at NASA and is undergoing commercial development under the trade name "Aorimide" (which stands for "atomic-oxygen-resistant imidazole"). Originally, this polymer was intended for use in thermal blankets for spacecraft in low orbit around the Earth, where degradation by monatomic oxygen limits the useful lifetimes of polymeric materials. If this polymer proves equally stable in terrestrial environments, then it might prove useful on Earth in outdoor applications in which sunlight and ozone degrade other plastics.

Aorimide can be used, for example, to make threads and to make films coated with metals for reflectivity. In preliminary experiments, film specimens of Aorimide with silver/nickel-alloy mirror coats were found to resist attack by atomic oxygen and to exhibit thermal-blanket performance comparable to that of Kapton (or equivalent) polyimide coated with aluminum.

This work was done by R. Ross Haghighat and Allan Shepp of Triton Systems, Inc., for **Marshall Space Flight Center.** *For further information,* ***write in 88*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center; (205) 544-0021. Refer to MFS-26335.

Computer Programs

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Physical Sciences

Software for Generation of ASTER Data Products

Software that functions in the EOS-DIS computing environment has been developed to generate data products from the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER). This software processes high-resolution image data from (a) visible and near infrared (VNIR), (b) short-wavelength infrared (SWIR), and (c) thermal infrared (TIR) radiometric readings to generate data on radiative and thermal properties of the atmosphere and surface of the Earth. The data products include the following:

- Brightness temperature at a horizontal resolution of 90 m;
- Surface reflectances and surface radiances in the VNIR band at a horizontal resolution of 15 m and in the SWIR band at a horizontal resolution of 30 m;
- Surface reflectance in the TIR band at a horizontal resolution of 90 m;
- Surface emissivity (over land only) at a horizontal resolution of 90 m,
- Land surface temperature at a horizontal resolution of 90 m;
- A polar classification map showing water, wet ice and slush, snow and ice, land, shadow, water cloud, and ice cloud, with resolutions of 15, 30, and 90 m; and
- Topographical information from along-track stereoscopic observations in the near infrared band.

This work was done by Alexander T. Murray, Bjorn T. Eng, and Charles C. Voge of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 77*** *on the TSP Request Card. NPO-19701*

Manufacturing/ Fabrication

Another Program Simulates a Modular Manufacturing System

The system can consist of a production line with as many as 18 stations in series.

SSE5 is a computer program that provides a simulation environment for modeling manufacturing systems that contain relatively small numbers of stations and operators. Although SSE5 was designed to simulate manufacturing of apparel, it could be used in other manufacturing domains.

The SSE5 simulation software package is most valuable for small or medium-size firms, including those that lack the expertise to develop detailed mathematical models or have only minimal knowledge in describing manufacturing systems and in analyzing the results of simulations on mathematical models. The user does not need to know a simulation language to use SSE5. SSE5 has been used by a number of apparel-manufacturing firms to design new manufacturing modules and to evaluate existing modules. SSE5 is one of a suite of programs that simulate small manufacturing systems. Two other programs, SSE3 and SSE6, are also available from COSMIC, bundled together as SSE (MFS-26245). Each program models a slightly different manufacturing scenario.

SSE5 can be used to design and evaluate a modular manufacturing system with one line and a maximum of 18 stations in a series. Each station can include a maximum of eight machines performing identical operations in parallel. A maximum of 26 operators, of variable efficiency, is allowed. Some operators are assumed to be cross-trained and able to work at any station at varying efficiency and some are fixed at a single station. The model incorporates the assumption that unlimited space is available for work in process in front of each station. There must always be enough items in front of the first station to prevent a delay while waiting for an item. Work is done in lots; a lot can consist of one or many items. SSE5 also incorporates the assumption that there are no machine breakdowns.

SSE5 is written in Turbo C v2.0 for IBM PC-series and compatible computers running MS-DOS and has been successfully compiled using Turbo C++ v3.0. Sample MS-DOS executable codes and sample input/output files are included on the distribution medium. The program requires a VGA graphics display and at least 128K of random-access memory for execution. The standard distribution medium for SSE5 is a 3.5-in. (8.89-cm), 1.44MB MS-DOS format diskette. SSE5 was developed in 1993.

This program was written by Bernard J. Schroer and Jian Wang of the University of Alabama in Huntsville for **Marshall Space Flight Center.** *For further information,* ***write in 75*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center; (205) 544-0021. Refer to MFS-26284.

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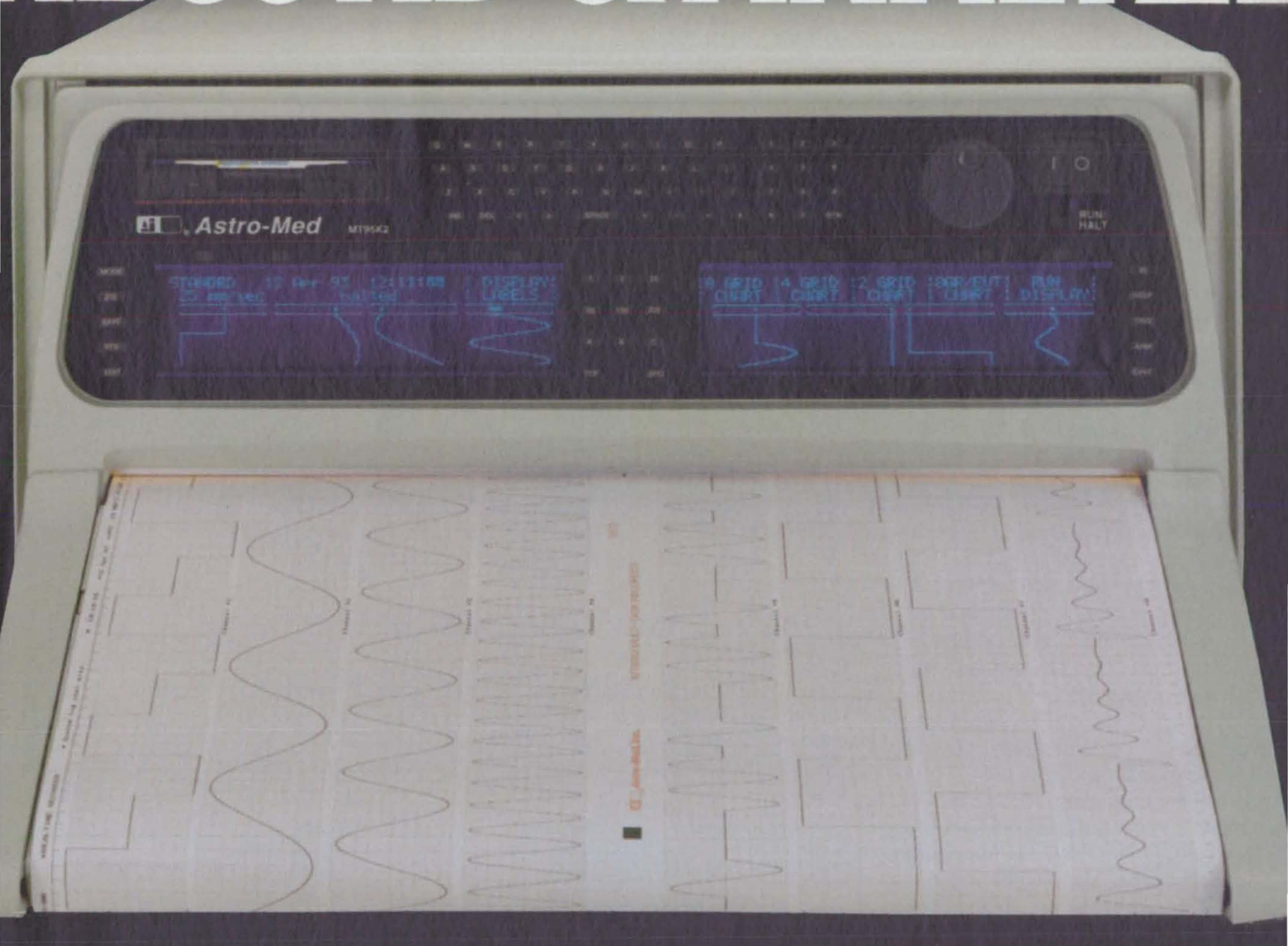

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Cross Coupling Between Attenuators in a Docking Mechanism

The capture envelope would be widened.

Lyndon B. Johnson Space Center, Houston, Texas

Cross coupling between motion attenuators on opposite sides of a docking mechanism has been proposed as a means of increasing the capture envelope. ("Capture envelope" denotes the ranges of translational and angular misalignments and rates of change of those misalignments within which the docking mechanism on one structure or vehicle can capture the mating docking mechanism on the other structure or vehicle.) The prototype system for application of the proposed cross-coupling concept is the one that was used for docking of the Apollo and Soyuz spacecraft; however, given the widespread use of docking mechanisms, the concept may prove useful in many terrestrial applications as well.

Figure 1 is a simplified illustration of the prototype docking mechanism without cross coupling. The six degrees of freedom (three translational and three rotational) of misalignment would be accommodated by six motion attenuators, which would be, essentially, combinations of springs and dampers. To provide for cross coupling, the spring-and-damper motion attenuators would be replaced by more complex attenuators. Each attenuator would contain a ball screw to convert its longitudinal extension and retraction to rotational motion, and vice versa. Each attenuator would also contain a centering spring and a hysteresis brake that could be put into a low-damping mode for capture and a high-damping mode for increased attenuation after capture.

A planetary differential would be interposed on the ball-screw shaft between the ball nut and the hysteresis brake. This differential would couple the rotary motion to one end of a flexible shaft. The other end of the flexible shaft would be connected similarly to the differential of the attenuator on the opposite side (see Figure 2). This cross coupling between attenuators on opposite sides would be configured to produce opposing linear motions: the extension or retraction of one attenuator would be

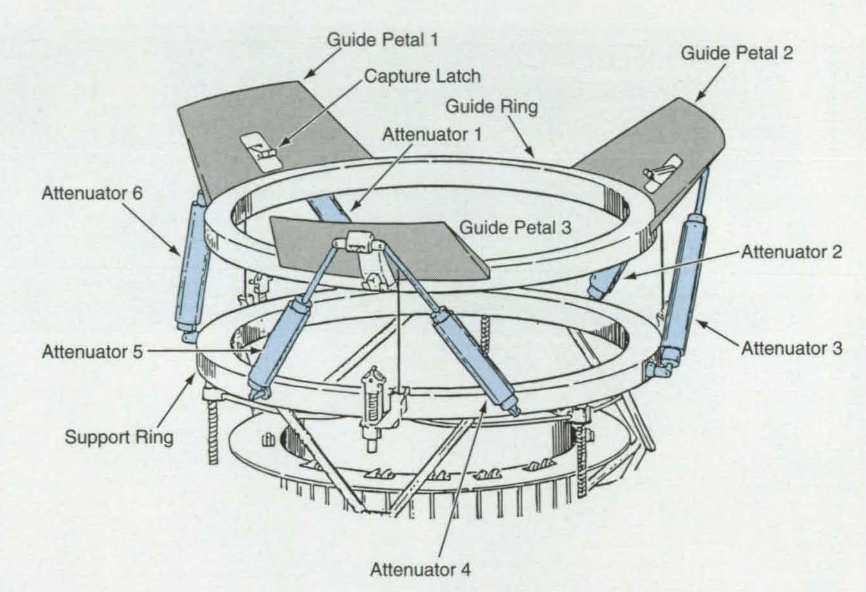


Figure 1. The **Docking Mechanism Without Cross Coupling** functions satisfactorily within a limited capture envelope.

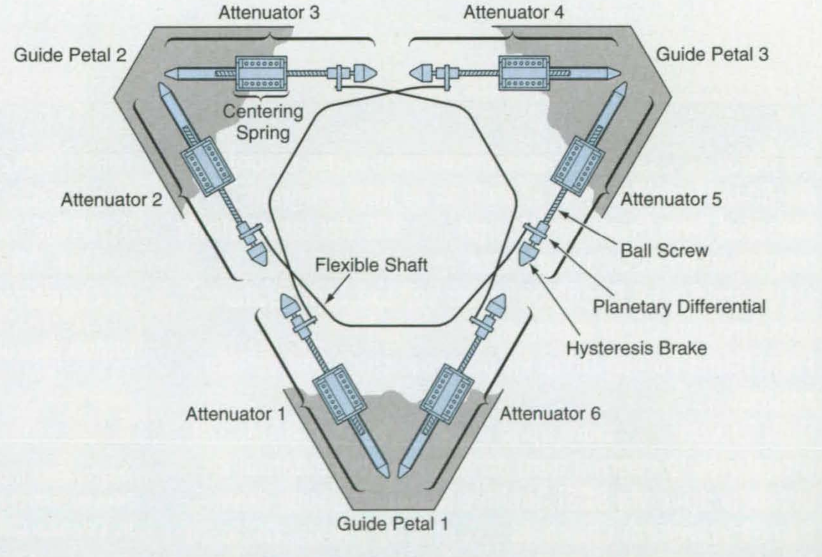


Figure 2. **Cross Coupling Between Attenuators** on opposite sides would divert some of the momentum and kinetic energy transferred in initial contact to generate motions that would reduce misalignment. As a result, the capture envelope would be widened.

converted into rotary motion of the flexible shaft, and the rotary motion would, in turn, be converted into retraction or extension, respectively, of the other attenuator. These complementary motions would help to remove misalignments between docking mechanisms, as in the following examples:

1. If the guide ring of the docking mechanism on the approaching vehicle made initial contact with guide petal 1 of the docking mechanism on the approached vehicle, then on the approached vehicle, attenuators 1 and 6 would be compressed, causing attenuators 3 and 4 to extend by equal amounts; this would help to remove the angular misalignment between the guide rings of the two vehicles.
2. If a guide petal of the approaching vehicle made contact with the guide ring of the approached vehicle at a location between guide petals 1 and 3, then attenuators 5 and 6 on the approached vehicle would be compressed, causing attenuators 2 and 3 to extend. As a result, guide petal 2 would be tilted upward, and misalignment between the guide rings would again be reduced.
3. Suppose that there were a large roll misalignment, such that a guide petal of the approaching vehicle made initial contact with one edge of guide petal 1 on the approached vehicle, forcing attenuator 1 to retract and attenuator 6 to extend. In this case, the cross coupling would cause attenuator 4 to extend and attenuator 3 to retract, causing the guide ring to rotate so as to reduce the roll misalignment.

This work was done by Arthur Holmberg, Matthew S. Schmidt, and Siamak Ghofranian of Rockwell International Corp. for **Johnson Space Center.** *For further information,* ***write in 46*** *on the TSP Request Card.*
MSC-22345

Soft Wire Seals for High Temperatures and Pressures

These seals can be fabricated easily, at relatively low cost.

NASA's Jet Propulsion Laboratory, Pasadena, California

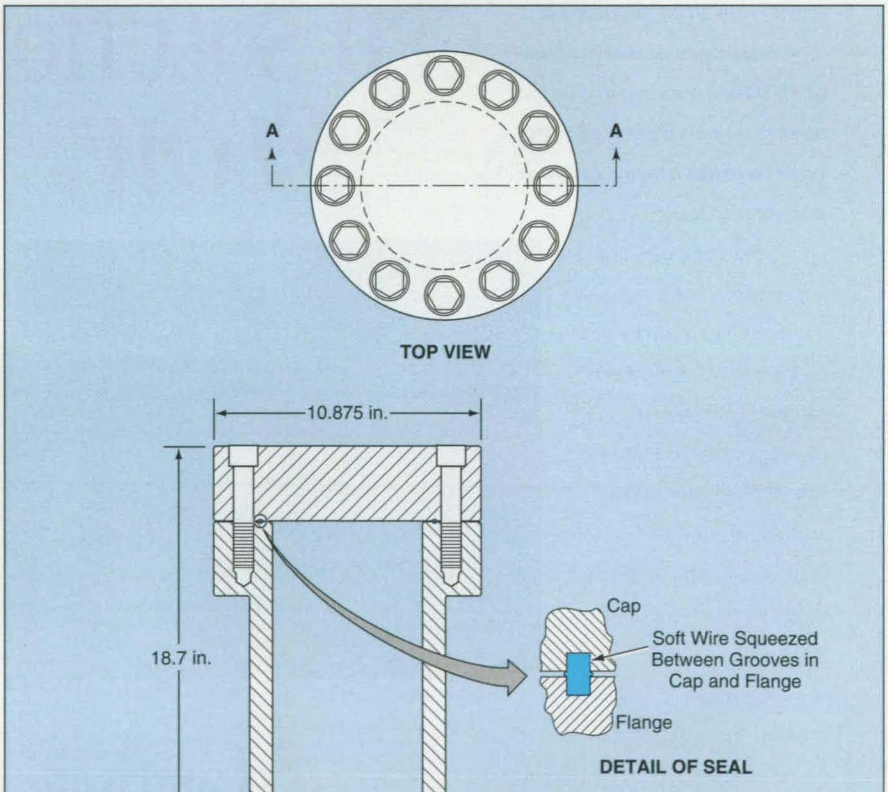
Soft metal wires can be used to make O-ring and similar seals for vessels, flanges, and fittings subject to pressures ≥1,000 psi (≥7 MPa) and temperatures ≥100 °C. Heretofore, seals for such high-pressure, high-temperature applications have been fabricated by precise machining of mating surfaces and have therefore been expensive; the prices of some commercial seals for these applications are as high as $6,500. The seals containing soft metal wires can be made inexpensively because they can be fabricated to looser tolerances like those of lower-temperature, lower-pressure elastomeric-O-ring seals, which they resemble.

The figure illustrates a laboratory pressure vessel with a soft wire seal. In fabrication of this vessel, matching sealing grooves are machined into a flange on the main body of the vessel and in a cap that is bolted onto the flange. The wire used as the O-ring seal is made of 1100 aluminum, which is relatively soft. The diameter of the wire is chosen so that the cross-sectional area of the wire exceeds the combined cross-sectional areas of the grooves: this is necessary to make excess wire material available to be squeezed out of the grooves to form a seal.

The wire is cut to the circumference of the groove, then the ends of the wire are fused together to form the sealing ring. The ring is laid in the sealing groove on the flange. Then the cap is laid over the sealing ring and bolted onto the flange, thereby squeezing the wire material both into the grooves and across adjacent areas of the flange and cap, forming a seal.

Seals of this type can also be made with noncircular grooves and with soft metals other than aluminum. For example, gold would perform well, though of course it would be expensive. For other applications, silver would be a good choice.

This work was done by Peter Tsou of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 62*** *on the TSP Request Card.*
NPO-19141



Soft Metal (Aluminum) Wire in Grooves forms a high-temperature, high-pressure seal between the cap and the flange.

Dual-Eccentric Clevis Joint

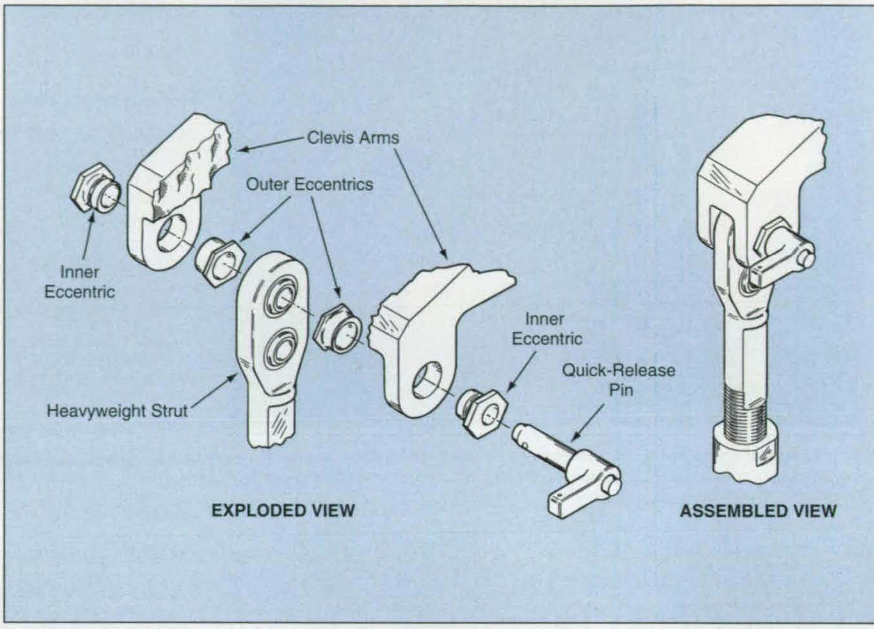
The joint accommodates anticipated variations of dimensions.

Marshall Space Flight Center, Alabama

A redesigned clevis joint incorporates dual mating eccentric cylindrical bushings to accommodate dimensional tolerances. The use of dual eccentrics to accommodate tolerances is not new; what is noteworthy is that in this particular application, the use of dual eccentrics for this purpose makes it possible to design components associated with the clevis joint to be smaller than they would otherwise have to be.

Previously, dimensional tolerances in this application were accommodated by use of a left-hand-threaded collar that turned against a right-hand-threaded bushing. The components were designed with a total of 11 separate details and were required to be wide enough to satisfy cylinder-wall-thickness and thread-depth requirements. However, in satisfying these requirements, they violated newly imposed design limits on available space.

The dual-eccentric clevis-joint design eliminates the need for the combination of the oppositely threaded collar and bushing and, by so doing, makes the overall joint hardware fit within the available space. The dual-eccentric clevis joint (see figure) includes the usual clevis parts, plus inner and outer eccentrics and a quick-release pin. The locus of joint-axis positions defined by turning the eccentrics to all possible combinations of angular positions is a circle that contains all anticipated variations of the joint-axis positions.



The **Dual-Eccentric** clevis joint and strut take up less room than did a more conventional clevis joint and a strut equipped with an oppositely threaded collar and bushing to accommodate misalignment.

During assembly, the inner eccentrics can be turned by hand to approximately align the inner hole of the clevis with the mating hole on the end of the strut. To refine the alignment, the outer eccentrics are turned, or the inner and outer eccentrics are turned simultaneously. The pin is then inserted through the clevis and the strut. A demonstration of the joint revealed that the pin forces the eccentrics on the opposite sides of the clevis to align themselves. Wrench flats on the eccentrics provide for occasions on which it becomes difficult to turn the eccentrics by hand.

This work was done by Diana L. Fairbank and John J. Sertich of Rockwell International Corp. for **Marshall Space Flight Center.** *For further information,* ***write in 40*** *on the TSP Request Card. MFS-30009*

Processing Laser-Velocimeter Measurements From a Turbopump

A program computes circumferentially averaged velocities, total pressures, and other flow quantities.

Marshall Space Flight Center, Alabama

The Laser Velocimeter Axial Plane Data Reduction computer program computes flow velocities and related flow quantities from laser-velocimeter measurements in a turbopump. This program replaces an older, less accurate program that required tedious manipulation of data to perform simple analyses.

The measurements are taken on radial laser-velocimeter lines of sight at 144 points in each of two planes perpendicular to the axis; one plane immediately upstream and one plane immediately downstream of a four-blade inducer. The measurement points in each plane are located at 9 equal radial intervals between the hub and the tips of the inducer blades, and at 16 equal angular intervals that together span the 90° interval between corresponding points on adjacent inducer blades (see figure). Thus, the measurements in each plane provide for characterization of the velocity field at 144 points distributed evenly in one complete blade-to-blade passage; by use of circumferential averaging under an assumption of symmetry, the measurements thus enable characterization of velocities throughout the plane.

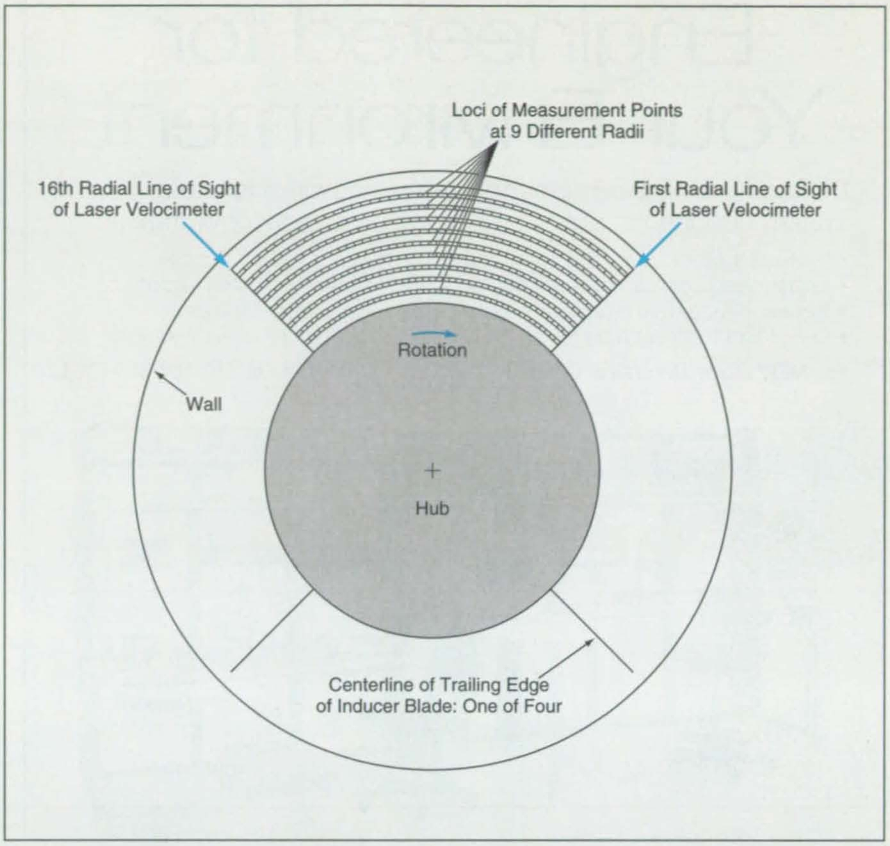
The output of the laser velocimeter is, in effect, a set of data on the magnitude and direction of the velocity vector at each measurement point. As part of the effort to understand the flow field, it is necessary to determine velocities in circumferentially averaged form; that is, to determine the components of velocities as functions of radius, independent of circumferential position. It is also necessary to verify the laser-velocimeter output data by comparison between rates of flow calculated from these data and rates of flow measured by independent means.

The program separates the velocity measured at each point into its components. An area-averaged axial velocity is calculated from the pointwise data by performing a spline integration over the 90°, hub-to-wall span. The circumferential and axial components of velocity are mass-averaged over the span under an assumption of constant density.

Inasmuch as no measurements are taken near the wall, calculation of the volumetric flow rate necessitates extrapolation of velocity to the wall. For this purpose, the inlet flow is assumed to be fully developed turbulent pipe flow with a speed v given by $v = V(y/R)^{1/n}$, where V is the maximum speed at the center line of the pipe, y is the distance from the wall, R is the radius from the center line to the wall, and n is a function of the Reynolds number of the flow and is determined by the user. V can be calculated from n, R, and the rate of flow measured by independent means.

Having calculated the circumferentially averaged velocities, the program calculates the spatial distribution of total pressure from these velocities plus a measurement of total pressure at one point in the plane of the laser-velocimeter data. The program does this by solving a differential equation for the total pressure as a function of the radius and the local velocity components. The equation was derived from (1) Euler's equation for the conservation of radial momentum in steady-state, axisymmetric flow of an inviscid fluid with no external forces and no radial component of velocity and (2) Bernoulli's equation for conservation of energy in the same flow. Finally, the program calculates the spatial distribution of efficiency by use of the Euler efficiency equation.

This work was done by Sen Y. Meng, Kevin J. Lunde, and Gerald A. Lee of Rockwell International Corp. for **Marshall Space Flight Center.** *For further information,* ***write in 101*** *on the TSP Request Card. MFS-30016*



Laser-Velocimeter Measurements are taken at 9 radii on each of 16 radial lines of sight spaced equally around a 90° sector of each measurement plane.

Rotary Release Mechanism With Fusible Link

The fusible link can be reused.

NASA's Jet Propulsion Laboratory, Pasadena, California

A rotary release mechanism includes a fusible rotary link made of an alloy that melts at the relatively low temperature of 60 °C. When solid, the link couples a driving shaft to a driven shaft. When necessary, the link is melted to temporarily decouple the two shafts. Upon cooling below its melting temperature, the link hardens, so that it once again couples the two shafts. This release mechanism is an extremely compact alternative to pyrotechnic release devices. The basic concept of this mechanism can be applied to such other mechanisms as pin pullers, pin pushers, electrical-disconnection mechanisms, and clutches.

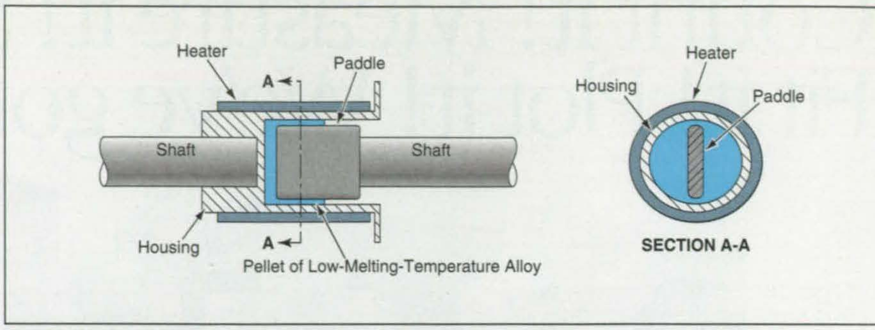
The fusible link is a pellet of the low-melting-temperature alloy contained within a cavity in a housing at the coupling end of one shaft. A paddle at the coupling end of the other shaft intrudes into the pellet, so that when the pellet is solid, a firm rotary coupling exists between the two shafts (see figure). An electrical resistance heater for melting the pellet is wrapped around the housing and secured with shrink wrap. When the heater has been energized sufficiently, the pellet melts, allowing the paddle and its shaft to rotate freely with respect to the housing and its shaft. When the heater is shut off, the pellet cools and hardens, gripping the paddle as before.

The alloy is Cerrobend (or equivalent), which is a mixture of bismuth, lead, tin, and cadmium. In its solid state, this alloy resembles lead and can withstand a shear stress of 25 MPa. In its liquid state, this alloy exhibits the consistency and cohesiveness of mercury.

The housing is made of aluminum, which conducts heat efficiently from the heater to the pellet. The cavity in the housing is made in a slightly elliptical cross section to prevent rotary slippage between the housing and the solid pellet. The housing, pellet, and paddle can withstand torque of 17 N·m. In the original application, the paddle and the affected portions of the shafts are made of titanium to reduce the conduction of

heat from the housing. Insulating material can be wrapped around the heater, housing, and nearby portions of the shafts to reduce convective and radiative losses of heat from the housing.

This work was done by Donald R. Sevilla and Richard S. Blomquist of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 13*** *on the TSP Request Card. NPO-19579*



The **Pellet Is Melted** to effect temporary decoupling between the left and right shafts.

Mathematical Modeling for Control of a Flexible Manipulator

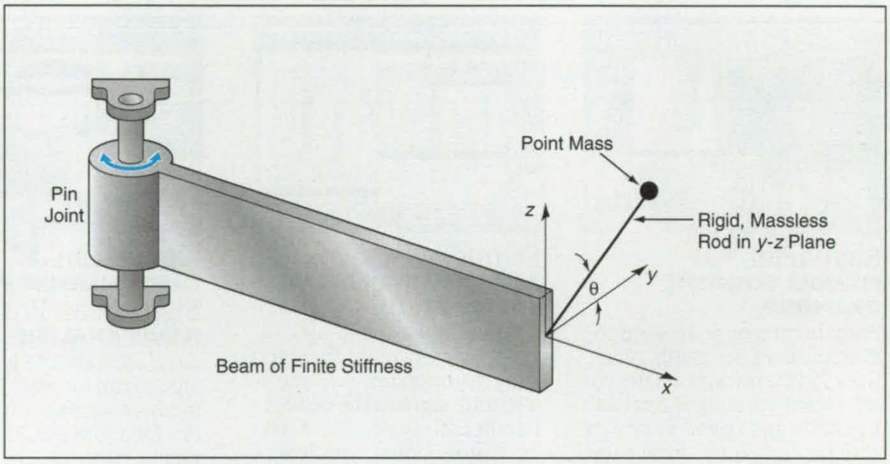
Closed-form equations account for changing inertial boundary conditions.

Marshall Space Flight Center, Alabama

An improved method of mathematical modeling of the dynamics of flexible robotic manipulators is being developed for use in controlling the motions of the manipulators. The method involves accounting for the effect, upon the modes of vibration of a manipulator, of changes in the configuration of the manipulator and the manipulated payload(s). Mathematically, these changes manifest themselves as changes in the inertial boundary conditions upon, and inertial parameters in, the differential equations of coupled vibrational, translational, and rotational motion of the manipulator and payload(s).

A flexible manipulator as contemplated here could be one that has one or more long, slender articulated link(s), like those used in outer space, but the method is also applicable to terrestrial industrial robotic manipulators with relatively short, stiff links, or to such terrestrial machines as construction cranes. Traditionally, the flexibility of long, slender links has been mathematically modeled via the assumed-modes approach. The fundamental assumption in this approach is that the boundary conditions, and hence, the eigenvalues and shapes of the vibrational modes do not vary with time. However, some maneuvers change the inertial properties in ways that change the modes significantly.

The development of the improved method began with the derivation of equations of motion for a simplified conceptual manipulator and payload; namely, a uniform beam that is pinned at one end and that supports a point mass on a rigid, massless rod at the other end (see figure). The rod can be set at an angle, θ, with respect to the y axis. Intuitively, one would expect the inertia of the rod-and-mass combination to affect the vibration of the beam to an extent that depends on θ, ranging from a maximum effect at $\theta = 0°$ to a minimum effect at $\theta = 90°$.



This **Beam-and-Mass System** served as a simplified conceptual flexible robotic manipulator and payload for purposes of initial development and assessment of the improved method.

Accordingly, closed-form equations for frequencies and shapes of vibrational modes as functions of changing inertia (more specifically, of changing θ) were derived from the equations of motion. Then, to provide for a comparison of the present method with the assumed-modes approach, two conceptual feedback control systems were tested by computational simulation. Each control system was designed to apply a time-varying torque to the pinned joint to suppress vibrations and to position the payload by rotating the beam to the desired angle.

Each control system included a linear quadratic Gaussian (LQG) controller in an outer loop and an inverse-dynamics controller in an inner loop. The designs of the controllers in one of the control systems were based on mathematical modeling of the dynamics according to the present method; those of the other control system were based on the assumed-modes approach, using $\theta = 0$. The numerical results confirmed that significant degradation of the performance of a manipulator under closed-loop control can occur if the control algorithm is derived via the assumed-modes approach and thus does not represent the changing dynamics accurately.

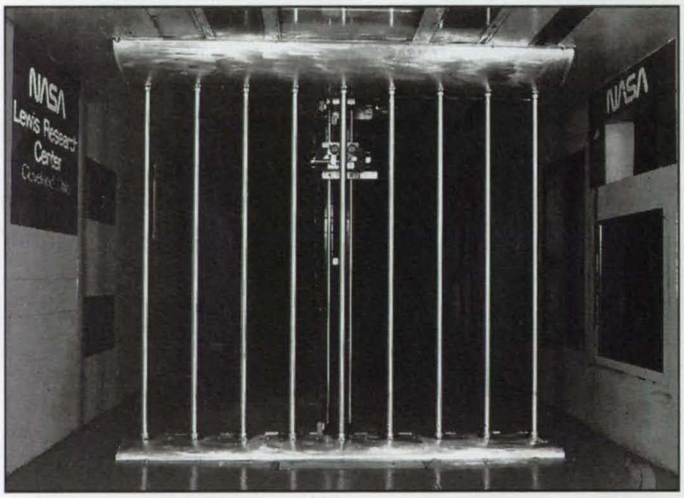
This work was done by Anren Hu of Dynacs Engineering Co., Inc., for **Marshall Space Flight Center.** *For further information,* ***write in 39*** *on the TSP Request Card. MFS-26272*

Apparatus Measures Thicknesses of Ice on Bars

An LVDT probe translated by a stepping motor measures diameters at selected locations.

Lewis Research Center, Cleveland, Ohio

A semiautomated apparatus measures the diameters, at selected lengthwise positions, of nine vertical ice-coated bars in an icing-research wind tunnel (see Figure 1). The measurements are needed to determine the degree of uniformity of icing conditions for experiments on aircraft models. The time taken by the apparatus to measure the diameters of all nine bars at lengthwise intervals of 0.5 in. (12.7 mm) is about 1 h, and the measurements are accurate to within thousandths of an inch (hundredths of a millimeter). In contrast, a technician using a tape measure takes about two hours and obtains measurements accurate to about 1/8 in. (3 mm).



BARS IN TEST SECTION OF WIND TUNNEL

MANUAL MEASUREMENT

Figure 1. **Ice Accumulates** on nine vertical bars, the diameters of which are then measured to determine the thickness of the ice. Measurements are taken by a measuring head that travels along the measured bar on two rails parallel to the bar.

The apparatus includes a measuring head (see Figure 2) that travels on rails parallel to a bar, driven by a ball screw actuated by a stepping motor. The position of the measuring head along the bar is measured by a string potentiometer, which thus provides position feedback for a closed-loop control circuit. This circuit provides for smooth motion of the measuring head, and can be used to select various programmed sequences of motions and measurements.

As the head moves along the bar, rollers at the ends of two arms travel along opposite sides of the bar. The rollers are held to the bar by a spring between the two arms. Changes in the distance between the two rollers (changes in the diameter of the bar) are sensed by a linear variable-differential transformer (LVDT).

The output of the LVDT and the readings of the string potentiometer

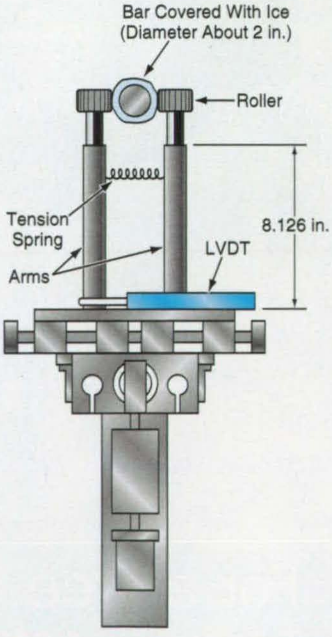


Figure 2. The **Measuring Head**, shown here in a simplified top view, functions essentially as a traveling, spring-loaded caliper equipped with an LVDT and rollers on the measuring tips.

are recorded and processed into data on diameter (and thus thickness of ice) as a function of position along each rod. A computer can also process the data into contour plots of accretion of ice.

This work was done by Theresa L. Gibson of **Lewis Research Center** *and John M. DeArmon of Sverdrup Technology, Inc. For further information,* ***write in 73*** *on the TSP Request Card.*
LEW-15976

Small, Lightweight Inspection Robot With 12 Degrees of Freedom

This robot can reach through openings and around obstacles.

NASA's Jet Propulsion Laboratory, Pasadena, California

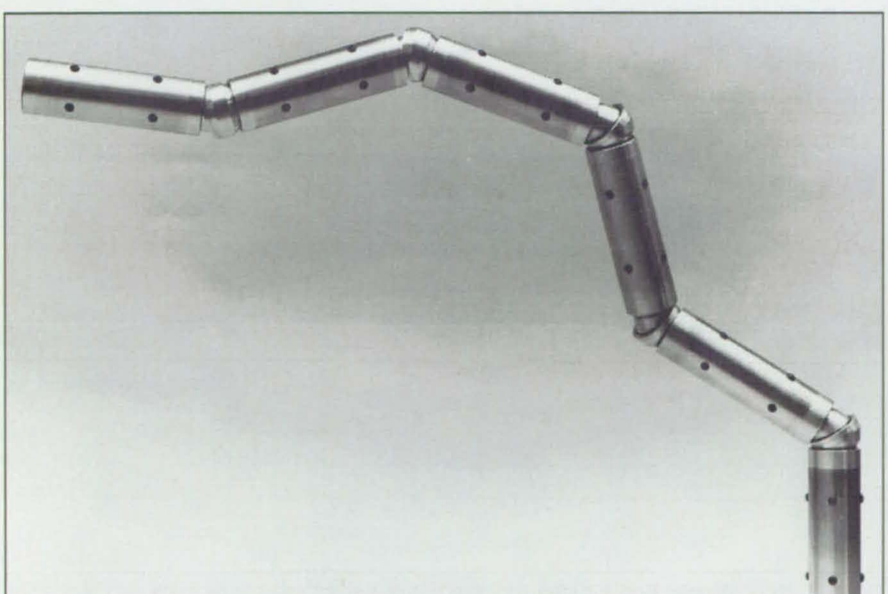
The figure shows a small serpentine robot that weighs only 6 lbs. (2.7 kg) and has a link diameter of 1.5 in. (38.1 mm). The robot is designed to perform inspections. Its multiple degrees of freedom enable it to reach around obstacles and through small openings into simple or complexly shaped confined spaces to positions where it could be difficult or even impossible to perform inspections by other means.

A fiber-optic borescope is incorporated into the robot arm, with the inspection tip of the borescope located at the tip of the robot arm. The borescope both conveys light along the robot arm to illuminate the scene to be inspected at the tip and conveys an image of the scene back along the robot arm to external imaging equipment. The robot arm acts as a flexible shield and guide tube to position the borescope. By use of a motor and cable drive within the robot, the tip of the borescope can be rotated (one of the 12 degrees of freedom) to a desired viewing angle within a 200° range.

The joints of this robot feature a unique compact design based partly on a universal-joint concept and partly on a concept of mating hemispheres, with miniature high-torque motors and gear heads with gear ratios of 1,111:1 for the upper links and 3,000:1 for the lower links mounted compactly inside the joint housings.

This is a modular serpentine robot and is designed so that sections can be readily added or removed. The motors in the joints are connected by wires to an external control and motor-drive circuits. A technician controls the movements of the robot by use of a joystick, with the help of a graphical menu on a computer video display.

This work was done by Thomas S. Lee, Timothy R. Ohm, and Samad Hayati of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 99*** *on the TSP Request Card. NPO-19367*



The **Serpentine Inspection Robot** can be mounted on the tip of the industrial robot. Motor-drive and other cables enter the serpentine inspection robot through its base, and are routed through interior openings.

Alignment Jigs for Bonding End Fittings to Truss Members

The jigs ensure collinearity of the end fittings.

NASA's Jet Propulsion Laboratory, Pasadena, California

Figure 1 illustrates the use of a set of alignment jigs to hold fittings during adhesive bonding of the fittings to the ends of truss members. For each member, the jigs hold the two end fittings collinear while the member is allowed to move slightly, within dimensional tolerances, during injection and curing of the adhesive. Once the adhesive has been cured, the fittings remain collinear even though the member is not necessarily perfectly straight between them.

In the laboratory setting in which the alignment jigs were devised, truss members have traditionally been made from tubing, and it had been assumed that the members could be mathematically modeled as straight and subject to pure lengthwise tensile and compressive loads. In practice, tubing is not precisely straight. As a result, when end fittings are simply attached without taking special care to align them, the angle between the two end fittings on a member can give rise to significant bending moments (see Figure 2) that are not taken into account in the mathematical model of the member.

The use of the alignment jigs to ensure collinearity of end fittings helps to remove the discrepancy between the theoretical and actual loading conditions in a member. The advantage of collinear end fittings is that a lengthwise load applied to the fittings acts along their common axis. Thus, the member can be modeled mathematically, to first order, as being subjected to pure lengthwise tension or compression, without a bending moment. Of course, the nominal axial loads acting on the slight unavoidable bends in the member generate some bending moments but these are small (second- or third-order) effects.

This work was done by Lee F. Sword of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 105*** *on the TSP Request Card.* *NPO-19113*

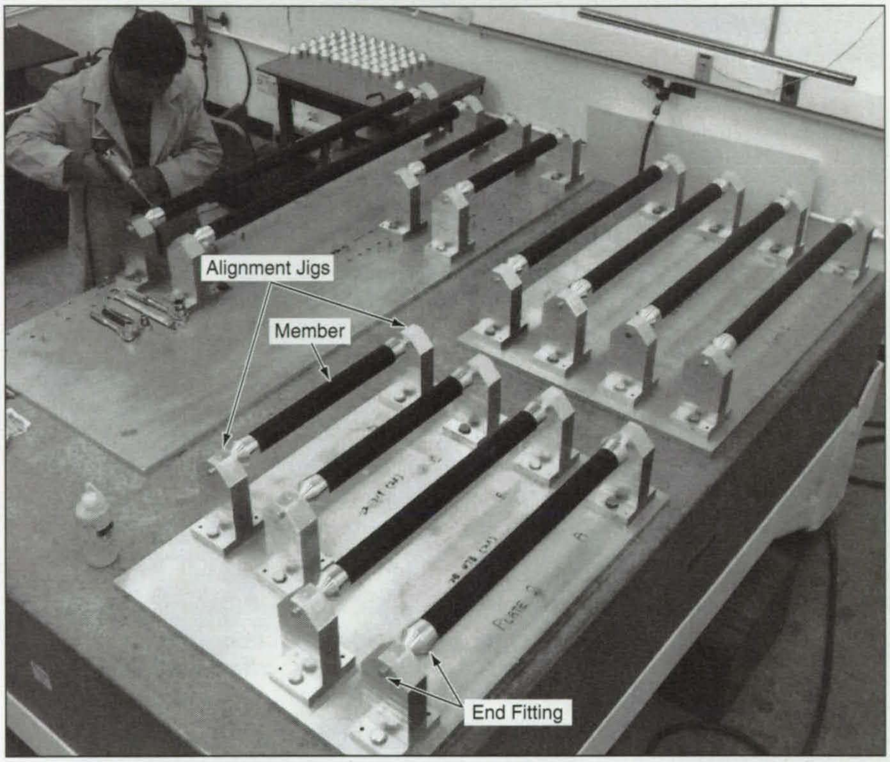


Figure 1. **Devices for Adhesive Bonding of End Fittings** on truss members include jigs that hold the fittings collinear until the adhesive is cured.

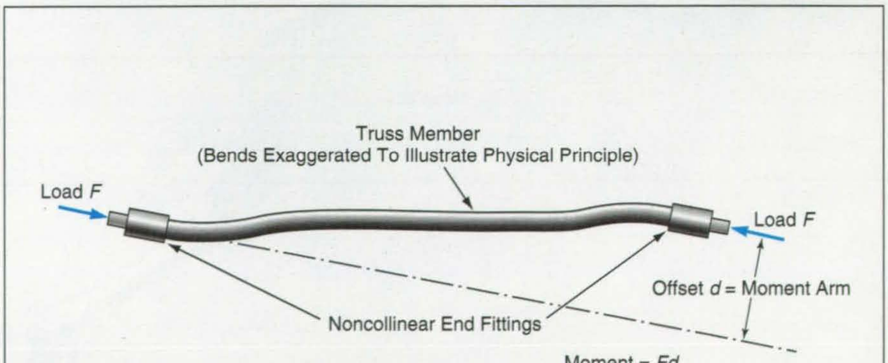
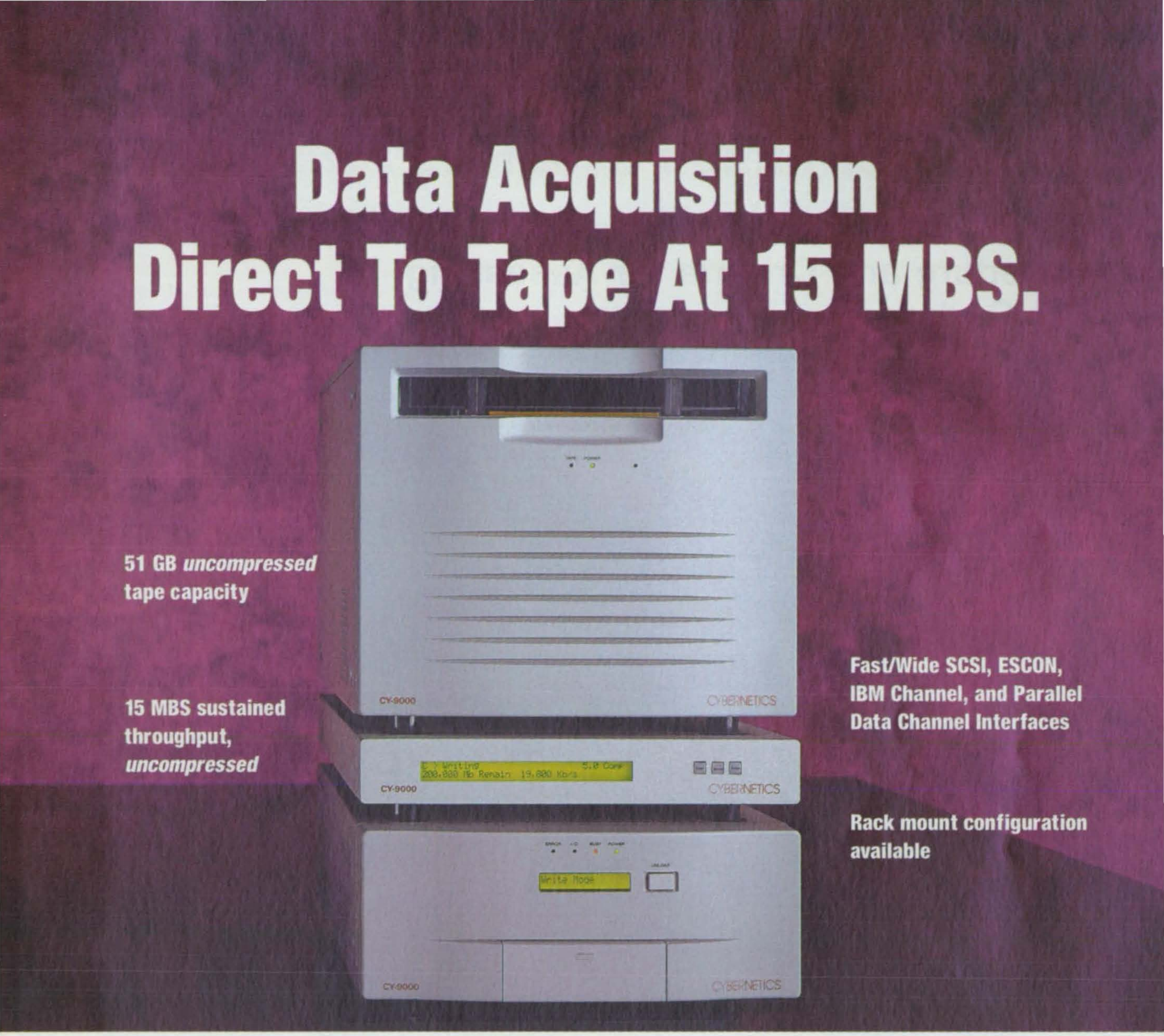


Figure 2. **Noncollinear End Fittings** can give rise to bending moments because the lines of action of the end loads can be offset by significant moment arms.



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Procedure and Criteria for Assessing CFD Codes

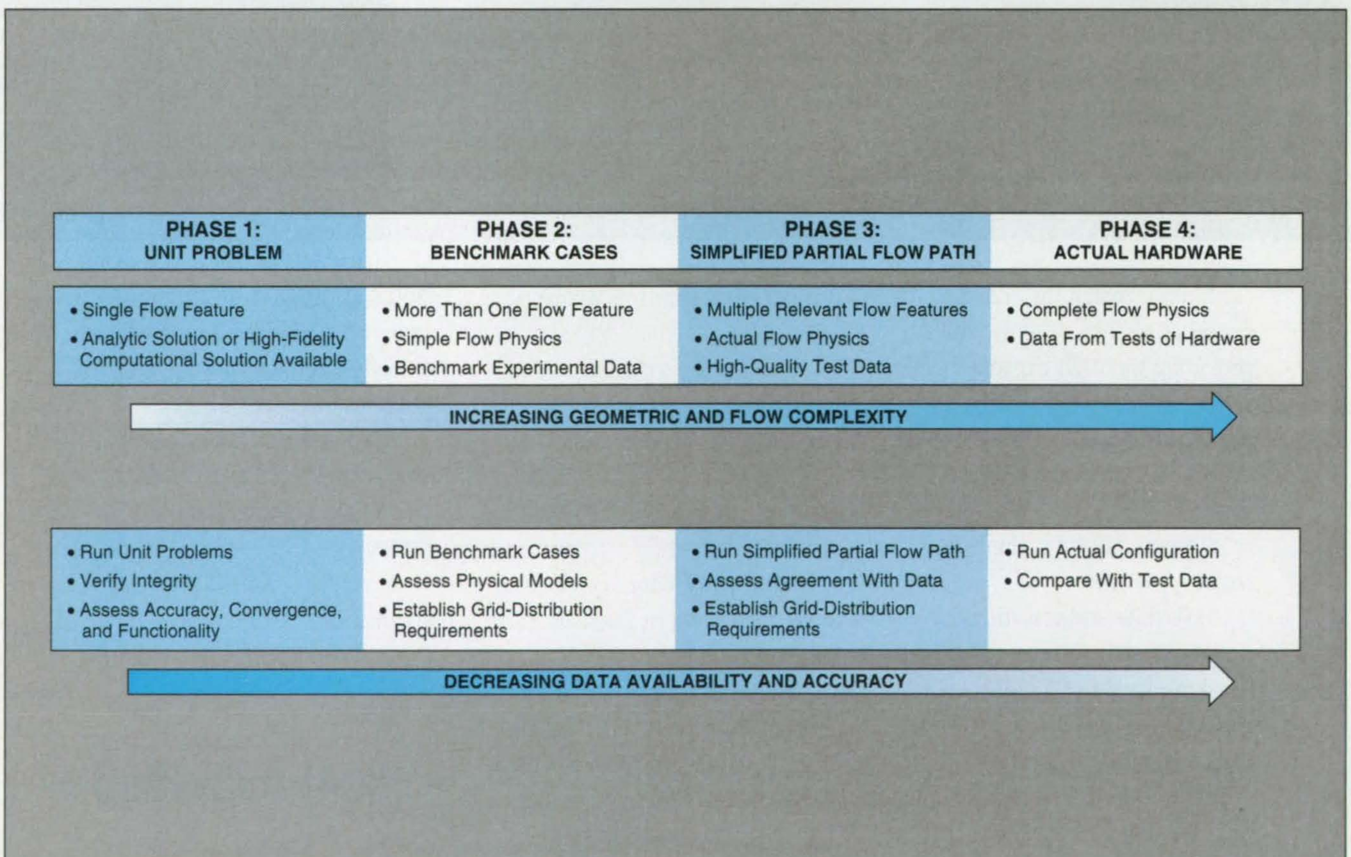
A systematic approach to validation can help ensure good designs.

Marshall Space Flight Center, Alabama

A four-phase procedure has been devised to standardize and systematize the assessment of performances of computational fluid dynamics (CFD) software used in designing aircraft, turbines, and other machines that interact with flows. Associated with the procedure is a set of criteria by which one can classify a given computer code and measure its ability to predict flows and flow-related quantities accurately.

The procedure and criteria are tied to the engineering design cycle, providing economical means for validation of a CFD code within typical constraints of an engineering environment and thereby relieving engineers from pressure to rely on CFD codes that have not yet been thoroughly validated. The procedure and criteria are general and flexible enough to be readily applicable to a wide variety of flow-engineering problems and computer codes. With respect to a given problem, the procedure is flexible enough to provide for validation to various levels of rigor and/or sophistication, as needed. The level of validation can be incrementally upgraded as the need exists and time and funding permit.

The four phases of the procedure are illustrated schematically in the figure. Phases 1 through 4 represent increasing levels in the complexity of geometry and flow. Relevant unit problems are identified in Phase 1. "Unit problem" denotes a problem characterized by a single dominant flow feature, for which an exact solution of the equations of flow is available. In Phase 1, the CFD code is exercised on several unit problems, each of which represents one basic flow feature of the end application. In this Phase, the fundamental characteristics of the CFD are thoroughly understood and documented. Basic code methodology is considered in terms of its applicability to the problem of interest. All aspects of the code relevant to the end application are exercised to verify accuracy, functionality, and convergence characteristics. At least one unit prob-



The **Four Phases of the Validation Procedure** represent increasing levels in the complexity of geometry and flow and, typically, decreasing availability of data.

lem is selected to test basic code logic extensively. In addition, studies of the sensitivities of computed flow quantities to changes in computational grids ("grid-sensitivity studies" for short) are performed, both to assess relative error and to provide guidance in specifying computational grids for more complex flow cases.

Relevant benchmark cases are identified in Phase 2. A benchmark case is characterized by more than one flow feature and includes basic physics relevant to the final application. Mathematical models of the relevant physics of flow within the CFD code are exercised to verify operability and to quantify accuracy relative to benchmark data. Only data from experiments of the highest quality should be used for comparisons with CFD solutions. Additional grid-sensitivity studies are conducted in this Phase to assess the level of refinement necessary to capture key physical effects. Error-assessment techniques are used as guides. Lessons learned from Phase 1 are applied in Phase 2. Fewer cases are run in Phase 2 than were run in Phase 1. A code that has been validated through Phase 2 and that satisfies all established criteria may be considered valid for use in conceptual design studies.

Test cases selected for Phase 3 are simplified versions of the final validation case. Each case in Phase 3 involves multiple geometric and flow features of the final application. Data should be selected according to defined criteria, but these criteria may be relaxed slightly if needed. An assessment of the effects of variations in topology and clustering of grids is done to provide guidance for the end application. Requirements for grids necessary to capture key physical effects are established. Relatively few test cases are considered in Phase 3. A code validated though Phase 3 may be considered valid for use in preliminary design studies.

Cases for Phase 4 should be selected from tests conducted on actual hardware. All relevant geometric and physical effects should occur simultaneously. Criteria for selection of tests should be carefully reviewed to provide for use of the best sets of data and to identify deficiencies in the data. The knowledge acquired in phases 1, 2, and 3 is applied in Phase 4. The most appropriate physical models, best grid topology, and appropriately refined grids are used. Typically, only one or two test cases are considered in Phase 4. A code that has been validated though Phase 4 and that satisfies all established criteria may be considered valid for use in detailed design studies.

This work was done by Shyi-Jang Lin, Steven L. Barson, and Munir M. Sindir of Rockwell International Corp. for **Marshall Space Flight Center.** *For further information,* ***write in 3*** *on the TSP Request Card. MFS-29972*

Transfer of Calibration Data via a Floppy Disk

Marshall Space Flight Center, Alabama

A system of hardware and software has been developed for a special application in which there is a need to transfer calibration data from (1) a Data General computer at an instrumentation laboratory via (2) a 3.5-in. (8.89-cm) floppy disk in IBM-PC-readable format to (3) another facility where the calibrated instruments are used. Previously, the calibration data were transferred by manual transcription, and it was desired to upgrade to automated transfer, without incurring the cost of developing the large amount of custom software that would ordinarily be needed for this purpose. The system includes an IBM-PC-compatible minicomputer that is connected to the Data General computer via an RS-232 serial link and that is configured, by use of commercial terminal-emulator software, as a remote Data General terminal. A program on the Data General computer that gains access to the data base was modified to display the requested data in the correct format on the screen. The operator runs the Data General program from the minicomputer by use of the emulator software. Upon command, the minicomputer captures the data displayed on the screen and stores them in a PC-readable file on the floppy disk.

This work was done by John P. Shonafelt and Cynthia M. Pratt of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information,* ***write in 100*** *on the TSP Request Card. MFS-30097*

Semiautomated Motility Assay for Determining Toxicity

Computer processing of images of swimming protozoa quickly yields documentation of toxicity.

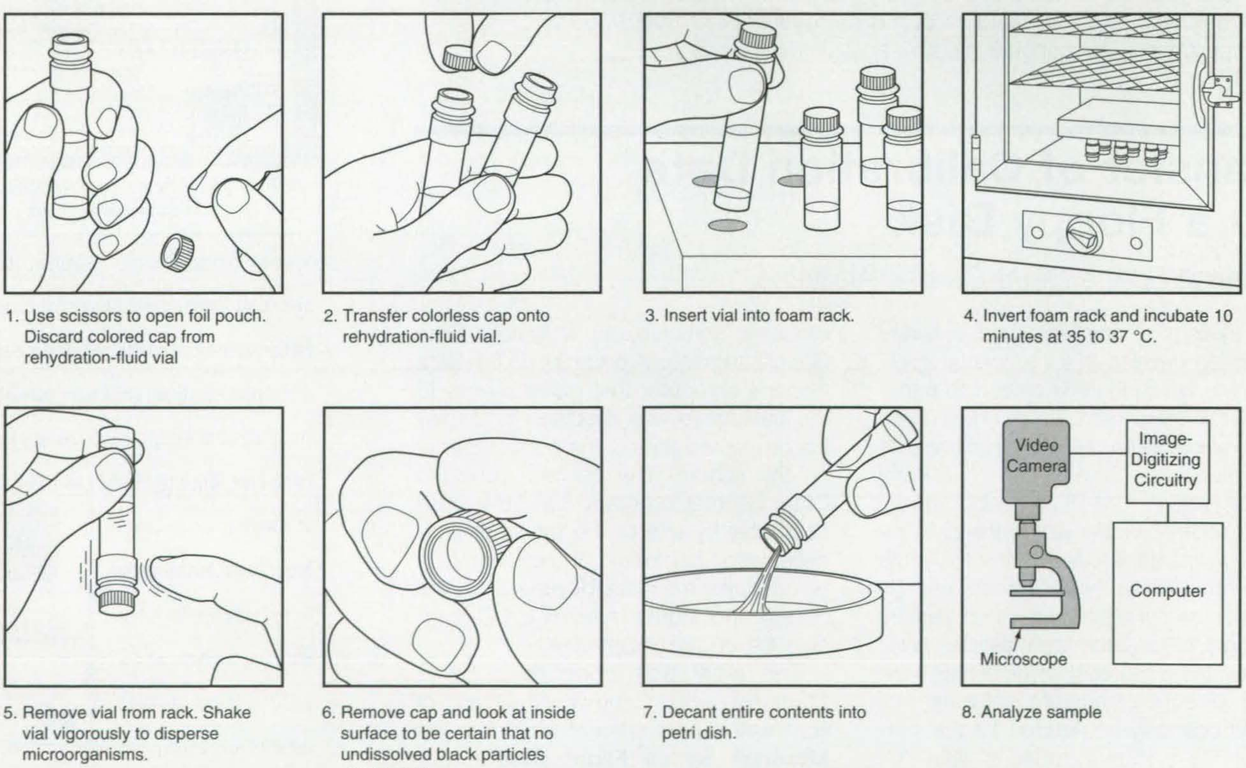
Marshall Space Flight Center, Alabama

An improved method of assessing the toxicities of various substances is based on observation of the effects of those substances on the motilities of a manageably small number of cells of the protozoan species *Tetrahema pyriformis*. The method provides a rapid and economical alternative to the Draize test, in which the toxicity of a substance is measured in terms of its effects on the eyes of living rabbits. The method provides repeatable, standardized tests with minimal handling by technicians and with minimal exposure of technicians to chemicals.

Toxicity is determined by observation of macroscopic patterns formed by large numbers of *Tetrahema pyriformis* organisms swimming in culture media containing toxins diluted in various degrees. Equipment for a bioconvective assay can be packaged in a kit that is stored under refrigeration to preserve a slant culture of the protozoa. Although a bioconvective assay is convenient in comparison with older techniques for determining toxicity, it still consumes a considerable amount of time (several days).

Like the bioconvective-assay method, the present method involves the use of a kit to prepare a culture of *Tetrahema pyriformis* and expose it to a toxin, but in this case, the preparation time is much shorter: Freeze-dried *Tetrahema pyriformis* cells are rehydrated and incubated for 10 minutes at a temperature of 35 to 37 °C (see figure). Then the mixture of cells and rehydration fluid is decanted into a petri dish that contains a medium with the appropriately diluted material to be tested for toxicity. A sample from the petri dish is placed under a microscope equipped with phase-contrast or dark-field optics and a video camera.

A line or videotaped sequence of video images of 50 or more single cells of *Tetrahema pyriformis* is digitized and analyzed by a computer to identify the cells, measure their concentration, and characterize their motility in terms of velocity and linearity. (Degradation of motility is an indication of toxicity.) The data from this analysis can be stored or printed out immediately to provide



1. Use scissors to open foil pouch. Discard colored cap from rehydration-fluid vial
2. Transfer colorless cap onto rehydration-fluid vial.
3. Insert vial into foam rack.
4. Invert foam rack and incubate 10 minutes at 35 to 37 °C.
5. Remove vial from rack. Shake vial vigorously to disperse microorganisms.
6. Remove cap and look at inside surface to be certain that no undissolved black particles are present.
7. Decant entire contents into petri dish.
8. Analyze sample

Freeze-Dried Protozoa From a Kit are rehydrated and incubated, then placed in a petri dish, where they are exposed to the material to be tested for toxicity.

quick documentation of toxicity.

This work was done by David A. Noever and Raymond Cronise of **Marshall Space Flight Center.** *For further information,* ***write in 45*** *on the TSP Request Card.* MFS-28906

Cultivating Insect Cells To Produce Recombinant Proteins

Cells are grown in a rotating bioreactor and infected with viruses containing selected genes.

Lyndon B. Johnson Space Center, Houston, Texas

A method of producing recombinant proteins involves (1) the growth of insect cells in a nutrient solution in a cylindrical bioreactor rotating about its cylindrical axis, which is oriented horizontally and (2) infecting the cells with viruses into which genes of a selected type have been cloned. The genes in question are those that encode the production of the desired proteins.

One reason for choosing insect cells for this method is that like most other animal cells, insect cells are versatile enough to produce a wide variety of functional proteins. Another reason is that in comparison with other animal cells, insect cells are highly productive in this regard; they are capable of producing protein products at concentrations that range from 1 to more than 500 mg/L.

The insect-cell line used initially in this method is that of the ovary of the lepidopteran known popularly as the fall armyworm and more technically as *Spodoptera frugiperda* ("Sf9" for short). The Sf9 cell line was selected for a number of reasons, including that (1) its characteristics are well-known from prior intensive research, (2) it is commercially available, (3) it is an immortal cell line, (4) the cells of this line grow more robustly than other insect cells do, and (5) Sf9 readily accepts foreign genes that code for recombinant proteins because it is very receptive to infection by, and replication of, viruses.

The viruses used initially in this method are baculoviruses, which are not hazardous to humans and other vertebrates but are pathogenic toward some species of insects (including Sf9), in which they cause cell lysis. (Baculoviruses are the active ingredients in some insecticides.)

As explained in several articles in prior issues of *NASA Tech Briefs*, horizontal rotating bioreactors have been developed to provide nutrient-solution environments conducive to the growth of delicate animal cells, with gentle, low-shear flow conditions that keep the cells in suspension without damaging them. The horizontal rotating bioreactor preferred for use in this method, denoted by the acronym "HARV," was described in "High-Aspect-Ratio Rotating Cell-Culture Vessel" (MSC-21662), *NASA Tech Briefs*, Vol. 16, No. 5 (May, 1992), page 150.

The protein β-galactosidase (β-Gal) has been chosen as a model protein to produce in experiments directed toward further development of the method. This protein is frequently used in Sf9 studies because it is readily available and can be readily assayed. A mutant form of the baculovirus *Autographa californica* containing the gene that codes for β-Gal is used as a cloning vector to introduce and express the β-Gal gene in Sf9 cells. As the virus replicates, the β-Gal gene is expressed along with production of native viral proteins.

The use of the HARV (as distinguished from other bioreactors) offers the potential to enhance production in a number of ways. Because the HARV cultures Sf9 cells to densities larger than those achievable in prior bioreactors, the overall production per unit volume may be correspondingly greater. The low-turbulence flow field in the HARV may enhance infectivity by promoting adherence of viruses to cells. The environment in the HARV may also enhance the metabolism of the cells in such a way as to increase gene transcription, protein translation, post-translational processes, and secretion of protein from the cells.

This work was done by Glenn Spaulding of **Johnson Space Center**, *Thomas Goodwin and Tacey Prewett of KRUG Life Sciences, and Angela Andrews, Karen Francis, and Kim O'Connor of Tulane University. For further information,* ***write in 56*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Johnson Space Center; (713) 483-4871. Refer to MSC-22336.

Books & Reports

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

Mathematics and Information Sciences

A* Decoding of Block Codes

A report presents a study of the application of the A* algorithm to maximum-likelihood soft-decision decoding of binary linear block codes. The A* algorithm is an artificial-intelligence algorithm that finds a path in a finite-depth tree that is optimum in the sense that the choice of path maximizes a function. In the study, a version of the A* algorithm for maximum-likelihood decoding of block codes is implemented for block codes up to 64 bits long. The efficiency of this algorithm makes simulations of codes with lengths up to 64 feasible. The report details the implementation, compares the complexity of decoding by use of this version of the A* algorithm with that of exhaustive-search and Viterbi decoding algorithms, and presents performance curves obtained with this version of the A* algorithm for several codes.

This work was done by Laura Ekroot and Samuel J. Dolinar, Jr., of Caltech for **NASA's Jet Propulsion Laboratory.** *To obtain a copy of the report, "A* Decoding of Block Codes,"* ***write in 44*** *on the TSP Request Card. NPO-19572*

Physical Sciences

Water/Ice Heat Sink With Quick-Connect Couplings

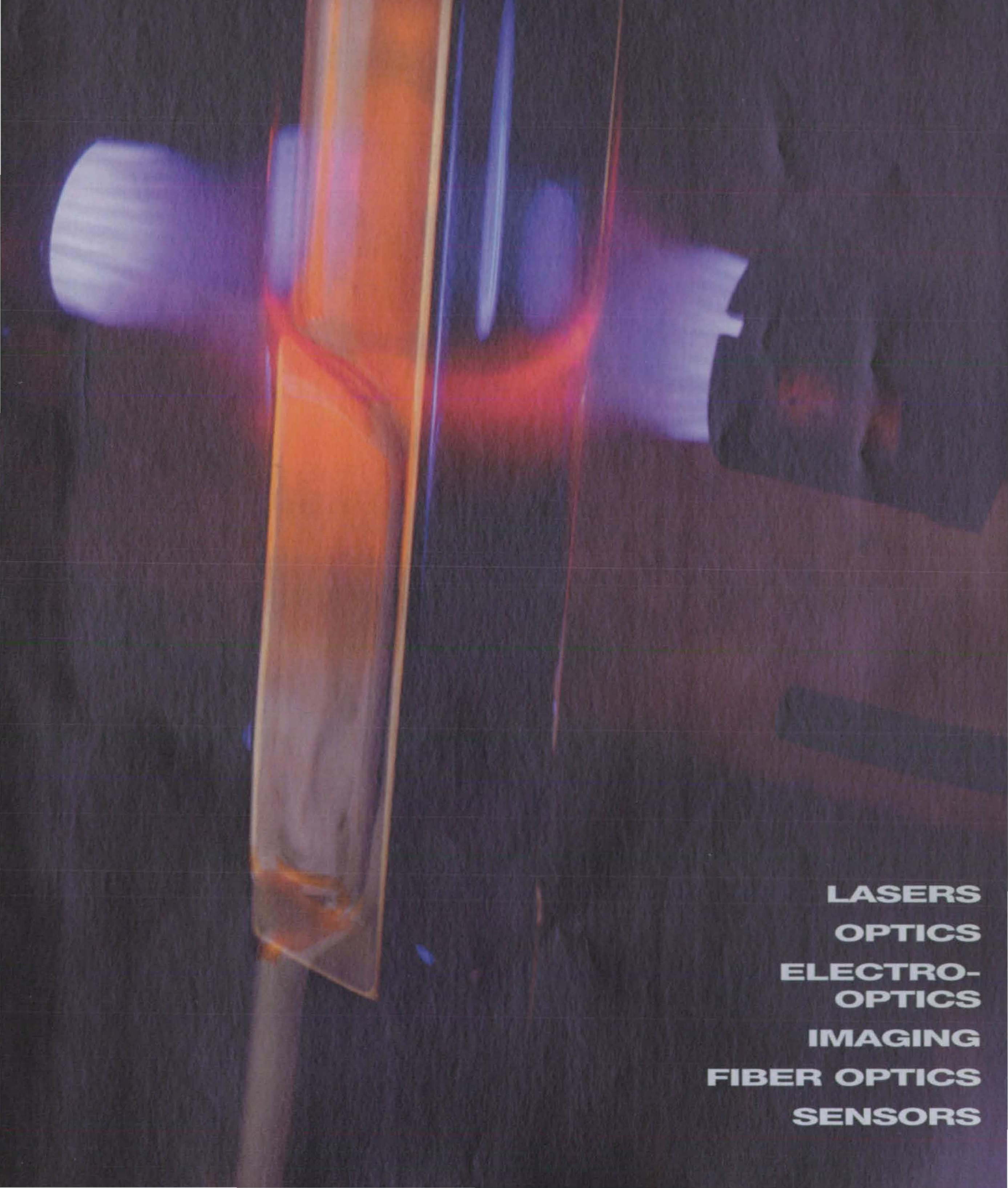
A report consists of the main text of U.S. Patent 5,392,844, which presents additional detailed information on the apparatus described in "Direct-Interface, Fusible Heat Sink" (ARC-11920), *NASA Tech Briefs*, Vol. 16, No. 9 (September 1992), page 114. To recapitulate: the apparatus is a phase-change heat sink in which heat is dissipated by direct contact between water (the circulated cooling fluid) and ice (the phase-change heat-sink material). The heat sink includes an elastometric bladder that contains the water/ice phase-change medium, through which the cooling water is circulated. The report describes the entire apparatus, with special emphasis on those features of the quick-disconnect couplings that govern the flow of water under various operating conditions and plumbing configurations; these features are the subjects of the patent claims.

This work was done by Curtis Lomax and Bruce Webbon of **Ames Research Center.** *To obtain a copy of the report, "Quick Connect Coupling,"* ***write in 72*** *on the TSP Request Card.*

This invention has been patented by NASA (U.S. Patent No. 5,392,844). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Ames Research Center; (415) 604-5104. Refer to ARC-13374.

FEDERAL LAB LASER TECH BRIEFS

REPORTING THE LATEST FEDERALLY-DEVELOPED PHOTONICS TECHNOLOGY



LASERS

OPTICS

ELECTRO-OPTICS

IMAGING

FIBER OPTICS

SENSORS

LASER TECH BRIEFS

Federal Lab Laser Tech Briefs Supplement to *NASA Tech Briefs* February 1996 Issue Published by Associated Business Publications

LASER TECH BRIEFS

FEATURE

DEPARTMENTS

On the cover:

The photograph shows the process of special profile shrinking at Andrews Glass Company (Minotola, NJ). Among the applications of this process is the preparation of some fiber optic preforms, such as those used in making couplers. Andrews Glass produces custom glass and quartz designs and configurations, including precision bore tubing, for products ranging from television cameras, optical scanners, lasers, and infrared systems to semiconductors and research laboratory apparatus.
Photo courtesy Andrews Glass Co.

NEWS BRIEFS

Notes from Industry and the Federal Laboratories

The commissioning of a new synchrotron radiation beamline at Lawrence Berkeley Laboratory's Advanced Light Source (ALS) in December brought to twelve the number of beamlines in operation. The facility, the basic structure of which was completed in 1993, is the nation's premier source of ultraviolet and x-ray light for scientific research, product development, and manufacturing. Though not the only US source of synchrotron radiation, Berkeley researchers point out that the ALS has an important advantage over its predecessors: It produces much brighter light than theirs, and thus improves spatial and spectral resolution in experiments.

The ALS produces light by accelerating electrons nearly to the speed of light in a linac (linear accelerator) and booster synchrotron, and then maintaining the electron beam at a constant energy (1.5 billion eV) inside a storage ring. As the electrons circulate inside the ring, more than a million times per second, hundreds of electromagnets focus and bend the beam, causing the electrons to emit light in the UV and x-ray areas of the spectrum. In some sections of the storage ring, the beam passes through special permanent-magnet arrays called undulators or wigglers. The resulting oscillations make the emitted light a hundred times brighter.

ALS scientists currently operate more than 20 systems with Windows NT workstations, over half of which are used in the control room. They monitor the ALS and report back on such parameters as electrical currents, device temperature, vacuum pressure, and other data. But even more critical is one Windows NT-based system that runs the undulator dipole compensation device. If changes occur in the undulator, they can affect the orbit of the electrons and spoil ongoing experiments. Thus the critical workstation monitors the undulator and activates corrector magnets if changes occur, so that the proper electron orbit is maintained.

The US Air Force awarded American Propylaea Corp. of Birmingham, MI, a $100,000 research contract to investigate the integration of interactive holography into US manufacturing processes. The award is the first phase of a projected 15-phase $200-million contract should Phase I results prove encouraging. Phase II would involve a $750,000 contract and Phase III a $5-million contract, according to James Fischbach, president and CEO of Propylaea. The company claims to have developed the world's first full-color commercial hologram in 1993, and followed that up a year later when it achieved a 32-X-45-in. (55-in. diagonal) full-motion true-color holographic display system. Fischbach predicts that holography will be a $5-billion-a-year business within ten years, calling the automotive, entertainment, medical, and retail markets those with the greatest potential.

In December McPherson (Acton, MA), a division of the Schoeffel Group and a prominent manufacturer of monochromators, spectrometers, and soft x-ray, UV and vacuum UV, and other spectroscopic equipment, acquired Space Optics Research Laboratory (SORL, Chelmsford, MA) from the Intergraph Corp. (Huntsville, AL) for an undisclosed amount. SORL, like McPherson an established company with more than 30 years of experience in the optical industry, makes a wide variety of mirrors, lens assemblies, and mounts for such applications as FLIR and LIDAR systems and interferometric devices.

At a formal ceremony in Tokyo in late October, the Foundation for C&C Promotion awarded Alfred Y. Cho, director of the Semiconductor Research Laboratory at Bell Laboratories, the C&C Prize for individuals who have made distinguished contributions to the fields of computers and communications technologies. Cho was honored for his role in the development of molecular beam epitaxy, a crystal growth process that is revolutionizing the fabrication of electronics and optoelectronics for computers and communications. Molecular beam epitaxy is responsible for the present generation of advanced multilayer crystals used in high-speed transistors, microwave devices, laser diodes, and detectors. Established in 1985 by the NEC Corporation, the nonprofit Foundation for C&C Promotion encourages growth in the electronics industry by supporting research and development.

Coherent Inc. of Santa Clara, CA, concluded an agreement to acquire the $3-million diode laser operation, exclusive of the laser aimer line, of Applied Laser Systems (ALS) of Medford, OR. ALS's Visible Light Modules™ are low-power laser diodes used in such commercial applications as medical instrumentation, alignment, and inspection systems. According to Robert Gelber, vice president and general manager of Coherent's Auburn (CA) Group, many of ALS's customers currently purchase products from this group. By applying Coherent's optics technology and global distribution system to the laser diode line, he expects to expand ALS's market share. ALS's design, manufacturing, and sales operations will be relocated to Coherent's Instrument Division site in Auburn.

Assembling a Laser Machinability Database

Software under development will incorporate cutting and welding data from a wide variety of sources.

by Dr. Mira Yankova

Lasers are commercially viable for a variety of manufacturing processes such as cutting, machining, welding, and surface modification. Because different materials and processes have different parameters for successful machining--laser power, lens focus, assist gases, machining speed, and so forth--a manufacturer required to machine an unfamiliar material needs data about laser setup and operation. The Manufacturing Technology Information Analysis Center (MTIAC) at IIT Research Institute in Chicago, Illinois, is developing a computerized handbook of laser machinability data.

MTIAC approached its task through laser manufacturers and organizations involved in laser materials processing and in research into it. All of the domestic and as many foreign laser manufacturers as possible were contacted in the data collection process.

Concurrently, a software interface was developed to display the data in a convenient format, utilizing a run-time version of a commercially available database program.

Every manufacturing process has operating parameters or setting variables that control it. For laser cutting and welding they fall into several categories:

- Laser beam: power and its temporal stability, wavelength, mode, polarization, focal length, and diameter and position of the focal spot;
- Assist gas: chemical composition, temperature, pressure, discharge, velocity, and volume;
- Material: optical, thermal, chemical, and hydrodynamic properties.

Parameters that most need optimization include as high as possible a cutting/welding speed for economic reasons, and high-quality geometric properties, small heat-affected zone, and controlled hardness of the cutting/welding surface.

The most important setting variables for a material of a given thickness include the laser power, the spot size of the focused beam, and the speed of the workpiece.

The figure shows the general data format for Nd:YAG laser cutting. The format for CO_2 laser data is identical, with the exception of pulse information: for cutting, the CO_2 is usually used in continuous mode, but the Nd:YAG operates only in pulsed mode. The format for laser welding data is similar. It contains additional information about the second weld material, welding joint type, penetration depth, and shielding gas.

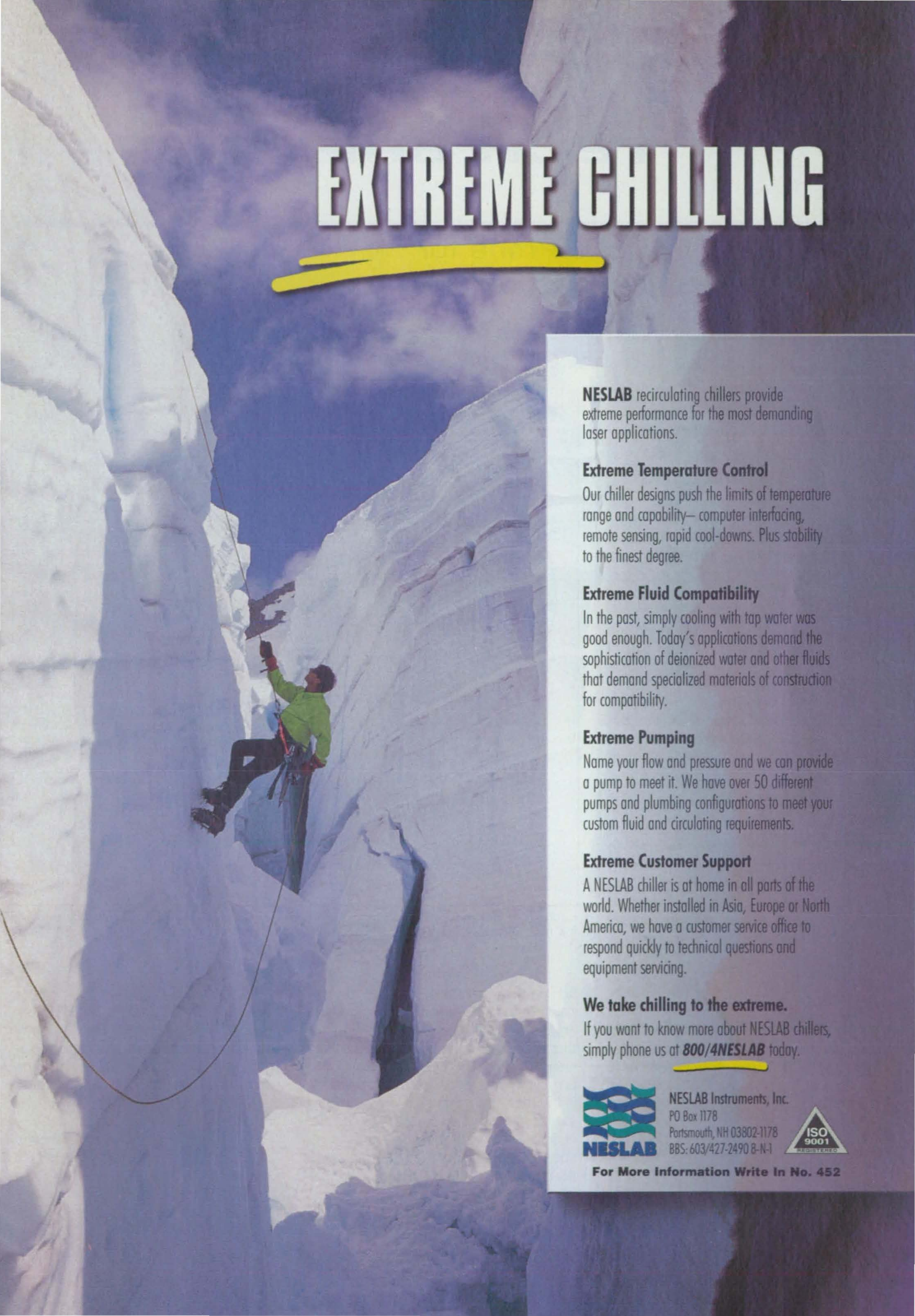
The software was developed not only to view and search the already gathered data, but to enable users to add, delete, modify, and evaluate their own data. Querying the database gives the user the option to select the material type: metal, nonmetal, or complete material list. Once the material of interest is chosen, if there are no available properties data for the one selected, the user is given the option to add them manually. He can make his own comments, which should not exceed 41 characters. Once he saves this information the software can graph data, using a theoretical curve and experimental data points from any part of the database.

MTIAC actively solicits cooperation and input on this database from the entire laser materials processing community. A number of users are acting as test sites to evaluate the database for completeness and ease of use. The completed database is available as a commercial product to any interested organization.

This work was done under the supervision of M. Yankova and S. Kalpakjian, and was supported by the Department of Defense under contract # DLA 900-90-D-0134. *For more information contact Dr. Yankova at Armour College of Engineering and Science, Illinois Institute of Technology, 10 W. 32nd St., 207C-E1, Chicago, IL 60616-3793; (312) 567-8863; FAX (312) 567-8875.*

Material	Thickness	Speed	Power	Assist gas/ Pressure	Lens/Focus Length	Spot diameter	Comments	User Comments
	in.	in./min	kW	bar	in.	mm		
Aluminum	0.04	355	1.1	70%N2, 30%Ar/10	2.5	0.14	IST, Vienna	
Aluminum	0.04	275	1.15	CO2/10	2.5	0.14	IST, Vienna	
Aluminum	0.04	244	3	Oxygen	N/A	N/A		
Aluminum	0.04	235	1.5	Nitrogen/5-14	5	0.2	PRC Laser Corp	
Aluminum	0.06	40	0.5	Oxygen	N/A	N/A		
Aluminum	0.08	140	1.5	Nitrogen/5-14	5	0.2	PRC Laser Corp	
Aluminum	0.08	88	1.2	Oxygen	N/A	N/A		
Aluminum	0.12	80	1.5	Nitrogen/5-14	5	0.2	PRC Laser Corp	
Aluminum	0.12	40	1	Oxygen	N/A	N/A		
Aluminum	0.12	24	1.1	70%N2, 30%Ar/10	2.5	0.14	IST, Vienna	
Aluminum	0.13	40	1.3	Oxygen	N/A	N/A		
Aluminum	0.16	60	1.5	Nitrogen/5-14	5	0.2	PRC Laser Corp	
Aluminum	0.2	50	1.5	Nitrogen/5-14	5	0.2	PRC Laser Corp	
Aluminum	0.25	40	3	Oxygen	N/A	N/A		
Aluminum	0.25	30	2	Oxygen	N/A	N/A		
Aluminum	0.28	43	1.5	Nitrogen/5-14	5	0.2	PRC Laser Corp	
Aluminum	0.3	60	0.5		N/A	N/A		
Aluminum	0.32	41	1.5	Nitrogen/5-14	5	0.2	PRC Laser Corp	
Aluminum	0.4	37	1.5	Nitrogen/5-14	5	0.2	PRC Laser Corp	
Aluminum	0.49	28	3	Oxygen	N/A	N/A		
Aluminum	0.5	100	12		N/A	N/A		
Aluminum	0.5	92	15		N/A	N/A		
Aluminum	0.5	32	3	Oxygen	N/A	N/A		

Nd:YAG laser cutting database format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Extreme Temperature Control
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Extreme Pumping
Name your flow and pressure and we can provide a pump to meet it. We have over 50 different pumps and plumbing configurations to meet your custom fluid and circulating requirements.
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Multiple-Fiber-Optic Probe for Light-Scattering Measurements

Measurements can be taken over a range of scattering angles, without mechanical scanning.

Lewis Research Center, Cleveland, Ohio

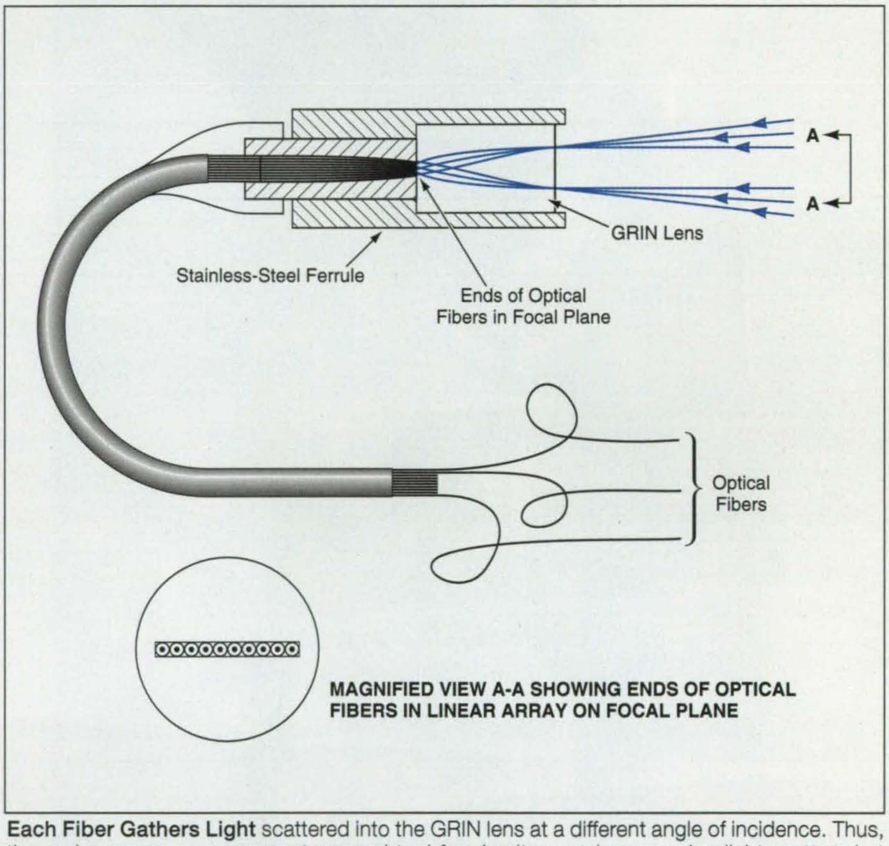
A multiple-fiber-optic probe has been developed for use in measuring light scattered at various angles from specimens of materials. The probe was designed for both static and dynamic light-scattering measurements of colloidal dispersions. Light-scattering measurements can yield information on the structures and dynamics of the light-scattering media; in particular, such measurements are often used to determine distributions of sizes of particles suspended in liquids.

Heretofore, light scattered to various angles has been measured by use of conventional bulk optical components scanned mechanically with goniometers. Mechanical scanning of bulk optics is not well suited for static light-scattering measurements at low angles (such measurements are needed for determining molecular weights of polymers); it also does not provide simultaneous dynamic measurements of scattering at small intervals over a range of angles (such measurements are needed to determine particle-size distributions).

The multiple-fiber-optic probe is a compact, rugged unit that contains no moving parts and remains stationary during operation. Unlike most mechanically scanned bulk optic probes, this probe does not have to be restricted to operation in a controlled, research-laboratory environment. It can be positioned inside or outside a light-scattering chamber. It provides simultaneous measurements at small angular intervals over a range of angles, which can be made to include small scattering angles by merely orienting the probe in the appropriate direction. The probe (see figure) includes a bundle of optical fibers (11 fibers in the prototype) with their input ends arranged in a linear array at the back focal plane of a gradient-index-of-refraction (GRIN) lens.

Light incident on the GRIN lens at a given angle is focused to a specific position on the focal plane. Thus, each optical fiber receives light scattered into an angular interval centered on an angle that depends on the position of the fiber along the linear array. The width of the angular interval and thus the uncertainty in the measurement angle is customarily expressed as the uncertainty in the direction cosine of the angle; this figure equals the ratio between the radius of the core of the optical fiber and the focal length of the GRIN lens.

The probe can be operated in a passive mode in which the light to be scattered is supplied by an external laser or other source. In that case, the output ends of all the optical fibers can be connected to photodetectors. Alternatively, one of the fibers can be used to carry light from a laser to the GRIN lens to illuminate the scattering medium, and the other fibers can then be used to measure the light back-scattered to various angles near 180°.



Each Fiber Gathers Light scattered into the GRIN lens at a different angle of incidence. Thus, the probe serves as a compact, rugged tool for simultaneously measuring light scattered at different angles, without need for mechanical scanning.

This work was done by Harbans Singh Dhadwal of the State University of New York and Rafat R. Ansari of Case Western Reserve University for **Lewis Research Center**. *For further information,* ***write in 71*** *on the TSP Request Card. LEW-15460*

Laser-Based Ultrasonic Coating Thickness Sensor System

New laser device provides intelligent control of high-temperature coating processes.

Wright Laboratory, Materials Directorate, Wright-Patterson Air Force Base, Ohio

A laser ultrasonic sensor system, linked to the coating equipment to maintain precision deposition rates, provides precision thickness control of high-temperature coatings during their application. Coatings down to two mils in thickness can be accurately measured with thickness control to ±5 percent, at application temperatures as high as 1400 °C (2550 °F). In operation, a pulsed laser ultrasonic generator directs a ring-shaped pulse at the surface being coated. Ultrasonic waves travel through the coating to a central laser sensor point and are picked up and reflected back to an interferometer sensor, so the coating thickness can be detected and read out directly. On-line, real-time measuring offers precision control over the coating process, especially when the interferometer sensor is linked to the coating equipment.

Innovative materials are answering the need to meet stringent performance demands for advanced Air Force systems. For example, crystalline silicon nitride coating has been developed to provide thermal protection for carbon-carbon components in high-temperature applications. This coating, applied by chemical vapor deposition, has protected carbon-carbon components in environments up to 1760 °C (3200 °F) for as long as five hours, successfully proving the feasibility of the control and the process. The thermal expansion rate of crystalline silicon nitride is very close to that of carbon, so the coating will not work loose and break off through hot and cold cycling.

Achieving the crystalline form of silicon nitride in coating deposition depends on intelligent control of the deposition rate and maintenance of application temperatures above 1400 °C (2550 °F). At lower deposition rates and temperatures the material structure remains uncrystallized, resulting in a coating with reduced oxidation resistance and lessened structural stability at elevated temperatures.

Besides nondestructive measurement of coatings for precision high-temperature barrier applications for Air Force turbine engines, the laser ultrasonic sensor can be used to measure ceramic and polymeric coatings on the skins of advanced aircraft, and as an end-process sensor to measure the thickness of virtually any kind of coating. Both crystalline and amorphous coatings can be measured with the same degree of accuracy. The coating process and intelligent control are being transferred to a manufacturing-scale reactor at the Amercom Corp., Santa Ana, CA.

This work was performed under a **Wright Laboratory Materials Directorate** *contract with United Technologies Research Center, East Hartford, CT. Kristen Kearns of the Materials Directorate is responsible for monitoring the contract.*

Inquiries concerning rights to the commercial use of this technology should be addressed to the Materials Directorate Technology Transfer Center, WL/MLI-TTC, 2977 P St., Suite 13, Wright-Patterson AFB, OH 45433-7746; (513) 255-4689.

Imaging Spectrometer With Liquid-Crystal Tunable Filter

A video camera collects wavelength-specific images.

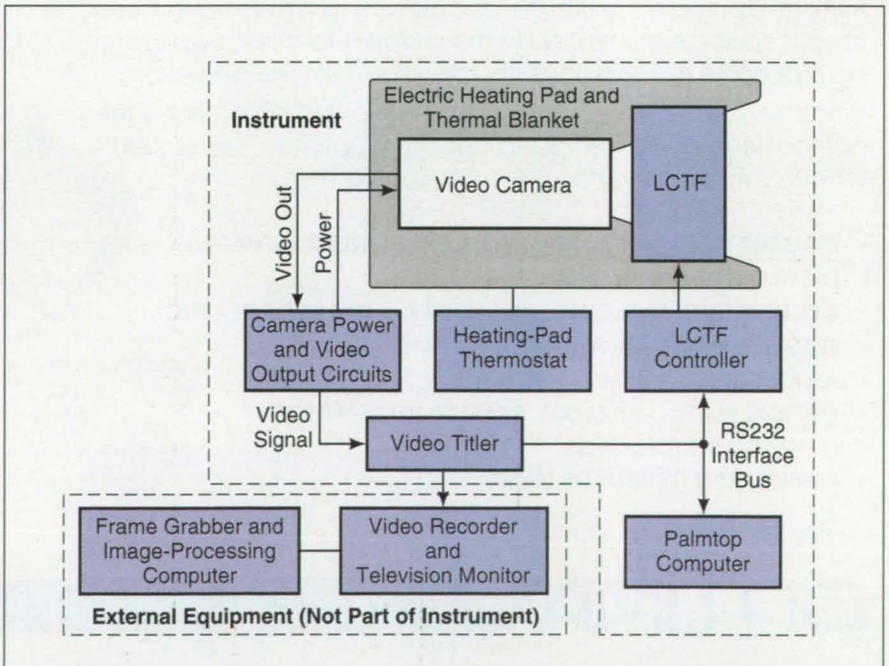
NASA's Jet Propulsion Laboratory, Pasadena, California

An imaging spectrometer has been constructed from a charge-coupled-device video camera; a liquid-crystal tunable filter (LCTF) placed in front of the camera lens; and associated digital and analog control, signal-processing, and data-processing circuits (see figure). To enable operation of this instrument in the specific application for which it was designed (balloon flights in cold weather), the camera and LCTF are surrounded by an electric heating pad. The total operating power, excluding that consumed by the heating pad, is 16 W. The instrument weighs 4.5 kg.

The LCTF is a six-stage Lyot-type polarization interference filter that functions as an electrically tunable band-pass filter, so that images in light of different wavelength bands can be acquired by the camera at different times. Liquid crystals are used to vary the retardance of each stage in the filter. Each stage also contains a quartz retarder that serves to double the retardance of the stage. The wavelength range of the filter is 430 to 680 nm, and its transmittance of unpolarized light ranges from 8 to 17 percent. The pass band is 30 nm wide at a wavelength of 430 nm, and its width increases to 50 nm at a wavelength of 633 nm.

The tuning of the six filter stages is controlled by a microprocessor, using parameters from a calibration look-up table stored in electronic memory. Values in the table are modified to compensate for effects of temperature, so as to null out the net temperature-dependent retardance in the liquid-crystal and quartz stages. Tuning time for moving from any given pass band to any other given pass band is 50 ms. A palmtop computer running a program in the BASIC computing language is used to initialize the filter, command a sequence of filter wavelength bands, and produce band-frequency labels for superposition on the video images produced by the camera. The video images are recorded by use of an external video tape recorder and are processed by an external computer.

This work was done by Thomas G. Chrien of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 8*** *on the TSP Request Card. NPO-19297*



The **Video Camera Takes Pictures in Wavelength Bands** selected by electrical tuning of the LCTF. The heating pad, wrapped in a thermal blanket, keeps the temperature of the camera and filter above their minimum operating temperature of 5° C in cold weather.

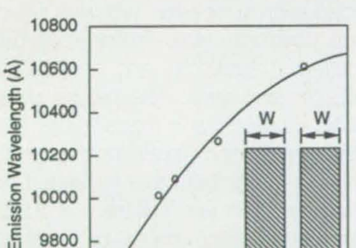
Integrable Photonic Devices by Selective-Area Epitaxy

The process enables the bandgap engineering necessary for the fabrication of photonic integrated circuits anywhere on a single wafer.

Microelectronics Laboratory, University of Illinois, Urbana, Illinois

Selective-area epitaxy (SAE) is the epitaxial growth of compound semiconductor layers using metallorganic chemical vapor deposition (MOCVD) on substrates patterned with dielectric films. For most materials, no deposition or crystal growth takes place on such films. Thus, as a result of the gas-phase diffusion of the source molecules, the growth rate and composition of the deposited material is defined by the geometry of the dielectric film. This enables design of the material thickness and composition (and thus the bandgap energy) anywhere on a single wafer by selection of the appropriate mask pattern.

The formation of InGaAs/GaAs/AlGaAs buried heterostructure photonic devices using selective-area epitaxy is a three-step growth process. The active region, consisting of an $In_xGa_{1-x}As$ quantum well surrounded by lower and upper GaAs barriers, is grown selectively using a dielectric mask described previously. The simplest geometry of the dielectric layer is the symmetric dual-stripe geometry (see inset). The spacing between



Emission wavelength vs. oxide stripe width for selectively grown InGaAs/GaAs/AlGaAs buried-heterostructure lasers with a mesa width S of 4 micrometers and a nominal 40-angstrom $In_{0.21}Ga_{0.79}As$ quantum well. Inset: schematic diagram of the dual oxide stripe mask used during the selective growth of the active region.

the dual stripes S defines the buried-heterostructure mesa width, while both the spacing between the dual stripes and the stripe width W defines the composition and thickness, and hence the emission wavelength, of the $In_xGa_{1-x}As$.

There are several advantages of fabricating photonic devices by this three-step selective-area epitaxy process. For example, no semiconductor crystal etching is required; only atmospheric-pressure MOCVD crystal growth is used. Most importantly, the crystal bandgap energy across the wafer is controlled independently in different areas on the wafer.

Several advanced photonic devices have been fabricated in the InGaAs/GaAs/AlGaAs material system using selective-area epitaxy. These devices include lasers with monolithically integrated modulators for high-speed transmission, broad spectrum light-emitting diodes (LEDs) for single-source wavelength-division multiplexing (WDM) applications, and very-low-threshold buried heterostructure lasers.

Lasers with monolithically integrated modulators are designed to exploit the wavelength selection of SAE to obtain a bandgap energy for the modulator that is slightly blue-shifted with respect to the laser. This enables the unbiased modulator to be transparent to the lasing wavelength of the device, while only a small reverse bias across the modulator yields high absorption and terminates laser action.

Other devices that have been fabricated in the InGaAs/GaAs/AlGaAs material system using SAE are lasers with monolithically integrated photodiodes for applications needing highly stabilized optical power, lasers with nonabsorbing mirrors for high-power applications, and multiwavelength laser arrays for WDM applications.

This work was done by R.M. Lammert and J.J. Coleman of the **Microelectronics Laboratory, University of Illinois**. *It was supported by the National Science Foundation Engineering Research Center for Compound Semiconductor Microelectronics (ECD 89-43166), the ARPA Center for Optoelectronic Science and Technology (MDA972-94-1-004), and the Joint Services Electronics Program (N0014-90-J-1270). For further information contact Prof. J.J. Coleman, Microelectronics Laboratory, University of Illinois, 208 N. Wright St., Urbana, IL 61801.*

Parametric Amplification for Detecting Weak Optical Signals

The performances of direct-detection optical-communication receivers could be enhanced.

NASA's Jet Propulsion Laboratory, Pasadena, California

Optical-communication receivers of a proposed type would implement a high-sensitivity scheme of optical parametric amplification followed by direct detection (see figure) for reception of extremely weak signals. Neither parametric amplification nor direct detection is new by itself; what is new here is the proposal to incorporate both optical parametric amplification and direct detection into an optimized design that would enhance the effective signal-to-noise ratios during reception in the photon-starved (that is, photon-counting) regime. Such a design would eliminate the need for the complexity of a heterodyne detection scheme and would partly overcome the limitations imposed on older direct-detection schemes by noise generated in receivers and by the limits on the quantum efficiencies of photodetectors.

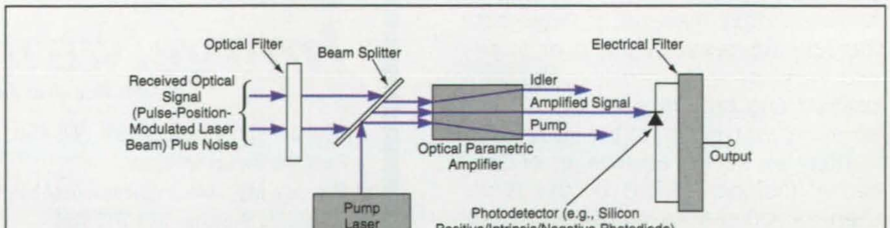
An optical parametric amplifier resembles a laser in some respects and differs in other respects, such that an optical parametric amplifier can function in the photon-starved regime, whereas a laser cannot because its operation depends on an input signal being above a threshold level. In addition, an optical parametric amplifier can operate over a wider wavelength range than a laser can, and is continuously tunable over a wide wavelength range.

Like a laser, an optical parametric amplifier includes a resonant cavity that contains a medium that responds nonlinearly to electromagnetic fields and emits coherent radiation. In general, the parametric amplification process occurs by virtue of interactions among photons in a nonlinearly responding medium: it involves the interaction between a relatively strong locally generated pump signal of frequency f_P and a weaker received signal (the signal that one seeks to amplify) of lower frequency f_S. The interaction can be characterized as a nonlinear mixing process in which the pump photons (f_P) are split into photons of both the received-signal frequency f_S and photons of an idler frequency f_I, where $f_P = f_S + f_I$ because of conservation of photon energy. This process results in amplification and/or oscillation at both f_P and f_I.

For a given f_P, an infinite number of pairs of f_S and f_I is possible. The particular pair, and thus f_S, is determined by the phase-matching condition in the nonlinear medium. This condition can be adjusted, providing wavelength tunability in an optical parametric amplifier or oscillator. Recent improvements in some nonlinearly responding crystalline materials have opened up the possibility of constructing efficient optical parametric amplifiers. These materials include $LiNbO_3$, $KTiPO_4$, BaB_2O_4, LiB_3O_5, and $KNbO_3$.

Performances in the reception of weak pulse-position-modulated optical signals by direct-detection receivers with and without optical parametric amplification have been predicted theoretically and analyzed by computer simulation. The results of this analysis showed that in a given case, parametric amplification would enhance performance by an amount that increased with the amplifier gain, and that the use of parametric amplification could be especially helpful in the case of a photodetector of low quantum efficiency. The net enhancement is estimated to lie between 3.75 and 5.1 dB, the exact value depending on the background noise and other factors.

This work was done by Hamid Hemmati, Chien Chen, and Prakash Chakravarthi of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 17*** *on the TSP Request Card.* *NPO-19514*



An **Optical Parametric Amplifier** would provide wavelength-tunable amplification to enhance the performance of a direct-detection optical receiver.

High-Speed Pattern Recognition Using Multiple-Quantum-Well Devices

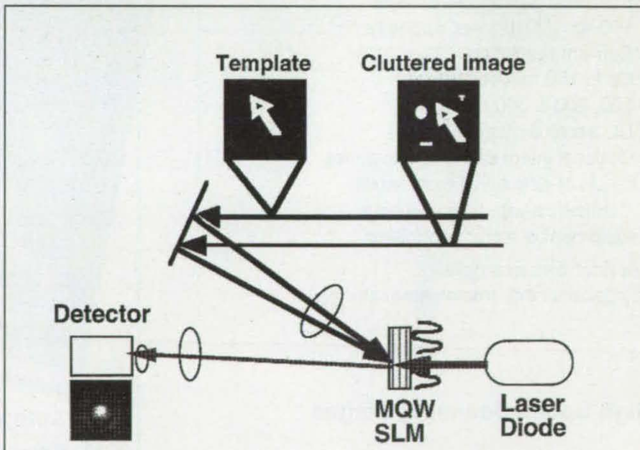
Advanced materials allow automated recognition of objects.

Naval Research Laboratory (NRL), Washington, DC

An optical correlator using multiple quantum-well spatial light modulators (SLMs) is being developed for automatic pattern recognition at rates exceeding 100,000 frames per second. Optical correlation is a holographic technique that can be used to compare an image to a stored template. Previous systems have used SLMs whose maximum speed was 10-100 times slower. This new system has the potential for much higher speeds because of an SLM that uses thin layers of semiconducting material. This technology can be used for any problem involving pattern recognition. In particular, it is being evaluated for identifying debris particles in a wear monitor for engines.

In general there are two ways to handle the problem of automatic pattern recognition. In an all-digital approach, the image to be analyzed is converted into digital form and processed using any of a wide variety of computer algorithms. This technique has a great deal of flexibility, but requires a tremendous amount of computing power. As a result, it is often limited in speed or requires very large and expensive computers.

An alternative approach is analog optical pattern recognition. In such a system the image is not converted to digital form, but is rather processed using optical techniques. This approach does not have the algorithmic flexibility of the digital one, but with the availability of new materials can greatly outperform computers in speed.



A typical **Optical Correlator** setup showing recognition of a shape in a cluttered background.

In fact, both these approaches have something in common: the Fourier transform. This mathematical transformation, which converts an image into its fundamental spatial periodicities, underlies many computer pattern recognition algorithms as well as the optical correlator. The difference is that the computer must calculate the Fourier transform using a computationally expensive algorithm that can take a substantial fraction of a second or longer, whereas optical techniques can automatically generate a Fourier transform of an image of any size in as little as a microsecond.

In a typical correlator two images are input into the system. One is the image for analysis and the other is a template to which to compare the first. A Fourier hologram of the two is formed on the spatial light modulator, which acts like a rewritable piece of film. The hologram is read out by a low-power laser diode. If the images are similar a bright readout spot results. If they are dissimilar, no spot or a much weaker spot results. The entire process can occur very quickly. In practice the only things limiting the speed are how fast the SLM can "develop" the hologram and how fast the template images can be changed.

Previous SLM materials, for instance ferroelectric liquid crystals, have been limited to speeds of 10 kHz or less, which has bottlenecked the processing speed of optical correlator systems. Recently, however, a new class of SLMs has appeared based upon multiple-quantum-well semiconductor materials. These consist of many ultrathin layers of GaAs and AlGaAs surrounded by transparent electrodes. A typical device is a square centimeter in size and a micron thick (the thin film is supported by a thick transparent substrate like quartz and is quite robust). The device is not pixellated; it is simply a uniform film of semiconductor. This makes fabrication quite simple and reliable. In addition the resolution of these materials is quite high, with features as small as 5 µm resolvable. A low (approx. 10-V) AC voltage is applied across the device, which activates it. When exposed to a pattern of light it changes its transmission, much as film does, but at a rate that can exceed a million frames a second. In addition, like film, these SLMs support a gray scale of transmission values.

Using those materials in combination with a fast template memory, such as an analog optical disk, rates of more than 100 kHz are possible. Real-time automatic pattern recognition problems come up in areas such as automatic navigation, robotic vision, automated cell identification for tissue culture, and others. In many of these applications the speed offered by an all optical system may be critical in its practical implementation.

This work was done by William Rabinovich, Steven Bowman, Rita Mahon, and Scott Katzer of the **Naval Research Laboratory.** *For further information, contact Steven Bowman, NRL, Optical Science Division, Code 5640, Washington, DC 20375; (202) 767-9418; FAX (202) 404-7530.*

Inquiries concerning rights for the commercial use of this invention should be directed to Dr. Richard Rein, Office of Technology Transfer, Code 1003.1, NRL, Washington, DC 20375.

LITERATURE SPOTLIGHT

Free catalogs and literature for *Laser Tech Briefs'* readers. To order, write in the corresponding number on the Reader Information Request Form (precedes page 81).

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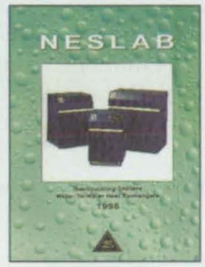

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NEW PRODUCTS

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International Light, Newburyport, MA, offers the IL1700 research radiometer that can autorange during exposure integrations over a 10-decade dynamic range. Depending upon the detector selected, it can autorange from moonlight to bright sunlight or for unpredictable short flash durations. The SHD033 detector offers sensitivity from 10 fW to 10 μW, and the SED033 from 4 pW to 4 mW. The data register permits dose integrations spanning a 40-decade range for up to 18 years without loss of data from previous ranges. The IL1700 is priced at $1647.

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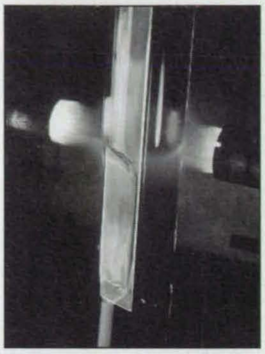

Precision Bore Tubing in Many Shapes

The capabilities of Andrews Glass, Vineland, NJ, in precision bore tubing enable the engineer to specify tightly toleranced tubing in round, rectangular, triangular, and other shapes for such applications as TV cameras, optical scanners, lasers, IR systems, semiconductors, and research-laboratory apparatuses. The company works in borosilicate, soda, fused quartz, and other glass, maintaining tolerances up to ± 0.0001 in. Sizes range from 0.010 to 6.000 in. inside diameter and up to 40 in. in length.

For More Information Write In No. 805

Auxiliary Work Surface for Optical Tables

Kinetic Systems, Roslindale, MA, announces an auxiliary work surface for use with its steel honeycomb optical tables. It provides a shelf 23 inches in depth positioned over the table and capable of holding up to 400 lb. of equipment. Running the length of any table from 3-6 ft., the shelf is independently supported by telescoping steel legs, preventing any interference with vibration isolation.

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Low-Profile X-Theta Positioner

New England Affiliated Technologies (NEAT), Lawrence, MA, says that the low-profile design of its new X-theta positioner suits it for lightweight optical applications and semiconductor wafer and computer-disk test and inspection. Only 1.188 in. in height, the positioner has X-axis travel of 15.3 cm, resolution of 0.125 μm/25.4 μm, and unidirectional repeatability of better than 0.0001 in. Position references are gauged by Hall-effect limit sensors.

For More Information Write In No. 807

High-Power Diode-Pumped Visible Laser

Spectra-Physics Lasers, Mountain View, CA, dubs its new compact, 110-V diode-pumped intracavity-doubled laser the Millennia. It produces more than 5 W of green TEM_{00} output with a wall-plug efficiency 100 times better than that of an argon-ion laser. The Millennia's z-fold laser head is end-pumped with the outputs of two fiber-coupled diode bars (FCbar™). The company says its patented doubling technique called QMAD creates second-harmonic generation with exceptionally low optical noise.

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Imaging Simulation Program

Skylight from Focus Software Inc., Tucson, AZ, is a new atmospheric imaging simulation program. It computes both long- and short-exposure atmospheric aberration effects, time-averaged MTF, instantaneous point spread functions, Strehl ratio, and much more. Skylight can export data to Focus' ZEMAX-EE optical design program. Price: $300.

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TE Coolers with Perimeter Seal

The SealTEC™ series of thermoelectric coolers from Melcor Corp., Trenton, NJ, features a perimeter seal to protect them from water condensation that often occurs when operating at or below the dew point or in humid conditions. The series comes in 12 models in various sizes with maximum power ratings between 2.5-24 A.

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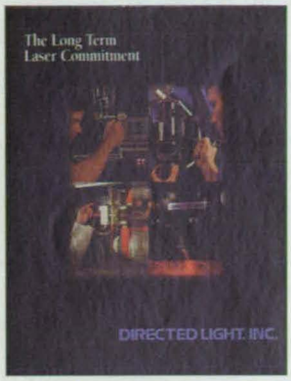
NEW LITERATURE



Industrial Laser System Design

"The Long Term Laser Commitment" is the title of a four-page capabilities outline by Directed Light Inc., San Jose, CA. Calling itself the "one-stop shopping" resource for industrial laser services, the company has three divisions at its corporate headquarters: Component Sales, a full-service Job Shop, and Systems Integration. The last is responsible for the design and integration of Nd:YAG and CO_2 machining systems for industries including electronic and commercial products, medical device manufacturing, aerospace, and the graphic arts.

For More Information Write In No. 801

Lasers "Ultraviolet to Ultrared"

A 28-page catalog from Uniphase, San Jose, CA, surveys the company's product line: the µGreen and µIR diode-pumped solid-state, DAYlight diode-array-pumped Nd:YLF, StableLight diode-pumped solid-state, argon ion, and red, green, yellow and orange HeNe lasers, and HeNe power supplies. Detailed specifications accompany each product category. A page is devoted to descriptions of new products and those in development, including the µBlue laser emitting several mW at 473 nm, and the single longitudinal-mode µGreen laser.

For More Information Write In No. 802

Laser Precision Optics and Optomechanics

The 1995-6 catalog from OptoSigma Corp., Santa Ana, CA, has 150 pages of information about the new company's line of optics, including broadband and laser-line mirrors, lenses, beamsplitters, polarizers, prisms, microscope objectives, and a wide selection of microlenses. It also has descriptions of the One Touch™ mirror mounts and a miniature optical mounting system with stages, component mounts, and the company's Opto Mike™ automatic positioning and encoder system for remote positioning capability. Technical and pricing information are also featured.

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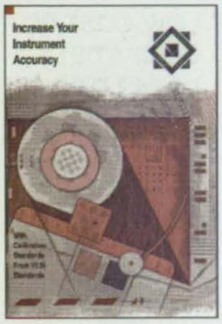

CALIBRATION STANDARDS CATALOG

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National Instruments

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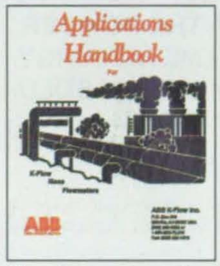

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Ferrofluidics Corp.

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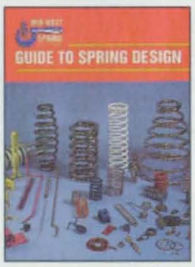

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Mid-West Spring Manufacturing Co.

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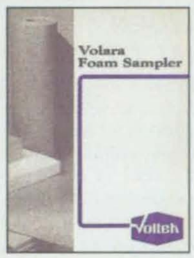

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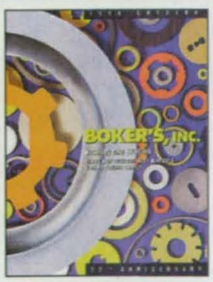

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American Precision Industries

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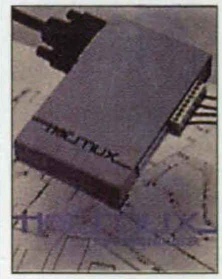

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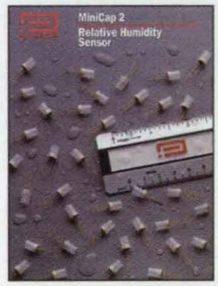

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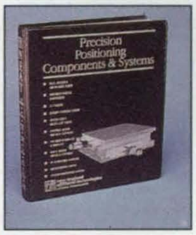

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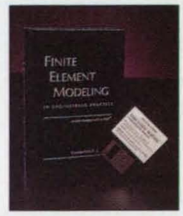

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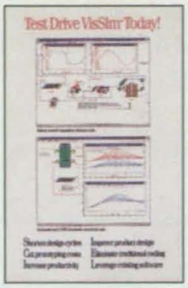

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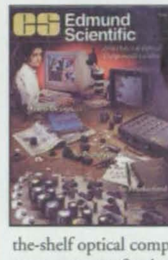

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NEURAL NETWORK/ PATTERN RECOGNITION SOLUTIONS

Pattern Recognition Workbench™ (PRW) is the first comprehensive software package which helps you find valuable patterns hidden in your data. Featuring a unique "Giga" Spreadsheet, powerful import/export capabilities, an extensive library of macros, mature neural networks and statistical algorithms, model validation, experiment management, automatic input and parameter optimization, and source code generation, in a fast, intuitive Windows environment. Everyone can now see a huge ROI from their data! Unica Solutions, Inc.; Tel: 508-371-1414.

Unica Solutions, Inc.

For More Information Write In No. 327

COATINGS PROTECT METALS AND IMPROVE WEAR-LIFE

Surface-enhancing permanent coatings protect metal parts against abrasion, corrosion and galling. They also dramatically increase wear-life and operational performance. These Magnaplate-applied coatings create a harder-than-steel, dry-lubricated, non-stick surface that won't chip or peel off; has superior release; and is easy to keep clean. Many are FDA/USDA approved. General Magnaplate Corp., 1331 Route 1, Linden, NJ 07036; Tel: 800-852-3301 or 908-862-6200; Fax: 908-862-6110.

General Magnaplate Corp.

For More Information Write In No. 328

WAVE/COMPRESSION SPRING CATALOG

Just updated, Catalog #WS-93A contains hundreds of NEW stock sizes of wave/compression springs, including spring design formulas, materials guide and typical applications. This 40-page engineering/ parts manual describes the many advantages of Smalley's exclusive edgewinding manufacturing process. Available from 3/8" to 84" in diameter, Smalley springs are produced by circle-coiling flat wire to exact specifications involving no dies or special tooling charges. Smalley Steel Ring Co., 385 Gilman Ave., Wheeling, IL 60090; Tel: 847-537-7600; Fax: 847-537-7698.

Smalley Steel Ring Co.

For More Information Write In No. 329

GIGABIT NETWORK

Introducing FibreXpress™, SYSTRAN Corp.'s new line of Fibre Channel adapter cards and switches. FibreXpress provides a way to connect computers at speeds of up to 1.0625 Gb/sec. Call: 800-252-5601 for this FREE booklet ... a $14.95 value!

SYSTRAN Corp.

For More Information Write In No. 330

"HANDS-ON" ADVANCED COMPOSITE WORKSHOPS SINCE 1983

The brochure describes 14 different "hands-on" workshops in advanced composite materials technology, including fabrication, repair, manufacturing, tooling, print reading, adhesive bonding, ultrasonic inspection of composites, resin transfer molding, and engineering. Emphasis is placed on glass, carbon and aramid fiber materials and processes, utilizing vacuum bagging and oven and autoclave curing. Three workshops are Canadian D.O.T. approved. REFRESHER WORKSHOPS OFFERED. Call toll-free: 1-800-638-8441; Fax: 702-827-6599. Abaris Training Resources, Inc., 5401 Longley Lane, Suite 49, Reno, NV 89511.

Abaris Training Resources, Inc.

For More Information Write In No. 331

VORTEX TUBES

Data sheet describes how EXAIR Vortex Tubes produce up to 10,000 Btu/hr. with no moving parts. Tubes convert an ordinary supply of compressed air into two streams: one hot and one cold. Temperatures are adjustable from -50° to +250°F. Bulletin highlights advantages for a variety of industrial cooling applications. EXAIR Corporation, 1250 Century Circle North, Cincinnati, OH 45246; Tel: 800-903-9247; Fax: 513-671-3363; E-mail: techelp@exair.com.

EXAIR Corporation

For More Information Write In No. 332

METAL BELTS AND DRIVE TAPES

This general product brochure describes the various attributes that make metal belts and drive tapes an exceptional and exciting option for design engineers. Manufactured by Belt Technologies for 25 years, this unique family of products has helped design engineers overcome challenging application requirements in the electronics, aerospace, biomedical, optical and packaging industries. Belt Technologies, Inc., PO Box 468, Agawam, MA 01001; Tel: 413-786-9922; Fax: 413-789-2786.

Belt Technologies, Inc.

For More Information Write In No. 333

HI-TEMP MATERIALS TO 3200° F

Aremco produces a complete line of high-temperature ceramics, adhesives, coatings, sealants, tapes, greases, castables and potting compounds. These materials are used throughout industry in the design of sensors, electrical components and analytical instruments, as well as in the maintenance of high-temperature industrial process equipment. Aremco Products, Inc., PO Box 429, Ossining, NY 10562-0429; Tel: 914-762-0685; Fax: 914-762-1663.

Aremco Products, Inc.

For More Information Write In No. 334

AIR KNIFE FOR BLOWOFF

The EXAIR-Knife reduces air consumption and noise levels on a wide range of blowoff applications. Using a small amount of compressed air as a power source, the air knife pulls in large volumes of surrounding air to produce a high-flow, high-velocity curtain of air for blowoff. Compressed air flow is amplified 30:1. Six sizes up to 36" in length are available. Applications include: blowing liquid, chips and contaminant from parts and conveyors, cooling hot parts, and air screening. EXAIR Corporation, 1250 Century Circle North, Cincinnati, OH 45246; Tel: 800-903-9247; Fax: 513-671-3363; E-mail: techelp@exair.com.

EXAIR Corporation

For More Information Write In No. 335

FIRESTONE AIR SPRINGS

Your motion control solution! Firestone Industrial Product Company's Airstroke® actuators and Airmount® isolators blow traditional cylinders and isolators away. The bellows-shaped air springs defy the traditional way of thinking about cylinders and isolators. They are durable, self-aligning, compact and cost-effective. Firestone Industrial Products Company, Carmel, IN; Tel: 800-888-0650; E-mail: firestone@industry.net.

Firestone Industrial Products Company

For More Information Write In No. 336

NEW BeCu RFI/EMI SHIELDING STRIP CATALOG

New 24-page catalog describes BeCu RFI/EMI shielding strips including Soft No-Snag Fingers, Omni Contacts, Panel Gaskets, Reverse Bend Contacts, Strip Gaskets, Cylindrical and Spherical Contacts, "D" Connector Gaskets, and Rings. Four mounting styles: Stick-on, Clip-on, Snap-on and Special. Shows compression values, finishes, custom options, and ordering information. Tech-Etch, Inc.

Tech-Etch, Inc.

For More Information Write In No. 337

LINEAR MOTION SYSTEMS

This new 168-page Master Catalog H800 has over 800 components plus complete production systems to make it much more affordable to design, build, or repair automated production, dispensing, inspection or testing machinery. Product sections include X/XY/XYZ stages and slides; mechanical components; aluminum extrusions; electronic components; and CAD/CAM production software. Techno-Isel, 2101 Jericho Tpke., Box 5416, New Hyde Park, NY 11042-5416; Tel: 516-328-3970; Fax: 800-737-7436.

Techno-Isel

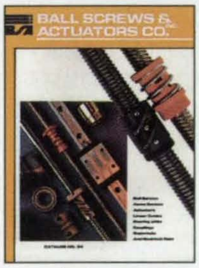
For More Information Write In No. 338

INSTRUMENT CATALOG 1996

Metric sells, rents and buys the latest in refurbished electronic test and measurement instruments from Hewlett Packard, Tektronix, Fluke, Keithley, etc. All products are tested in our lab to insure compliance to original manufacturers' specifications and are traceable to N.I.S.T. Six-month warranty on most models, five-day free trial, complete with accessories and manuals. BIG SAVINGS 20% to 60% off list. For free catalog call Metric; Tel: 800-432-3424; Fax: 415-341-8874.

Metric Equipment Sales, Inc.

For More Information Write In No. 339



NEW BALL & ACME SCREWS

BS&A catalog 94 offers mechanical designers the largest selection of precision ball and acme screws that feature standard and preloaded nuts. Many new sizes and leads have been added to the ball screw and acme screw line. Low-cost Supernuts feature a simple, patented preload adjustment for every precision acme screw size and lead. End bearing units, flanges and all accessories are included. For catalogs or engineering assistance call Greg Traeger, Sales Manager; Tel: 800-882-8857; Fax: 408-629-2620.

Ball Screws & Actuators Co., Inc.

For More Information Write In No. 340

1996 PCMCIA PRODUCTS CATALOG

The new PCMCIA-PC CARD standard has brought many new devices such as Video Capture, 16-bit Stereo, CD-ROM, Pager, and mini PC Card Camera Cards. ENVOY DATA has just released its new catalog with these new products plus many more like: Memory, I/O (serial, parallel, SCSI, A/D, etc.) along with Industrial Card and Drives, Multimedia, Industrial, and Engineering tools for PCMCIA applications. Envoy Data Corporation, 953 E. Juanita Ave., #A, Mesa, AZ 85204; Tel: 602-892-0954; Fax: 602-892-0029.

Envoy Data Corporation

For More Information Write In No. 341

PRECISION TEST & MEASUREMENT EQUIPMENT

Stanford Research Systems' 1996 Catalog contains specifications, technical discussions and application notes on their complete line of scientific and engineering test instruments. The catalog includes details on their latest function generators, spectrum analyzers, lock-in amplifiers, delay generators, etc., and is a useful reference for a wide range of test and measurement applications. Stanford Research Systems, 1290 D Reamwood Ave., Sunnyvale, CA 94089; Tel: 408-744-9040.

Stanford Research Systems

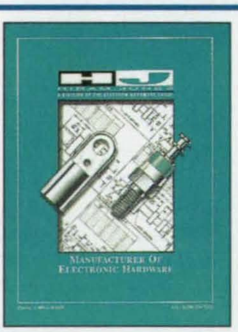
For More Information Write In No. 342

FIBEROPTIC TESTER

Automatically measure the surfaces of a variety of fiber components including connector end faces, ferrules, APCs, PCs, fibers, etc. In seconds, obtain non-contact, three-dimensional measurements and industry-standard statistics of roughness, apex offset, apex angle, protrusion/undercut, radius of curvature, and more. For more information, contact WYKO at: 800-FON-WYKO; E-mail: sales@wyko.com.

WYKO

For More Information Write In No. 343



Hiram Jones Electronics, Inc./A Division of the Seastrom Hardware Group manufactures a complete line of standard miniature and subminiature terminals including: insulated test jacks, assembled standoffs and press-type terminals. All standard catalog items are available for immediate pricing and delivery. Call today for your free 27-page catalog: 800-634-2356.

Hiram Jones Electronics, Inc.

For More Information Write In No. 344

continued from page 22

eral partners to develop a diverse array of insulated products such as blankets, gloves, scuba-diving skins, and firefighting gloves.

For more information: MCTTC, Technology and Economic Development, Texas Engineering Extension Service, Texas A&M University System, 301 Tarrow, College Station, TX 77843-8000; (409) 845-8762; Fax (409) 845-3559; Gary Sera, director.

Far West Regional Technology Transfer Center

Headquartered at the University of Southern California in Los Angeles, the Far West Regional Technology Transfer Center serves an eight-state area: Arizona, California, Nevada, Washington, Oregon, Idaho, Alaska, and Hawaii. The center estimates that in the first quarter of last year its clients' revenues increased by more than $6 million, more than 60 jobs were created or saved, and cost savings to clients exceeded $120,000.

One recent initiative to yield promising results began when SpiraMed Corp., a California startup, became interested in a NASA Ames Research Center technology developed to determine whether life has existed on other planets. In collaboration with the Search for Extraterrestrial Intelligence and San Jose State University, Ames developed a carbon-isotope laser spectroscopic analysis technique for soil samples from other planets. Believing the analysis of such isotope ratios in soil and in breath can use the same process, SpiraMed requested Far West's assistance in obtaining rights to commercialize the technology for medical diagnostics. The result was a Space Act Agreement with Ames, as well as negotiations between the company, venture capital firms, and medical equipment manufacturers to fund product development.

Even when a NASA project seems space-specific, Far West has probed commercial possibilities. The Stardust program at NASA's Jet Propulsion Laboratory proposes a spacecraft to fly through the extended tail of an active comet to image it and obtain comet dust samples. Far West assisted the JPL team in identifying commercial potential in the work and developing marketing strategies. This led to a Technology Cooperation Agreement between a substantial commercial partner and JPL for development of aerogel, a gel from which the liquid is removed and replaced with gas without shrinkage.

Far West extended its reach as far as NASA Langley on the east coast when H&H, a California bioremediation services company, came to it looking for a material to increase the life of fan knife blades used in its Turborator, a machine for cutting and mixing contaminated soil for hydrocarbon bioremediation. H&H will test a new polyimide coating spawned at Langley that should allow diamond and other hard substances to be embedded in the blade surface. Far West also identified commercial markets—for example, making one-piece epoxy composite golf clubs—for a company whose composite molding technique was developed for defense purposes, and introduced it to Langley resilient coating technology for application to the epoxies.

For more information: Far West RTTC, University of Southern California, 3716 S. Hope St., Suite 200, Los Angeles, CA 90007-4344; (213) 743-2353; Fax (213) 746-9043; Robert I. Stark, director.

To reach the RTTC nearest you, call (800) 472-6785.

1995 Product of the Year

In the December 1995 issue of *NASA Tech Briefs*, we asked for your votes for Product of the Year. Thank you to all of our readers who responded.

The Co-Winners of 1995 Product of the Year are:

Autodesk's CD-ROM mechanical library
and
SolidWorks' solid modeling mechanical design software, SolidWorks 95

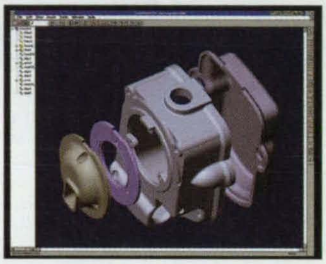
In 1995, Autodesk (San Rafael, CA) introduced the first two titles in its Mechanical Library, which appeared as May's Product of the Month. The first title, PartSpec™, is an interactive, easy-to-use, single-source database of more than 200,000 ready-made parts from 17 leading manufacturers. Customers can search the database by manufacturer name or parts category and instantly view a variety of information, including a preview or full-screen image. They can then pick-and-place a drawing of the part and other nongraphic data into any AutoCAD or AutoCAD LT drawing.

The second title, MaterialSpec™, provides a comprehensive, electronic database of more than 25,000 plastics, ceramics, metals, and composites from 300 leading manufacturers. Customers can search for materials information by manufacturer, material type or trade name, typical applications, and property characteristics.

According to Chris Hock, product manager for the Autodesk Mechanical Library, 32% of the engineers who purchased PartSpec last year did so to avoid having to redraw parts; 26% purchased it because they liked the concept of having all parts information on one CD-ROM. These engineers use PartSpec an average of five times per week, have a more consistent look and feel to their drawings, and produce more accurate drawings, according to Hock.

Both databases are available for Windows and DOS platforms and cost $295 each, or $495 for the pair. The titles are the first products from Autodesk's new Autodesk Data Publishing unit, which offers them as one-year subscriptions with semi-annual updates. During 1996, the mechanical library will expand to include more parts, manufacturers, and industry categories.

Contact Autodesk at 415-507-5000 or write in no. 758



SolidWorks 95 solid modeling mechanical design software from SolidWorks (Concord, MA) is the first product to put the power of production-level solid modeling into a native Windows environment, which made it November's Product of the Month. While other programs of its type have versions that run on Windows, SolidWorks 95 is the first to completely conform to the Windows graphical user interface, allowing engineers to be productive without extensive training.

The program's mechanical design system forms the basis of a 3D-centric design process, developed by SolidWorks CEO Jon Hirschtick, in which a fully detailed solid model can be used by every engineer as a master model for producing drawings and performing other functions such as finite-element analysis and numerical control programming.

SolidWorks 95 features a dual-mode user interface called DesignBrowser™, which displays the model as well as a list of features used to build it; and OLE 2.0, which provides users with the ability to embed spreadsheets, text files, or any other OLE-compliant documents into SolidWorks 95 or vice-versa. The program also allows users to design parts and then fully define the model later.

The SolidWorks 95 graphical user interface has all the features of Windows, plus some that are unique to the software including the ability to drag and drop features to different locations, real-time reshaping of parts, right mouse button control, and feature construction wizards.

Priced at $3995, SolidWorks 95 is targeted for mechanical design and manufacturing environments, including aerospace, automotive, consumer products, and heavy machinery industries.

Contact SolidWorks at 508-371-2910 or write in no. 759

Solve your toughest design engineering problems in just days at the 44th Design Engineering Show and Conference.

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Sound too good to be true? Not when you consider that only at the 44th **Design Engineering Show and Conference** will you find three miles of aisles packed with the most advanced OEM products, tools and materials for the forward-looking design engineer searching for the latest ideas and possibilities in process and product design. You'll find **more solutions... more technology... more innovations** per square foot than anyplace else... to help you solve any of your design and development challenges.

The **Design Engineering Show and Conference** is where 31,339 design engineers and manufacturing management from across North America attended in 1995, including 4,568 decision makers from the *Top 500 Industrial Giants.* They all agree on two things. **First** – no matter what your enterprise manufactures, you and your design team will find what your company needs to keep its products on the cutting edge with ever shorter time-to-market windows, at the **Design Engineering Show and Conference. Second** – they'll be back next year.

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For More Information Write In No. 556

New on the Market

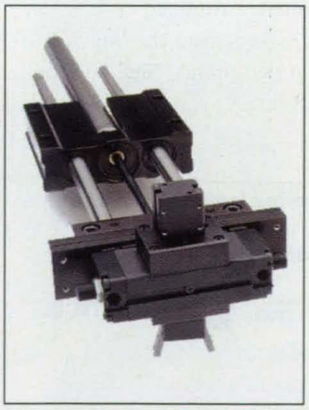
Product of the Month

Silicon Graphics, Mountain View, CA, has introduced Onyx InfiniteReality™, a **visualization supercomputer** that simultaneously processes graphics, imaging, and video data in real time. Delivering more than 10 million polygons per second, the system provides 5 GFLOPS for image processing and downloads 200 MB of data per second into a visualization pipeline. The system enables creation of virtual 3D characters, 3D imaging, and volume rendering, and incorporates geospecific texturing for realism in visual simulation and high-end CAD applications. The computer supports from two to 24 MIPS® R4400™ processors and 64 MB to 16 GB of memory.

For More Information Write In No. 700

Saturn Industries, Hudson, NY, offers grain, isotropic, ultrafine, and copper-infiltrated Sigma™ **graphite** material for use in fabricating electrodes, molds, and dies. It provides high strength, a high metal removal rate, and a wear-resistant surface finish.

For More Information Write In No. 701



RotoGrippers **component placement systems** from Tol-O-Matic, Hamel, MN, can pick and place virtually any component in an assembly operation. The 180° and 360° rotation systems, used with rod cylinder slides, linear slides, and band cylinders, can change levels and orientation of components in multiaxis applications. They are available in drive-from-behind and drive-in-front styles.

For More Information Write In No. 702

Maple Systems, Bothell, WA, offers OITman **operator interface terminals** featuring LCD and VFD displays, 2 x 40 to 8 x 40 display sizes, and 12 to 16 function keys. The terminals provide bar graph capabilities, printer/PC ports, Windows configuration software, status LEDs, and 500 configurable message screens.

For More Information Write In No. 704

RGB Spectrum, Alameda, CA, has introduced the SynchroMaster™ 100HD color field sequential **scan converter**. Compatible with high-definition television signals, it can be used with virtual reality helmet- and boom-mounted displays for military, medical, and industrial applications. The device converts RGB parallel signals from workstations or scene generators to VR serial displays.

For More Information Write In No. 703

Swagelok® tube-fitting **flange connectors** from the Swagelok Companies, Solon, OH, provide installation between process lines and instruments, and are machined from one-piece forgings to eliminate weld seams and joints. They are available in ANSI 150-lb. or 300-lb. configurations for 1/2" pipe and are made of 316 stainless steel.

For More Information Write In No. 705

The LEO 435VP variable-pressure **scanning electron microscope** from LEO Electron Microscopy, Thornwood, NY, uses differential pumping to control the specimen chamber pressure. It operates in a Windows graphical environment, and can store, print, or transfer results to a remote site.

For More Information Write In No. 707

New on the Market

Yokogawa Corp. of America, Newnan, GA, has introduced the OR1400 **oscillographic recorder**, which combines high-speed, real-time recording with data capture capabilities. It can be configured with one to eight channels, and accepts high volts to thermocouple inputs. Other features include computation functions and enhanced triggering.

For More Information Write In No. 706

The Model 2010 low-noise **multimeter** with 7.5-digit resolution is available from Keithley Instruments, Cleveland, OH. Up to 2000 measurements per second can be made at 4-1/2-digit resolution. The device is designed for production testing of sensors, transducers, converters, and electronic subsystems.

For More Information Write In No. 709

Eastman Kodak Motion Analysis Systems Div., San Diego, CA, offers the Model 1000HRC EktaPro **digital motion analyzer** for recording color images at up to 1000 full-frame images per second. The system records tests that occur too fast for the human eye to follow. It uses standard C-mount camera lenses and stores images for downloading to videotape or optical disk.

For More Information Write In No. 708

Endevco, San Juan Capistrano, CA, has introduced the Model 2258AM2 series triaxial Isotron® **piezoelectric accelerometers** for measuring vibration in three orthogonal axes on small structures. They feature a replaceable subassembly and output sensitivity of 10mV/g and 100mV/g. The meters incorporate three standalone, internal hybrid signal conditioners.

For More Information Write In No. 710

The Dual Axis FastScan **optical scanner** from Scientific Technologies, Hayward, CA, uses digital signal processing to measure two dimensions of a moving object's profile. Resolutions of 0.1" and scan lengths from 6.4" to 44.8" are standard. It features two transmitters, two receivers, and a built-in microprocessor that reports the size and location of the objects detected.

For More Information Write In No. 711

The Inter Changer **personal computer support device** from Robotic Electronics, Doylestown, PA, combines hardware and interchangeable firmware to provide nine PC support functions. The device automatically reboots crashed PCs, checks AC power reliability, provides over 50,000 baud rates, cleans and debugs RS-232 communication, provides PC on/off control, signals a crash, provides AC power delivery control, and frees PCs from data acquisition tasks.

For More Information Write In No. 712

MTS Systems Corp. Sensors Division, Cary, NC, offers the Temposonics SE magnetostrictive position **sensor**, which consists of a probe and sensing head with a stainless steel housing. The probe may be flexible or rigid and sized as small as 3/16" in diameter. Embedded applications include automotive and medical equipment.

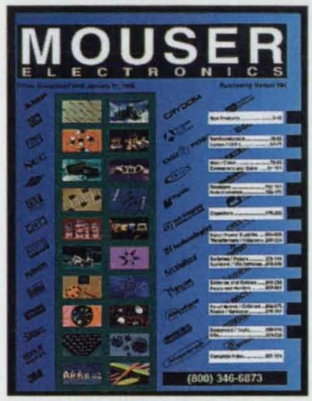
For More Information Write In No. 743

The AstroDAQ **paperless data acquisition system** for acquiring, conditioning, analyzing, and networking data has been introduced by Astro-Med, West Warwick, RI. The system includes a variety of signal conditioners with A/Ds and sampling circuitry, plus a hard drive. It features Windows-based AstroLINK software for control, real-time waveform monitoring, and data review.

For More Information Write In No. 744

For More Information Write In No. 430

New Literature



More than 59,000 products are featured in a catalog of **electronic components** from Mouser Electronics, Mansfield, TX. The 324-page catalog includes connectors, resistors, power supplies, switches, relays, tools, and capacitors.

For More Information Write In No. 730

Data Translation, Marlboro, MA, offers a 1996 handbook that features **data acquisition and imaging products**. Included are hardware and software that operate across all Windows platforms.

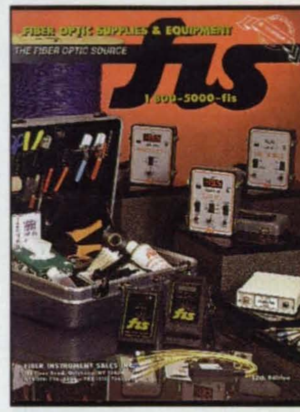
For More Information Write In No. 731

Bal Seal Engineering Co., Santa Ana, CA, offers a catalog of **EMI spring gaskets** for controlling electromagnetic and radio frequency interference. Applications include electronics, computers, and telecommunications equipment.

For More Information Write In No. 733

A 1560-page catalog of **electrical and electronic components** has been released by Newark Electronics, Chicago, IL. Featured are more than 120,000 products, including new factory automation, robotics, and multimedia components.

For More Information Write In No. 736

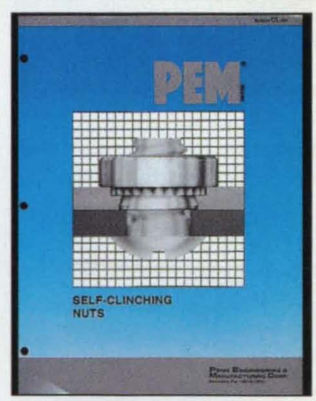


A 52-page catalog of **fiber-optic supplies and equipment** is offered by Fiber Instrument Sales, Oriskany, NY. Included are components, epoxies, light sources, microscopes, power meters, test equipment, tool kits, and adapters.

For More Information Write In No. 734

Krautkramer Branson, Lewistown, PA, offers a four-page brochure describing the CL304 ultrasonic **thickness gauge** that measures materials from 0.0050" thin. The gauge has keypad controls, off-block calibration, and interchangeable probes.

For More Information Write In No. 735



Penn Engineering & Manufacturing Corp., Danboro, PA, offers an eight-page brochure describing **self-clinching nuts** for load-bearing threads in thin sheets of aluminum, steel, and other ductile materials. Included are performance data and installation information.

For More Information Write in No. 737

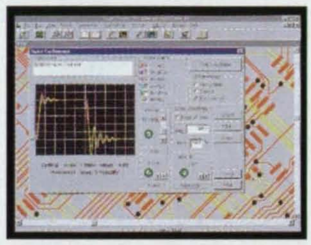
The VMC 186/40-TQ four-axis **motion control module** is described in a brochure from Delta Computer Systems, Vancouver, WA. The module can be used for coordinated position control and equipment or material movement.

For More Information Write In No. 732

New on Disk

National Instruments, Austin, TX, has released version 4.0 of LabVIEW® **graphical programming software**, which allows users to create a workspace to match their industry, experience level, and habits. Included are new editing and debugging tools, Windows connectivity, and more than 30 new analysis instruments. Prices start at $995 for PCs, $1995 for Macintosh, and $2995 for Sun SPARCstations and HP workstations.

For More Information Write In No. 715

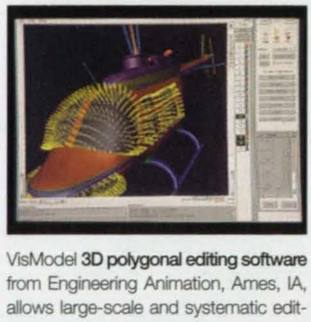


HyperLynx, Redmond, WA, has introduced BoardSim for Windows v1.45 **signal integrity software** for use by digital designers in predicting transmission-line problems on printed circuit board layouts. The program includes a board-report feature that allows design-rule checking on an entire PCB. Prices range from $1875 to $3495.

For More Information Write In No. 717

Pragmatic Instruments, San Diego, CA, announces **waveform creation software** for Windows that also provides waveform analysis, manipulation, and direct instrument download. WaveWorks Pro software enables users to work in multiple domains, including time, frequency, digital pattern, and data files.

For More Information Write In No. 716



VisModel **3D polygonal editing software** from Engineering Animation, Ames, IA, allows large-scale and systematic editing and creating of 3D polygonal models. Users can create organic models, extruded or revolved surfaces, primitive shapes, and groups of elements. The program operates on Silicon Graphics workstations and costs $1995.

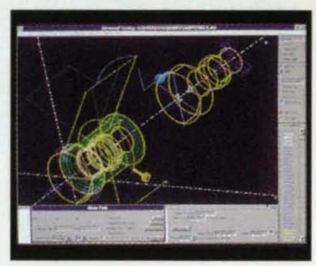
For More Information Write In No. 718

Matra Datavision, Andover, MA, has released a Windows 95 version of Prelude Design **solid modeling software**, which builds 3D solid parts and multi-component assemblies. The program combines Prelude/Drafting, a drafting/documentation program; Prelude/Solids, a solid modeler; Prelude/Photo for photorealistic rendering; and Prelude/Interfaces, which transfers models to and from outside CAD systems.

For More Information Write In No. 740

Systems Modeling Corp., Sewickley, PA, has released Arena 2.0 **simulation software** for Windows 95. Users can build and animate simulation models in a variety of applications. The program includes OLE support for linking and embedding clip art, spreadsheets, documents, and databases.

For More Information Write In No. 723



CAMAX Manufacturing Technologies, Minneapolis, MN, has released Version 4.1 of SmartCAM Advanced Turning™ **millturn and turning software** that supports two-, four-, and six-axis lathes, turning, and millturn equipment. It allows the milling and turning operations to be combined on a single machine to reduce rework, scrap, and production time. The Windows and UNIX versions cost $7495.

For More Information Write In No. 724

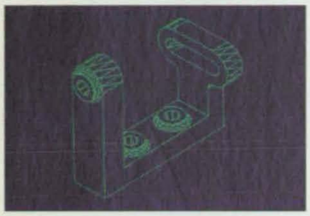
Spacetec IMC Corp., Lowell, MA, has released a Windows version of SpaceWare® 3D-I Always **3D design and interaction software** for AutoCAD. The program provides 3D design and manipulation capabilities to all AutoCAD applications. Users can rotate, zoom, and move models in one step in an active AutoCAD viewport. The software requires the AutoCAD R13 C4 patch upgrade, and costs $295.

For More Information Write In No. 725

New on Disk

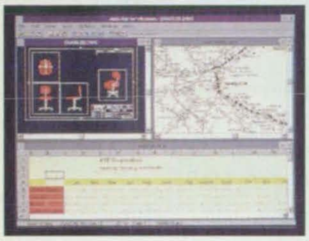
Breault Research Organization, Tucson, AZ, has introduced MACOS and S-MACOS **modeling and analysis software** for optical system simulation and analysis, as well as support for multi-disciplinary system design and engineering. The program can be used in telescope, camera, spectrograph, and interferometer imaging.

For More Information Write In No. 721



EMT Software, Bellingham, WA, has released Make*It*3D **drawing software**, which turns 2D, multi-view AutoCAD drawings into 3D solids. New or existing 2D orthographic drawings with at least two views can be converted. Up to six views, including top, side, and front, can be identified. The cost is $295.

For More Information Write In No. 719



Cimmetry Systems, Cambridge, MA, offers AutoVue Professional v14.0 **viewing and markup software** for Windows. Users can perform viewing and markup of documents on Windows, UNIX, and DOS platforms without the original application. File comparison, on-screen measurement, printing, plotting, and conversion are provided for CAD, bitmap graphics, databases, and spreadsheets.

For More Information Write In No. 720

AutoCAD Data Extension Release 2, a **productivity and data integration toolset** from Autodesk, San Rafael, CA, allows designers to organize and integrate multiple drawing files and related databases into a single, shared AutoCAD environment. The Windows program features new data management tools and costs $795; upgrades cost $119.

For More Information Write In No. 722

Superscape VRT 4.0 virtual reality **modeling and building software** from Superscape, Palo Alto, CA, enables 3D, computer-generated information to be created in real time on PCs. Featured are a Virtual Reality Modeling Language (VRML) output for authoring Web sites and an upgraded virtual clip art library. The Windows program costs $3995.

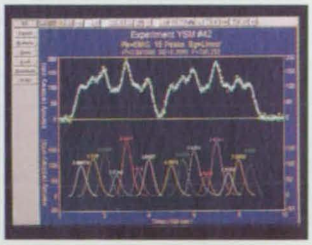
For More Information Write In No. 726

Deneb Robotics, Auburn Hills, MI, has introduced Envision® real-time **3D simulation software** for virtual prototyping of structures, mechanical systems, and humans, as well as simulation-based design, concurrent/simultaneous engineering, and integrated product and process development. Supported platforms include Hewlett-Packard, Intergraph, Sun, and Silicon Graphics.

For More Information Write In No. 727

TAL Technologies, Philadelphia, PA, offers SoftwareWedge™ **serial I/O control software**, which enables automatic serial data input from any instrument, sensor, or other serial device into a Windows or DOS application. The program allows real-time data charting, analysis, and graphing on the PC, and costs $395.

For More Information Write In No. 728



Jandel Scientific, San Rafael, CA, has introduced version 4.0 of PeakFit **peak analysis software** for Windows, which automatically finds and separates overlapping peaks in spectroscopy, chromatography, and electrophoresis data. PeakFit finds peaks, picks initial parameters, and outputs optimal, individual peak positions, areas, widths, and heights. The cost is $595.

For More Information Write In No. 742

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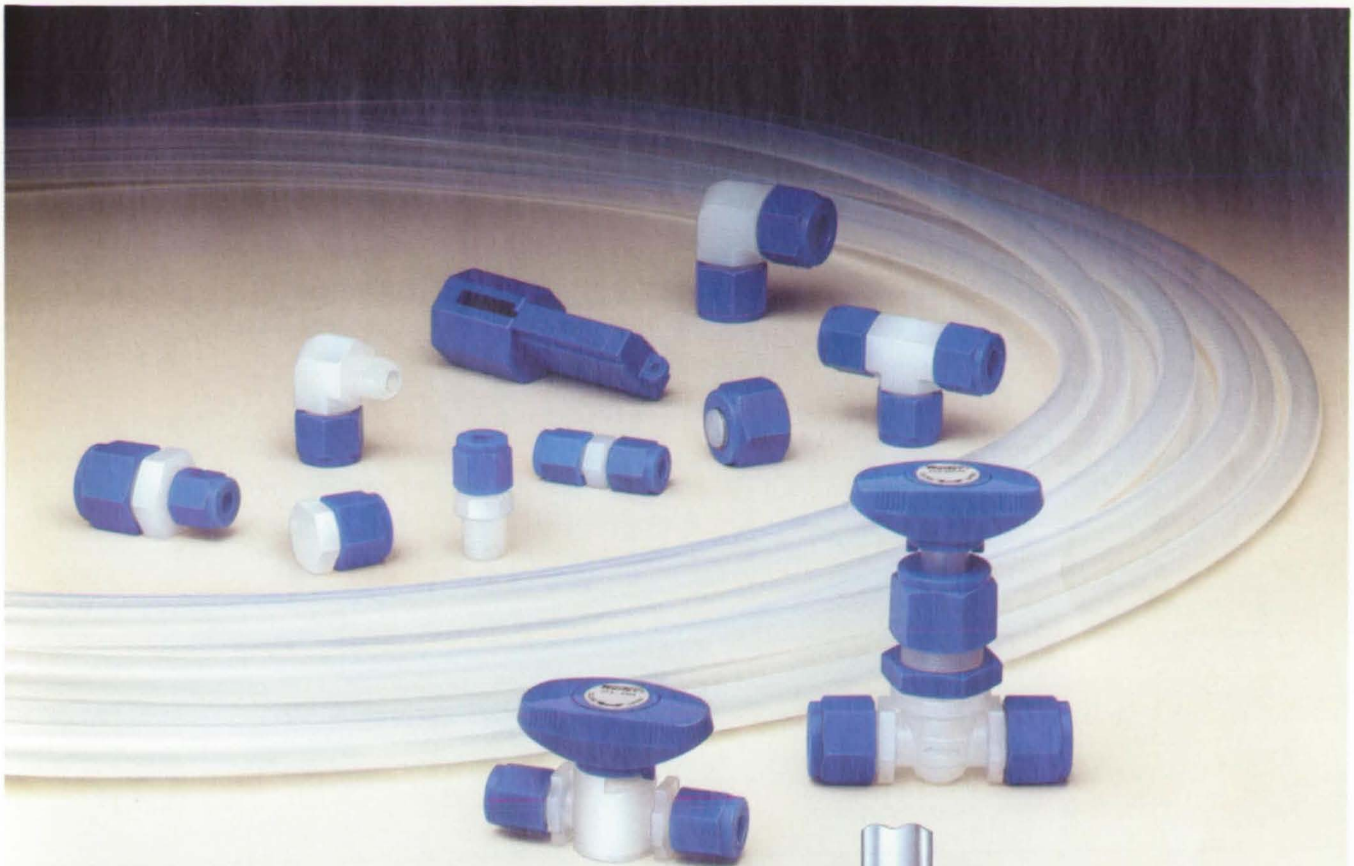

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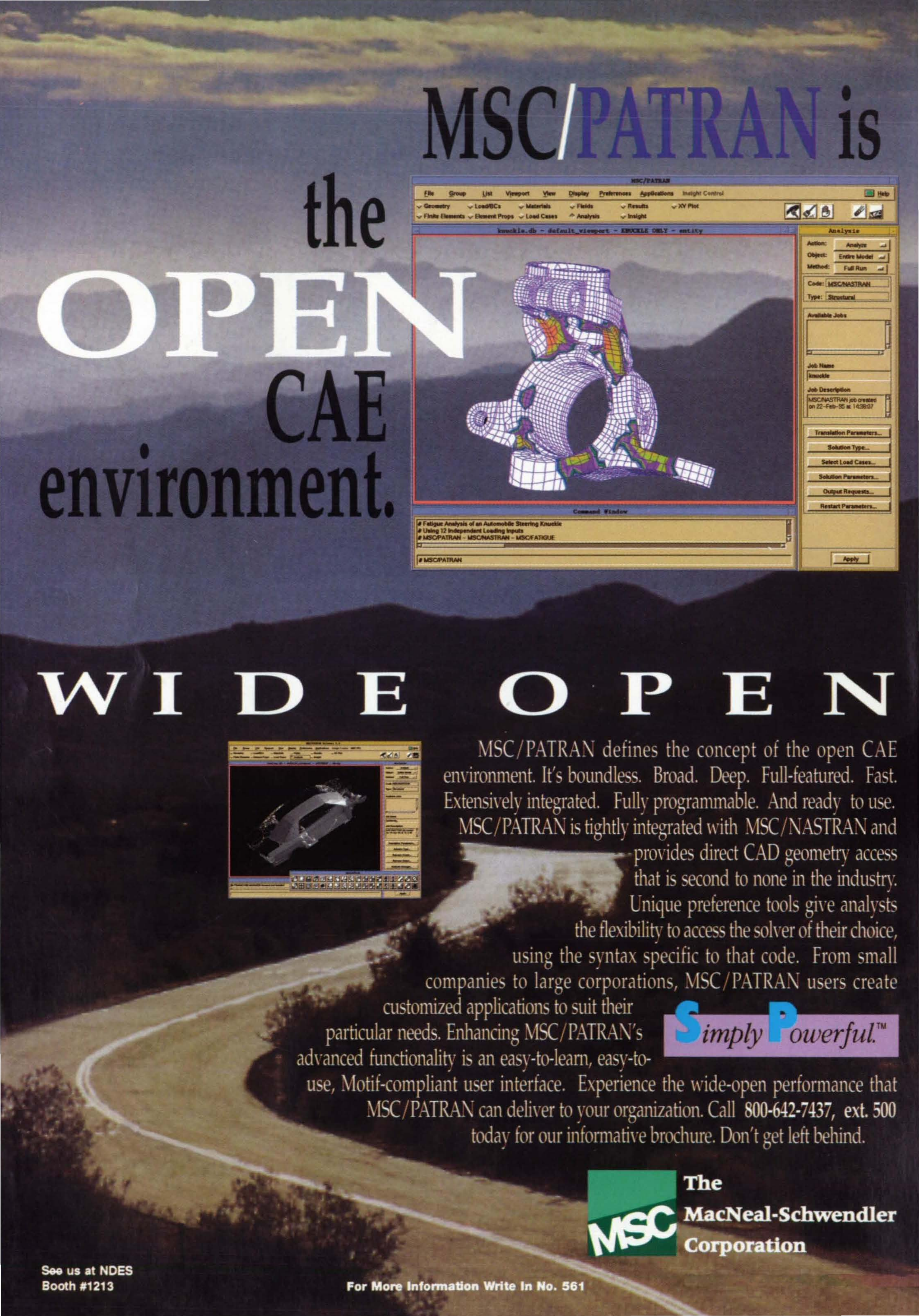

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