TECH BRIEFS

ENGINEERING SOLUTIONS FOR DESIGN & MANUFACTURING

NASA's Software of the Year

Portable Device Tests Pressure Sensors in the Field

Photonics Tech Briefs

Motion Control Tech Briefs

Meet Robonaut
(page 24)


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CO_2 Laser Applications of the Month

SYNRAD®
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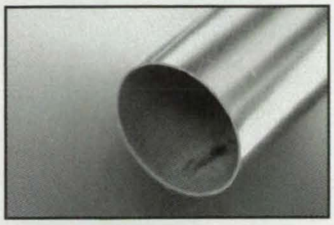
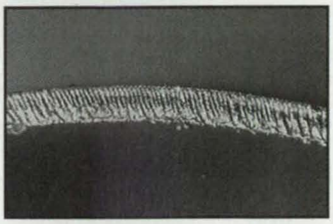
Cutting Stainless Steel Tubing with Sealed CO_2 Lasers



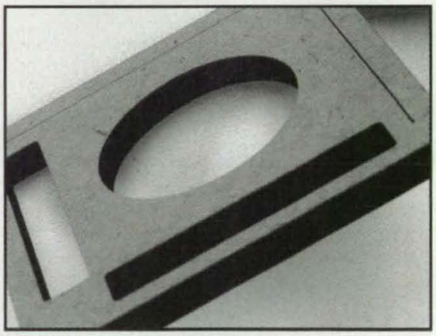


Stainless steel tubing is normally difficult to cut without deformation, however, the 0.018" thick tubing shown in the photos on the left was cut using a Synrad 240W sealed CO_2 laser.

Unlike traditional mechanical cutting methods, non-contact laser cutting prevents distortion or deformation of the material with the added benefit of no mechanical parts to wear out. The photo on the bottom left shows a close-up view of the cut edge quality.

The 5/8"-diameter tubing (with a .018" wall) was cut using 240W with 40psi Oxygen assist gas while being rotated at a speed of 241rpm. Cut speed was 7.8 inches per second, resulting in a cycle time of .25 seconds.

Laser Cutting Particle Board



Sealed CO_2 lasers are ideal for cutting, engraving, and marking wood and paper products. The 0.237"-thick particle board, in the photo to the left, was cut at a speed of 75 inches per minute using a Synrad 100W laser with 40psi N_2 assist gas. The cuts were made using a 0.004" spot size with a 0.07" depth of focus. The wood provided an even 0.008" kerf on both the top and bottom cut sides.

Additionally, the cuts were made with a linearly polarized beam. By cutting slightly below the maximum cutting rate, no noticeable differences in the kerf can be seen in the X and Y cut direction.

This material can also be cut at a speed of 150ipm using a 240W laser. The random polarization of Synrad's Evolution-240 model ensures consistent cut widths in all directions, even at high speeds.

Laser Marking PVC-Coated Bottles

PVC marks very well with CO_2 lasers. The material generally provides a brown contrasting mark, easily readable with the human eye. 1D and 2D bar codes also generate the same type of contrast on PVC, and can be read by bar code vision systems in production environments.

The PVC-coated bottle in the photo to the right was marked using a 10W laser and FH marking head, with a 200mm lens. The text was marked at a speed of 25 inches per second in a cycle time of 0.27 seconds.

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*All applications on this page were processed at **Synrad's Applications Laboratory**. Synrad, the world's leading manufacturer of sealed CO_2 lasers, offers free process evaluations to companies with qualified applications. Call 1-800-SYNRAD1 for more information.*

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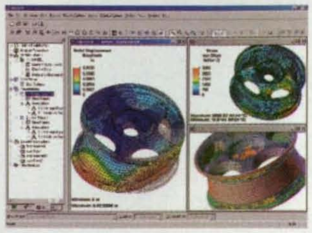

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FEA Software Chosen to Verify Wheel Design for Goodyear "Run-Flat" Tires

The Effect of Low Inflation Pressure on Tire Wheel

The Goodyear Tire & Rubber Company developed a run-flat tire called an extended mobility technology (EMT) tire that can be safely driven without air for at least 80 km (50 miles). Before these new tires could be used, Goodyear needed to verify that existing wheel designs would support this new technology. Goodyear EMT tires are now original equipment on the Chevrolet Corvette, Daimler Chrysler Prowler and the Mini from BMW Group.

The Challenge

Goodyear needed to make certain that the wheel design could handle the low pressure caused by an under-inflated tire. The final design needed to maintain the safety benefit of controlled handling and braking.

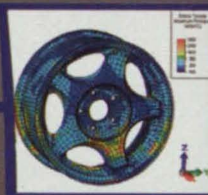
The Solution

While a Ph.D. candidate at the University of Akron, John Stearns performed a parametric study of inflation pressure and stresses in a standard wheel. A typical aluminum wheel was modeled in Pro/ENGINEER and the geometry was captured with ALGOR. Constraints were applied to represent the wheel's attachment to a vehicle and a combination of pressure loads were applied to simulate vehicle weight and inflation pressures of 0, 17 and 35 psi. Higher stresses were found at lower inflation pressures, but the magnitude of the stresses was low enough that a standard wheel could be recommended for EMT tires. Over one million run-flat EMT tires are now being used on the road.

"I chose ALGOR for this project because InCAD technology offers better control over CAD geometry and flexible meshing capabilities."
-John Stearns, Ph.D.

The wheel geometry was modeled in Pro/ENGINEER and captured using InCAD technology.

A non-uniform pressure load of 296 psi at 0 degrees to 0 psi at 40 degrees was applied to simulate the vehicle weight.



Maximum principal stress results revealed that the wheel experienced greater stress at lower inflation pressures.

Laboratory test results correlated well with ALGOR's FEA results.

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Contents *continued*

PRODUCT OF THE MONTH

The LP3500 Fox single-board computer from Z-World, Davis, CA, provides embedded control where power is limited, such as in portable and remote monitoring systems.

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ON THE COVER

The Robot Systems Technology Branch of NASA's Johnson Space Center in Houston, TX, has developed Robonaut, a humanoid anthropomorphic robot that is designed to function as an astronaut equivalent for future NASA missions. He is equipped with five-fingered, tool-handling end effectors, and a telepresence and control system that allows its human operator to "see" what it sees via virtual reality. To learn more about Robonaut, as well as other robotic innovations, see the feature beginning on page 24.

(Photo courtesy of NASA)

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NASA Commercial Technology Team

NASA's R&D efforts produce a robust supply of promising technologies with applications in many industries. A key mechanism in identifying commercial applications for this technology is NASA's national network of commercial technology organizations. The network includes ten NASA field centers, six Regional Technology Transfer Centers (RTTCs), the National Technology Transfer Center (NTTC), business support organizations, and a full tie-in with the Federal Laboratory Consortium (FLC) for Technology Transfer. Call (609) 667-7737 for the FLC coordinator in your area.

NASA's Technology Sources

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

Ames Research Center
Selected technological strengths: Information Technology; Biotechnology; Nanotechnology; Aerospace Operations Systems; Rotorcraft; Thermal Protection Systems.
Carolina Blake
(650) 604-1754
cblake@mail.arc.nasa.gov

Dryden Flight Research Center
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Jenny Baer-Riedhart
(661) 276-3689
jenny.baer-riedhart@dfrc.nasa.gov

Goddard Space Flight Center
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Nona Cheeks
(301) 286-5810
Nona.K.Cheeks.1@gsfc.nasa.gov

Jet Propulsion Laboratory
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Merle McKenzie
(818) 354-2577
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Johnson Space Center
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commercialization@jsc.nasa.gov

Kennedy Space Center
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Jim Aliberti
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Jim.Aliberti-1@ksc.nasa.gov

Langley Research Center
Selected technological strengths: Aerodynamics; Flight Systems; Materials; Structures; Sensors; Measurements; Information Sciences.
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s.a.morello@larc.nasa.gov

John H. Glenn Research Center at Lewis Field
Selected technological strengths: Aeropropulsion; Communications; Energy Technology; High Temperature Materials Research.
Larry Viterna
(216) 433-3484
cto@grc.nasa.gov

Marshall Space Flight Center
Selected technological strengths: Materials; Manufacturing; Nondestructive Evaluation; Biotechnology; Space Propulsion; Controls and Dynamics; Structures; Microgravity Processing.
Vernotto McMillan
(256) 544-2615
vernotto.mcmillan@msfc.nasa.gov

Stennis Space Center
Selected technological strengths: Propulsion Systems; Test/Monitoring; Remote Sensing; Nonintrusive Instrumentation.
Kirk Sharp
(228) 688-1929
kirk.sharp@ssc.nasa.gov

NASA-Sponsored Commercial Technology Organizations

These organizations were established to provide rapid access to NASA and other federal R&D and foster collaboration between public and private sector organizations. They also can direct you to the appropriate point of contact within the Federal Laboratory Consortium. To reach the Regional Technology Transfer Center nearest you, call (800) 472-6785.

Joseph Allen
National Technology Transfer Center
(800) 678-6882

Ken Dozier
Far-West Technology Transfer Center
University of Southern California
(213) 743-2353

James P. Dunn
Center for Technology Commercialization
Westborough, MA
(508) 870-0042

B. David Bridges
Southeast Technology Transfer Center
Georgia Institute of Technology
(404) 894-6786

Gary Sera
Mid-Continent Technology Transfer Center
Texas A&M University
(409) 845-8762

Charles Blankenship
Technology Commercialization Center
Newport News, VA
(757) 269-0025

Pierrette Woodford
Great Lakes Industrial Technology Transfer Center
Battelle Memorial Institute
(216) 898-6400

NASA ON-LINE: Go to NASA's Commercial Technology Network (CTN) on the World Wide Web at **http://nctn.hq.nasa.gov** to search NASA technology resources, find commercialization opportunities, and learn about NASA's national network of programs, organizations, and services dedicated to technology transfer and commercialization.

NASA Program Offices

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

Carl Ray
Small Business Innovation Research Program (SBIR) & Small Business Technology Transfer Program (STTR)
(202) 358-4652
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rcrouch@hq.nasa.gov

Granville Paules
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(202) 358-0706
gpaules@mtpe.hq.nasa.gov

NASA's Business Facilitators

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

Wayne P. Zeman
Lewis Incubator for Technology
Cleveland, OH
(440) 260-3300

B. Greg Hinkebein
Mississippi Enterprise for Technology
Stennis Space Center, MS
(800) 746-4699

Julie Holland
NASA Commercialization Center
Pomona, CA
(909) 869-4477

Bridgette Smalley
UH-NASA Technology Commercialization Incubator
Houston, TX
(713) 743-9155

John Fini
Goddard Space Flight Center Incubator
Baltimore, MD
(410) 327-9150 x1034

Thomas G. Rainey
NASA KSC Business Incubation Center
Titusville, FL
(407) 383-5200

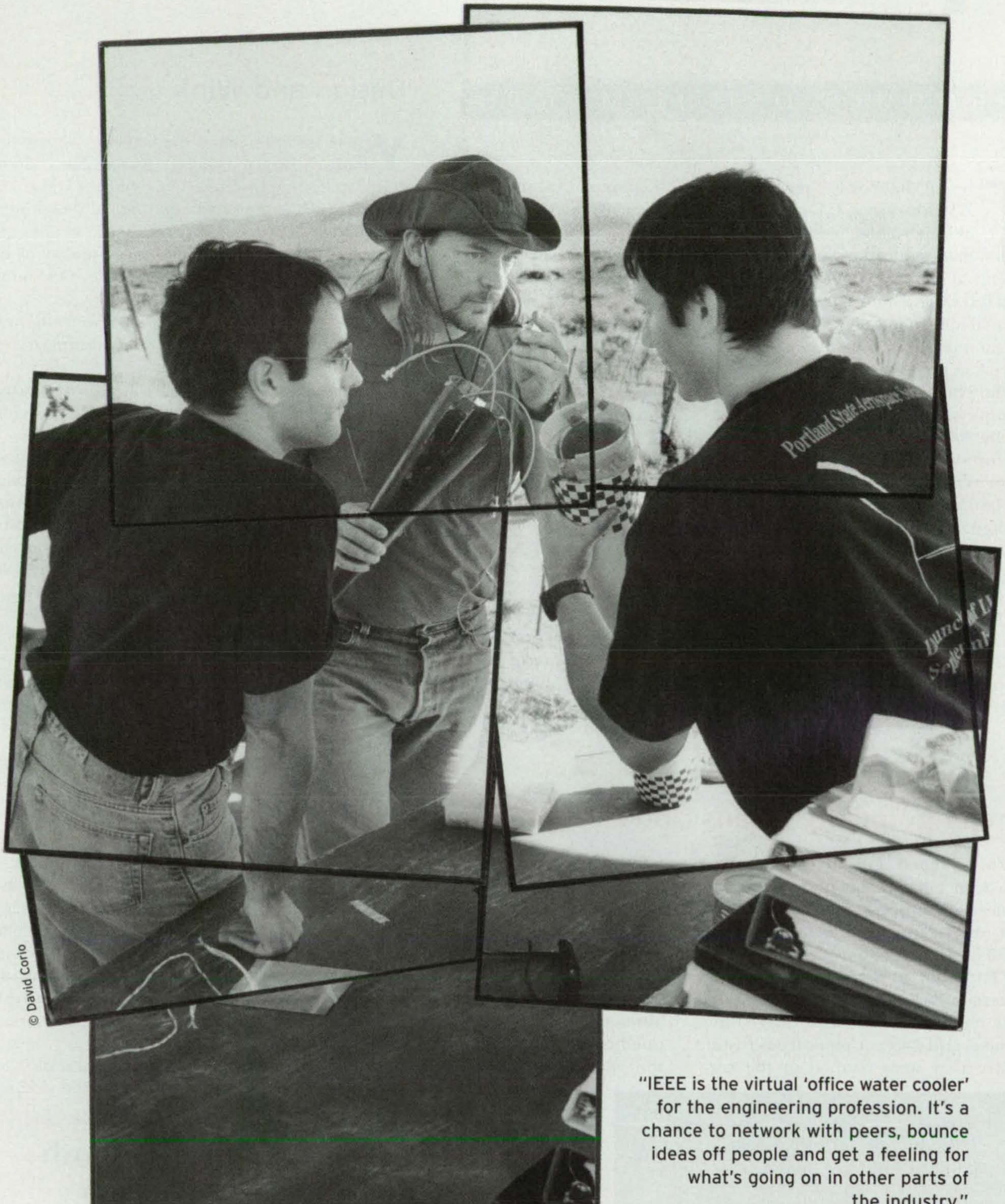
Joanne W. Randolph
BizTech
Huntsville, AL
(256) 704-6000

Joe Becker
Ames Technology Commercialization Center
San Jose, CA
(408) 557-6700

Marty Kaszubowski
Hampton Roads Technology Incubator (Langley Research Center)
Hampton, VA
(757) 865-2140

Paul Myrda
NASA Illinois Commercialization Center
West Chicago, IL
(630) 845-6510

If you are interested in information, applications, and services relating to satellite and aerial data for Earth resources, contact: Dr. Stan Morain, **Earth Analysis Center,** (505) 277-3622.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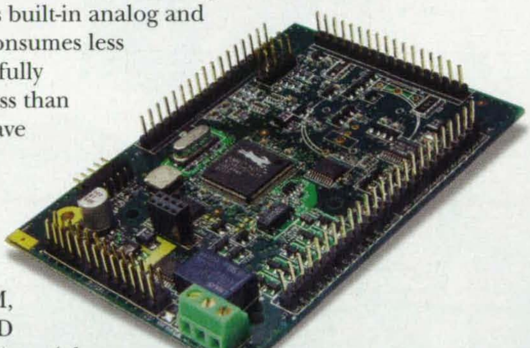
UpFront

PRODUCT OF THE MONTH

The LP3500 Fox low-power single-board computer from Z·World, Davis, CA, operates where power is limited, such as in portable, handheld, battery-powered, and remote data acquisition and monitoring systems. It features built-in analog and digital I/O, and consumes less than 20 mA when fully operational and less than 100 μA in power-save mode. The board incorporates the Rabbit 3000 microprocessor, up to 512K each of Flash and SRAM, 26 digital I/O, A/D converter inputs, six serial ports, one relay, and two dedicated function ports. The board runs at up to 7.4 MHz at a variety of power levels under software control, and can be awakened from the power-save mode by an internal timer, RS-232 signal, or via polling of an external input. An optional keypad/display module is available as a user interface. A library of drivers and demo programs is also provided.



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- Safety — mechanical or electromechanical designs to improve personal safety during travel, work, recreation, or at home;
- Transportation — mechanical or electromechanical designs that improve the functionality, performance, or cost basis of transportation products.

The Grand Prize winner will receive a hybrid automobile or $20,000 in cash. One First Prize winner will receive a Segway Transporter or a trip for four to Florida to tour NASA's Kennedy Space Center and attend a Space Shuttle launch. Dozens of other prizes will be awarded, and all qualified entrants will receive a POP® PowerLink 30 repair kit/hand rivet tool from Emhart, valued at $50.

So, get those creative juices flowing — entries must be received by November 15, 2002. Winning entries will be featured in *NASA Tech Briefs*. Visit **www.emhartcontest.com** for the contest rules and entry form.

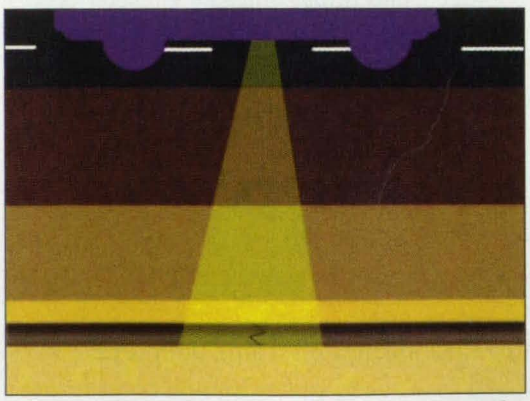
Power Company Cleans Up With NASA Sensors

Consolidated Edison of New York (Con Edison) has turned to NASA to develop sensor technology to detect and analyze polychlorinated biphenyls (PCBs) and perfluorocarbon tracers (PFTs), both of which are hazardous materials. PCBs are toxic chemicals that were used to insulate high-voltage transformers and prevent pipes from rusting before they were banned in the early 1970s. PFTs are injected by Con Edison into the insulating oil used in high-voltage transmission lines routed under the streets of New York City to pinpoint oil leaks from underground power lines.

Traditional methods of lab analysis can take up to eight hours; Con Edison wants to reduce that time to less than one hour. The power company will use the Reversal Electron Attachment Detection system, developed at NASA's Jet Propulsion Laboratory in Pasadena, CA, to sample and analyze PCB concentrations on the spot in about 30 minutes. This would let Con Edison determine what worker protection is necessary, and if any personnel or equipment exposed to PCBs must be decontaminated.

The first phase of the project was completed in August, and consisted of JPL researchers testing pure PCB samples from New York manholes. The system not only detected the PCBs, but also quantified their concentrations. In the second phase, JPL and Con Edison will make the sensors portable, and compatible for use by Con Edison. The system also can be used for detecting other chemical vapors such as explosives and nerve agents at airports, harbors, and public buildings.

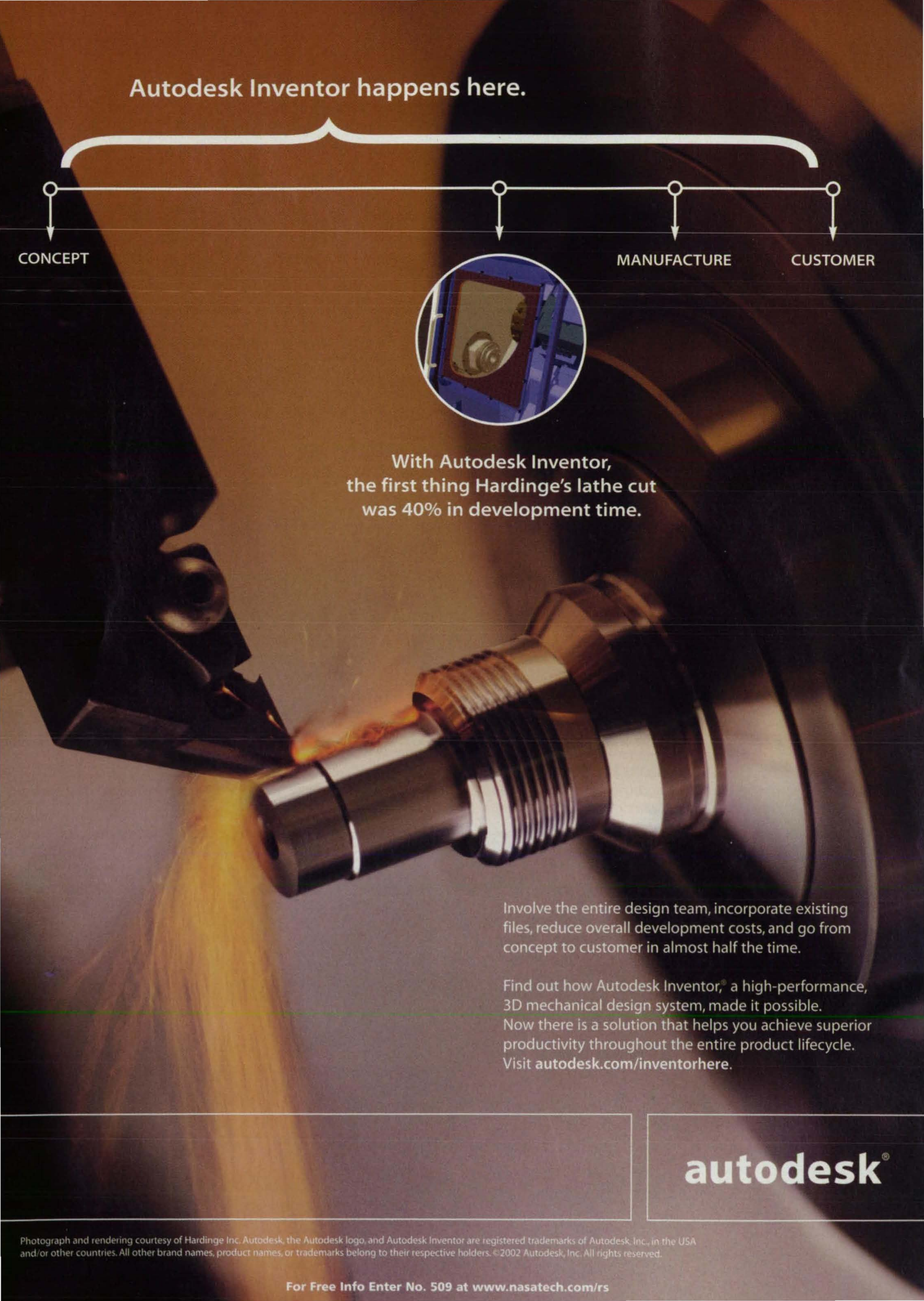
For more information, visit www.jpl.nasa.gov/releases/2002/release_2002_152.html.



Artist's concept of the subsystem detection system under a city street.

Next Month in NTB

The November issue of *NASA Tech Briefs* will feature a report on the Analysis and Simulation Software market — the products, companies, and industry leaders shaping the way engineers view and analyze their designs.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Reader Forum

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I recently read the tech brief "Aircraft Anti-Icing Systems Utilizing Induced Hydrophobicity" in the May issue of *NASA Tech Briefs* (p. 69), and came up with a thought. If one could section a bead of frozen water that is adhered to a highly polished surface such as glass or aluminum aircraft skin, and examine it under an electron microscope as it melts, could this provide insight into the forces that cause frozen water to tightly adhere to a surface that simply tends to shed liquid water?

John S. Roy
royjs@inel.gov

*(**Editor's Note:** John, you may want to share your question with NASA's Glenn Research Center in Cleveland, OH, which contributed the aircraft anti-icing brief. You can contact Glenn's Commercial Technology Office at 216-433-3484.)*

Technologies Wanted

Periodically in Reader Forum, we feature abstracts of Demand-Pull Technology Transfer projects. These projects identify technology needs within an industry segment — such as Augmentative Communication — and find solutions to meet those needs. The Rehabilitation Engineering Research Center on Technology Transfer, in partnership with the Rehabilitation Engineering Research Center on Communication Enhancement and the Federal Laboratory Consortium, has developed the Project on Communication Enhancement to identify technologies like those listed below to help persons with communication disabilities who use Augmentative Communication devices. For more details on the project, or to submit technology proposals, visit **http://cosmos.buffalo.edu/aac**.

Wireless Integration

Augmentative and Alternative Communication (AAC) systems should provide wireless access to and control of personal computers and the Internet. This capability would provide important educational, employment, recreational, and social opportunities.

AAC systems also should allow users to wirelessly control entertainment technology such as TVs and stereos, their environment (temperature and humidity), and access (doors and window shades). Users would benefit from increased independence and comfort.

Finally, AAC systems also should have built-in cell phone capabilities. Text-to-speech synthesis should provide good sound quality. Headphones — ideally with a wireless link to the AAC system — would enhance communication privacy.

NEW

10 NEW PRODUCTS
33 UPDATED PRODUCTS

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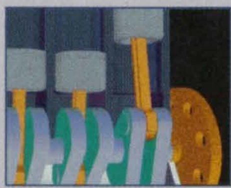

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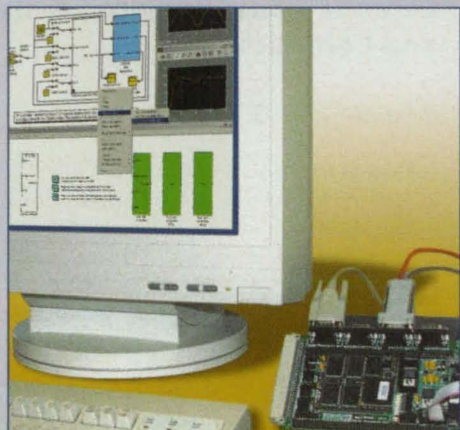

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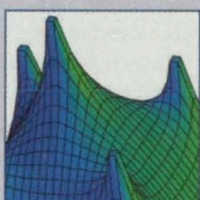

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Technologies of the Month

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Compression/Freezing Improves Microwaveable Frozen Baked Goods

Kao

The life of baked goods is usually extended through freezing; however, thawing and reheating gives baked goods a stale flavor and less airy texture. A compression and freezing process from Kao Corporation improves the taste and texture of frozen baked goods by using the steam generated by internal cooking to restore original bulk and moist freshness.

After the product is cooked or semi-cooked, the edges are rapidly frozen. The product is then compressed and vacuum packed, and typically sealed in a flexible or rigid plastic package. In addition to microwaves, other means of internal vibration heating such as magnetic vibration, high frequency heating, and far infrared heating can be used to reheat the product.

Get the complete report on this technology at:
www.nasatech.com/techsearch/tow/kao-compression.html
Email: nasatech@yet2.com
Phone: 617-557-3837

Ceramic Fibers Replace Costly Superalloys and Ceramics

Bayer AG

Next-generation combustion systems in power generation, aeronautics, and automotive applications are putting heavier demands on materials and components as the need for greater fuel efficiency and reduced emissions increases. Conventional nickel, cobalt, and superalloys typically sustain a threshold for high-temperature performance at around 1200°C, but only at combustion temperatures of 1500°C can fuel savings of 20% or better be achieved.

SIBORAMIC is a low-density ceramic fiber that does not require electron radiation curing, provides low thermal and electrical conductivity, and eliminates the interface coating between the fibers and matrix. The material's double layer provides efficient oxygen resistance, enabling the fibers to regenerate themselves if they become damaged in an oxygen atmosphere. It is also corrosion-resistant to liquid metals like copper and silicon.

Get the complete report on this technology at:
www.nasatech.com/techsearch/tow/BayerAG.html
Email: nasatech@yet2.com
Phone: 617-557-3837

Water-Shrinkable Film

Kimberly-Clark

Films have varied applications, including gaskets or seals, medical and healthcare products, and electronics or mechanical switching systems. A new technology provides controllable shrinkage of films without the use of heat, resulting in efficient production, high capacity, and low-cost operation.

The films are prepared by mixing water-dispersible and elastomeric polymers, then forming a film by traditional extrusion or casting. The direction of shrinkage may be predetermined to be in one or two dimensions. The extent of film shrinkage and film integrity may be controlled by the amount of water to which the film is exposed. Residual contraction may be pre-set during manufacture so that the film will shrink to a specific extent.

Get the complete report on this technology at:
www.nasatech.com/techsearch/tow/Kimberly-Clark.html
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Three Technologies Work Together to Reduce Combustion Engine Noise and Vibration

Hitachi

Combustion engine noise and vibration are often caused by torque fluctuation. Hitachi has developed three technologies that harness a vehicle's generator to create counter torque against torque fluctuation, reducing combustion noise and vibration. Sensors in the vehicle's main power transmission system monitor crankshaft rotational speed variations with each combustion cycle and then use the previous cycle's information to provide the right amount of counter torque to the crankshaft.

The second technology is an acceleration rate-of-change sensor and control system designed to eliminate the characteristic "jerk" that follows vehicle acceleration, particularly from a stand-still. Utilizing a sensor comprised of a pendulum and electromagnetic actuator, the process measures the rate of acceleration by using relative movement to generate an electric current. The third technology is a non-fouling gasoline fuel injector that reduces deposit formation and buildup.

Get the complete report on this technology at:
www.nasatech.com/techsearch/tow/hitachi.html
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*(**Editor's note:** This technology was inadvertently accompanied by an incorrect photo when it originally appeared as a Technology of the Month in the July issue.)*


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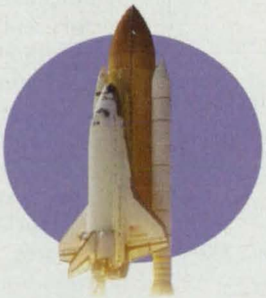

First Prize
Segway Transporter or
Travel & Tour of NASA
for party of four during a launch day

Second Prize
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combination kit

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Dr. Meyya Meyyappan, Director, Center for Nanotechnology, Ames Research Center

Dr. Meyya Meyyappan is the Director and Senior Scientist at the Center for Nanotechnology at NASA's Ames Research Center in Moffett Field, CA. His team is presently researching and developing carbon nanotubes.

***NASA Tech Briefs:* How long has Ames' Center for Nanotechnology been operating?**

Dr. Meyya Meyyappan: We started as a small group in 1996, and since then, the center has grown to have 50 full-time scientists. Our nano center is the largest in-house nanotechnology effort within the government, and it is also one of the largest in the world.

NTB: What nanotechnology projects are you currently working on?

Dr. Meyyappan: First, we are using nanotechnology in the area of electronics and computing, or nanoelectronics and computing. We are also developing nanotechnology-based sensors and detectors, and we are utilizing nanotechnology in gene sequencing. Our project focus is primarily material-driven and we are looking at a variety of nanoscale materials. The first and the major focus is on carbon nanotubes.

The next class of materials that we are working with is inorganic nanowires, like zinc oxide and gallium nitride, for the manufacture of sensors and detectors. The third class of materials is protein-based nanotubes, which are biological. We synthesize them in large quantities and purify them. We are using them for applications like templates for lithography.

NTB: What are carbon nanotubes?

Dr. Meyyappan: Carbon nanotubes look like nanoscale cylinders, about 1 nm or so in diameter and a few microns long. Imagine rolling up a sheet of graphite into a tube; that is what we are talking about. There are a few procedures in the lab we are using to grow these structures. One method is called Chemical Vapor Deposition (CVD), which uses some hydrocarbon gases such as methane with a catalyst material like iron. In the second method, called plasma enhanced CVD, we use low-temperature plasmas to grow nanotubes.

NTB: Why are nanotubes so versatile and functional to many industries?

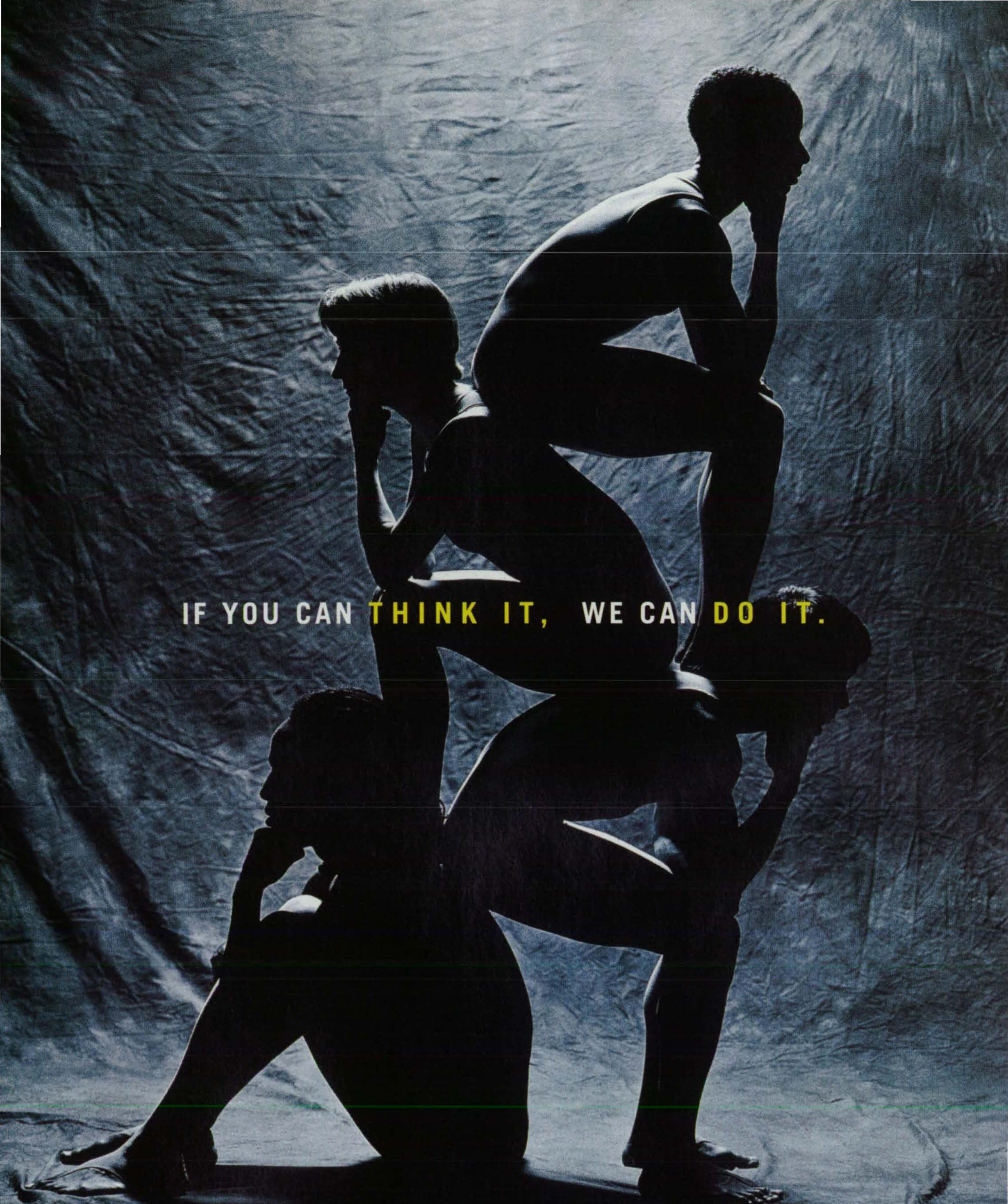
Dr. Meyyappan: Carbon nanotubes have extraordinary mechanical properties. For example, compared to steel, nanotubes have a strength-to-weight ratio of 500. At the same time, nanotubes can be used to make a computer chip, because in addition to these wonderful mechanical properties, they also have very exciting electrical properties.

Historically, the materials we used for computer chip applications were impractical for construction of an aircraft. The same with aluminum or stainless steel — these metals could be used to manufacture an automobile, but they could never be used to make a computer chip. Carbon nanotubes can be used for both fine applications like computer chips and sensors, and for massive applications in the aerospace and automotive industries.

NTB: Is NASA currently using carbon nanotubes?

Dr. Meyyappan: There are some applications that are already beginning to emerge. We have used carbon nanotubes as a tip in an atomic force microscope. We are also trying to create biosensors using carbon nanotubes because biosensors are important to NASA in terms of astrobiology applications. We are also involved in a program with the National Cancer Institute to develop carbon nanotube-based biosensors for cancer diagnostics. We are pretty much in the research stage, but I believe that in a few years' time, we will slowly start migrating up the ladder towards deploying the actual applications.

*A full transcript of this interview appears on-line at **www.nasatech.com/whoswho**. Dr. Meyyappan can be reached at meyya@orbit.arc.nasa.gov.*


IF YOU CAN THINK IT, WE CAN DO IT.

Application Briefs

NASA Replaces Astronaut Training Aircraft Data Computers

Digital Air Data Computers (DADCs)
Innovative Solutions and Support (IS&S)
Exton, PA
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NASA's T-38 Talon is a twin-engine, high-altitude supersonic jet aircraft used to flight-train astronauts. It has been used in a variety of missions because of its design, economy of operation, ease of maintenance, high performance, and exceptional safety record. Built by Northrup Grumman, the fleet of T-38s contains an air data computing system that is being upgraded with a Digital Air Data Computer (DADC) that uses sensors and electronics that makes them compliant with Reduced Vertical Separation Minima (RVSM) standards.

Innovative Solutions and Support (IS&S), which previously replaced the altimeter, airspeed indicator, and alerters on the T-38 fleet, was chosen to retrofit the aircraft with the state-of-the-art systems. IS&S manufactures flat-panel cockpit and cabin displays, fuel measurement instruments, and RVSM systems for various aircraft types.

The DADC outputs airspeed, altitude, flight control, and temperature data to support the operations of altimeters, Mach airspeed indicators, and autopilot controllers. It uses pitot-static pressure, total temperature, angle of attack, baro correction, and target altitude input data to compute the air data provided by its output signals. The DADC performs data checking and fault detection/status indication functions to ensure that only valid data is provided to the equipment it supports.

An IS&S integrated cockpit display.

For Free Info Visit www.nasatech.com/iss

MEMS Sensors to Help NASA Monitor Weather

Microelectromechanical (MEMS) sensor probes
ENSCO, Inc.
Cocoa Beach, FL
703-321-4405
www.ensco.com

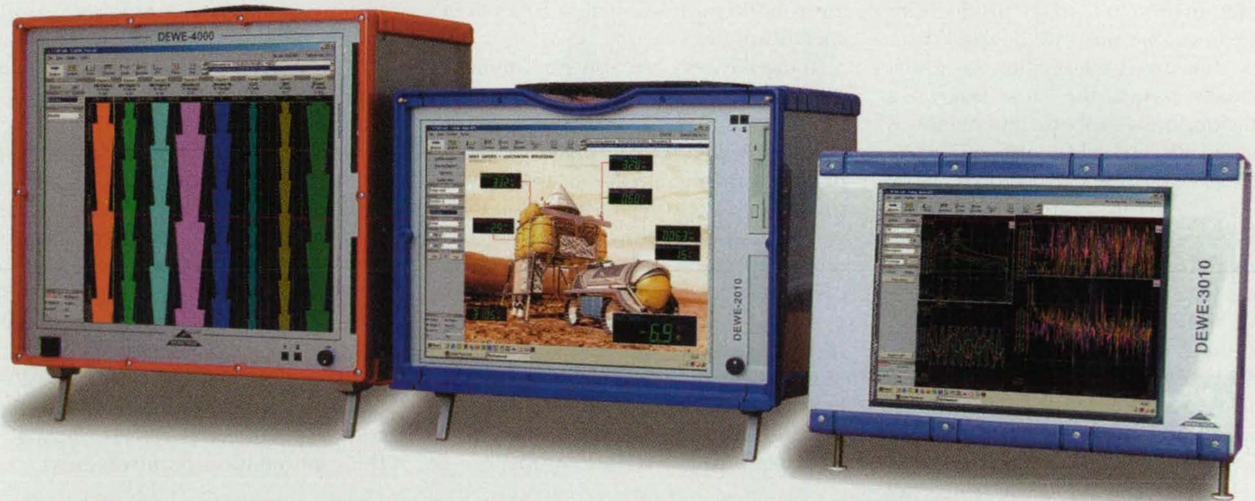
ENSCO is one of 16 companies designing advanced systems and architectures for the NASA Institute for Advanced Concepts' (NIAC) new observing system, the Global Environmental MEMS Sensors (GEMS) system. The company is designing *in-situ*, micron-scale airborne probes that will monitor weather and environmental conditions. The GEMS concept was inspired by technological advancements in MEMS and nanotechnology.

While existing sensor systems typically measure a few millimeters across, ENSCO's probes would be roughly 100 microns in diameter — the width of a strand of hair. This minute size would allow the probes to be suspended in the atmosphere and carried by wind currents for long periods of time. Once suspended in the atmosphere, the GEMS probes would measure meteorological parameters including temperature, pressure, moisture, and wind speed, and relay that data back to Earth via a wireless communication protocol.

Resulting improvements in forecast accuracy would translate directly into cost benefits for the weather-sensitive space launch and aviation industries, and mitigate the risk factors associated with life-threatening weather phenomena such as hurricanes, floods, tornadoes, and severe storms.

"With GEMS, we're actually working on an application for MEMS sensors," said John Manobianco, GEMS principal investigator and program manager for ENSCO. "GEMS could be used locally, regionally, and globally to take better environmental measurements. Once they land on the ground — on Earth or even possibly other planets — they might be able to take surface-level measurements as well."

For Free Info Visit www.nasatech.com/ensco


DEWE-4000
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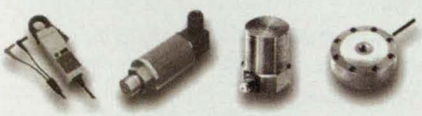



DAQP-DMM
0 ... ±1000 V
2 kVpp max
1 kVrms max
DEWETRON

Robotics Plays a Key Role in Manufacturing Productivity

For businesses to grow, manufacturers know that they must remain competitive in respect to product quality and cost. Many companies have turned to robotic automation to increase productivity, reduce downtime, and save or avoid costs. Rather than fixed automation — which perpetually repeats the same task on a production line — robotic automation is characterized as flexible automation, allowing manufacturers to produce more than one item on a single production line. Because of this flexibility, the medical, manufacturing, and automotive industries have been able to optimize production while reducing costs.

Because robotics and automation offer such diverse uses in varied applications, engineers are striving towards developing innovations that use more artificial intelligence and require less human supervision. However, the biggest challenge lies in actually creating these technologies.

This past year, the robotics industry has been hard hit by the economic downturn, adversely affecting the research and development process. Fortunately, the industry is showing signs of recovery. According to Robotic Industries Association (www.roboticsonline.com) of Ann Arbor, MI, by the end of the first quarter of this year, North American customers ordered 2,350 robots — an increase of 1% over the comparable period in 2001. RIA estimates that 120,000 robots are now at work in United States factories, trailing only Japan in use.

Analysts see this upturn as a sign of things to come. Analysts also believe that in almost every industry, the use of robotics offers more cost savings overall than outsourcing to overseas manufacturers. "In most assembly applications, robots increase the quality and yields compared to manual processes," said John Dulchinos, vice president of sales for Adept Technology (www.adept.com), a Livermore, CA-based robot manufacturer. "Even in many low-cost labor markets such as China, robotic assembly still makes financial sense since the level of scrap and rework is reduced significantly," Dulchinos added.

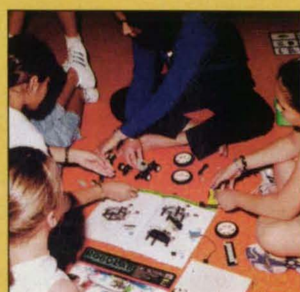
Traditionally, robots have been suitable for repetitive tasks on similar pieces, but the increasing use of artificial intelligence is breaking production barriers in almost every industry. At present, several companies design robots for manufacturing and often are able to create robotic parts according to a client's specifications.

Today's robots are also not limited to operating on the factory floor. Robots and robotics are finding applications in semiconductor, photonics, machine vision, fiber optics, and precision assembly automation. Adept Technology, for example, designs direct-drive robots, database-driven software, integrated vision and conveyor tracking, and digital servo control networks. The company offers a line of high-speed SCARA and Cartesian robots for assembly and material handling tasks. Payloads — which determine the size and weight of welding torches, cable assemblies, and torch mounts that can be carried by the robot arm — range from 6 to 55 pounds, and most models are available with optional rating for installation in cleanroom environments. For fiber optic automation components, Adept manufactures high-speed alignment stages, process-ready robotic assembly platforms, and assembly for epoxy bonding and laser welding.

Other robotics manufacturers such as Staubli (www.staubli.com), Reis Robotics (www.reisrobotics.com), Fanuc Robotics (www.fanucrobotics.com), Motoman (www.motoman.com), and EPSON Factory Automation/Robotics (www.robots.epson.com) all offer turnkey robotics and automation systems, including industrial robots, controllers, and software, providing customers with one-stop shopping for their automation requirements.

NI and LEGO Teach Future Robotics Engineers

In 1997, Chris Rogers, a user of LabVIEW graphical programming software from National Instruments of Austin, TX (www.ni.com), was working on a project for NASA through which students were learning to build and program planetary rovers. Rogers thought the concept of programming with LabView was very translatable to children, since it is a graphical, drag-and-drop environment. Chris brought National Instruments (NI) into collaboration with LEGO to create the Mindstorms for Schools system.

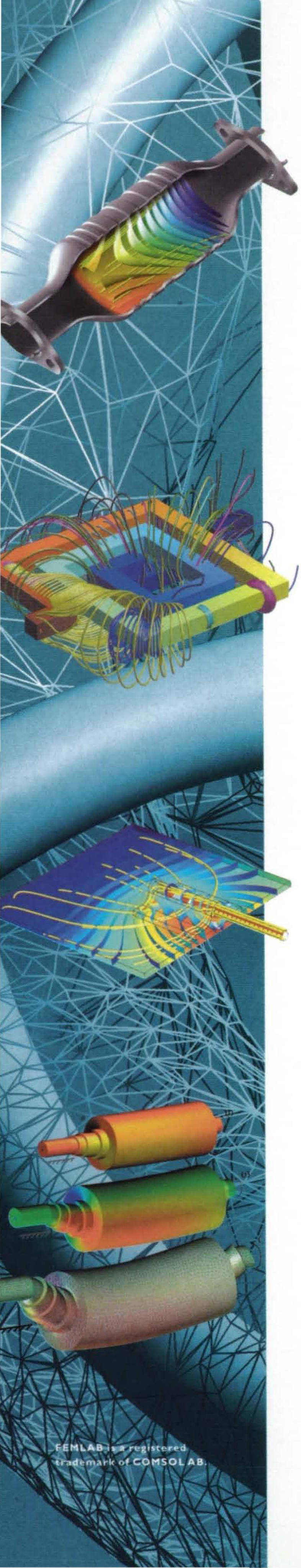

Students construct their robot using the LEGO Dacta kit with RoboLab.

The system uses a combination of LEGO microcomputer "bricks," traditional LEGO building pieces, and a modified version of LabVIEW called RoboLab, to introduce engineering concepts to students. By building LEGO-based robotic systems, students learn the same concepts that engineers face in the real world, including basic computer programming and problem-solving skills.

With RoboLab, robotic construction is facilitated using LEGO Dacta components and pieces to construct a robotic model built around the programmable LEGO RCX (Robotics Command System) microcomputer brick. RoboLab software uses familiar drag-and-drop techniques that help students think logically as they program a series of events or commands for the controller to perform. After completing the program, it is sent to the brick, which stores it to run when activated.

NI engineers partner with teachers on a voluntary basis to teach RoboLab to students to bring engineering and science principles to Texas classrooms. "It's good for the teachers to be able to relate to the students that what they're doing in the classroom is what the real engineers are doing in the real world," said Michael Zeller, academic relations manager for NI. "It's amazing to see how complex the kids can get with their robots in such a short amount of time."

For more information on RoboLab, visit ***www.pitsco-legodacta.com****. To find out how National Instruments has helped promote the Mindstorms for Schools program, contact Michael Zeller at* ***michael.zeller@ni.com****.*



◀ The most common reactor for environmental protection, which we encounter or use everyday, is the catalytic converter in automobiles. In these monolithic catalysts, carbon monoxide and nitrous oxides are converted into relatively harmless species like carbon dioxide and nitrogen. To optimize the utilization of the expensive catalyst, it is important to be able to model the reactor at different operational conditions. In this FEMLAB model, mass and heat balances are coupled to compute temperature distribution and flowlines in the reactor.

◀ This square-shaped spiral inductor is used for bandpass filters in micro electromechanical systems (MEMS). The FEMLAB simulation takes the nonuniform current density in the coils into account to compute an accurate magnetic flux arround the coils. The inductance of this inductor is 2.1 nH, which is obtained by integrating the magnetic energy. Using the programming language of FEMLAB for parametric analysis, you can find the correlation between the induction and the input parameters of the model.

◀ In the design of electrodes for water electrolysis, it is important to minimize the voltage losses at a given total current. FEMLAB modeling helps the engineer in the design of the electrode geometry and the current collector. The model gives the current density distribution and the potential distribution in the system. These results make it possible to avoid excessive degradation of the active electrode surface and overheating of the welds at the position of the current collector.

◀ When designing an electric motor it is important to design the rotor shaft so that no eigenfrequencies exist in the working range of the rotational speed. It is also important to study the shape of the eigenmode and not just the eigenfrequencies. In the eigenfrequency analysis, one end of the shaft is fixed and the other end is free to rotate and axially deform. The image shows deformation and rotation angle in the second eigenmode, using different visualization options like colormaps and scaling.

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Software automation is an increasing trend in robotics. Rather than simply programming a machine to do a repetitive task, software is enabling real-time supervisory control and monitoring over a network or the Web. EPSON, for example, recently introduced its EPSON RC+ programming software for the Windows 2000 platform. By using an operating system they're already used to, customers can program and monitor their robotic systems faster, and can integrate other third-party automation devices without additional programming.

Simulation software also plays a role in robotics and automation helping engineers conceptualize and implement robotic workcells. Adept offers an operating system, the V+, for controlling multiple devices while integrating vision, force sensing, and workcell logic. "The key technologies that allow us to adapt to changes in our environment are vision and force sensing," said Dulchinos. "Vision allows us to pick parts that are mis-oriented and place them relative to changing features on their mating assembly. Force sensing allows us to assemble parts by feeling how they go together, such as in a snap fit assembly."

The Future of Robotics is Now

NASA has always been at the forefront of robotics innovations, often relying on robots for research and exploration. But technologists do not limit themselves to utilizing rovers for terrestrial investigations; instead, NASA engineers have developed and used robotic systems for various bio-medical and manufacturing purposes.

The Robot Systems Technology Branch of NASA's Johnson Space Center in Houston, TX, has developed Robonaut, a humanoid robot designed in cooperation with the Defense Advanced Research Projects Agency (DARPA) to meet the dexterous manipulation needs foreseen in future NASA missions. The anthropomorphic robotic system can function as an astronaut equivalent, and is equipped with five-fingered, tool-handling end effectors; modular robotic components; and a telepresence and control system that allows its human operator to "see" what it sees.

Telepresence requires that a human operator control the actions of a remotely operated robot. In the case of Robonaut, the human operator must control 43 individual degrees of freedom. Because Robonaut is anthropomorphic, it is controlled by a master-slave relationship whereby the operator's motions are essentially mimicked by the robot. The operator performs the arm, head, and hand motions for a task, which is duplicated in Robonaut.

Telepresence uses virtual reality display technology to visually immerse the operator in the robot's workspace. This way, the astronaut operator feels as if he or she is in the place of Robonaut. Visual

NASA's Robonaut features advanced mechatronics, including more than 150 sensors per arm. (Photo courtesy of NASA)

feedback is provided by a stereo display helmet and includes live video from Robonaut's head cameras. Arm, torso, and head tracking is accomplished with the use of magnetic-based position and orientation trackers.

While Robonaut may have the appearance of a "science fiction" creation, the robotic innovations built into it can be applied to manufacturing applications, including its mechanisms, work envelope, range of motion, and strength and endurance capabilities. Robonaut features a mix of sensors, including thermal, position, tactile, force, and torque instrumentation, which also are transferable to many industrial robotic systems.

Robonaut's human-scale arms, for example, have embedded avionics elements within each link, reducing cabling and noise contamination. It also features a biologically inspired neurological system that brings all feedback to a central nervous system. This approach enables learning and optimization in mechanical, electrical, and software forms.

To learn more about Robonaut, visit the project Web site at: ***http://vesuvius.jsc.nasa.gov/er_er/html/robonaut/robonaut.html.***

NASA Selects Two Design Tools as Software of the Year

Two software programs that save significant amounts of time and money over more traditional methods have been selected as co-winners of the 2002 NASA Software of the Year Award. The DSMC Analysis Code (DAC), developed at Johnson Space Center in Houston, TX, and Cart3D from Ames Research Center in Moffett Field, CA, have both been adopted by other government agencies, private industry, and academia.

Cart3D

Development of Cart3D began in 1992 by Michael Aftosmis and Dr. John Melton of NASA's Ames Research Center, and Professor Marsha Berger of the Courant Institute at New York University. The aerodynamic simulation tool provides engineers and designers with an automated computer-simulation suite that streamlines the conceptual and preliminary analysis of both new and existing aerospace vehicles.

Surface pressure contours on an Apache-Longbow attack helicopter computed with Cart3D simulation software.

The result of more than 10 years of research and development, Cart3D provides a revolutionary approach to computational fluid dynamics (CFD). Before the development of Cart3D, the basic computational tool — the grid layout used in analyzing designs of airplanes and spacecraft — had to be hand-generated and required months or years to produce for complex models. Cart3D automates grid generation, enabling even complex geometries to be modeled up to 100 times faster than before.

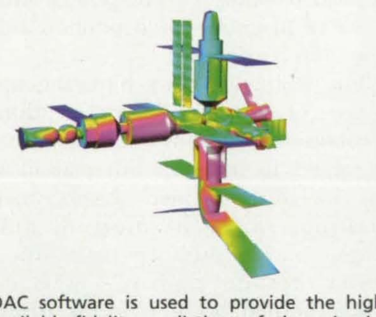
The geometry for the Cart3D mesher is a collection of components, each of which is a closed triangulated surface with conformal facets. Cart3D produces topologically unstructured, adaptively refined Cartesian meshes. "Cart3D's novel algorithms and its state-of-the-art computational efficiency combine to provide designers with a new level of automation that reduces simulation time requirements by a factor of at least 250," according to co-developer Michael Aftosmis.

Simulations generated by Cart3D help identify and fix problems in military transport aircraft and helicopters. It is used at leading universities, within NASA, and by more than 100 commercial users for analysis and conceptual design of military vehicles and commercial aircraft.

Ames' Commercial Technology Office licensed the software for commercialization to ICEM CFD Engineering, a subsidiary of ANSYS, an engineering analysis tool provider in Canonsburg, PA. It has been integrated into ICEM CFD Cart3D, the company's CFD product suite. In addition to its exclusive distributor status for Cart3D to the aerospace, automotive, and turbo machinery industries, ANSYS also has distribution rights for the electronics/electromagnetics and process industries, which will extend Cart3D well beyond traditional aerospace uses.

DSMC Analysis Code

The Direct Simulation Monte-Carlo (DSMC) Analysis Code was developed by Gerald J. LeBeau, Forrest E. Lumpkin, Katie A. Jacikas, and Phil C. Stuart of NASA Johnson, along with Richard G. Wilmoth and Christopher E. Glass of NASA's Langley Research Center in Hampton, VA. DAC uses the DSMC simulation method to model the flow of low-density gases over flight surfaces.



DAC software is used to provide the highest available fidelity predictions of plume impingement for orbiting structures, including the Russian Mir Space Station.

The software provides insight into the interaction of spacecraft and rarified environments, such as those encountered during a spacecraft's re-entry into Earth's atmosphere. It models complex geometries using easily generated unstructured triangular elements that act as sampling zones for surface quantities.

DAC was used to provide information and help optimize and verify maneuvers of spacecraft that orbited Mars after they were slowed by repeatedly skimming through the Mars atmosphere, instead of relying on thrusters for deceleration. The technique enabled the spacecraft to be lighter, reducing launch costs.

The program also has been used in analysis of plume impingement — the effects of firing thrusters by one spacecraft on another spacecraft nearby. An early application of this capability was analyzing the effect of Space Shuttle thruster firings as the vehicle approached the Russian Space Station Mir during the Shuttle-Mir program. This has since led to significant changes in docking procedures and venting operations on the International Space Station. Because tests to gain this type of knowledge are difficult and expensive to perform, DAC has the potential to save millions of dollars.

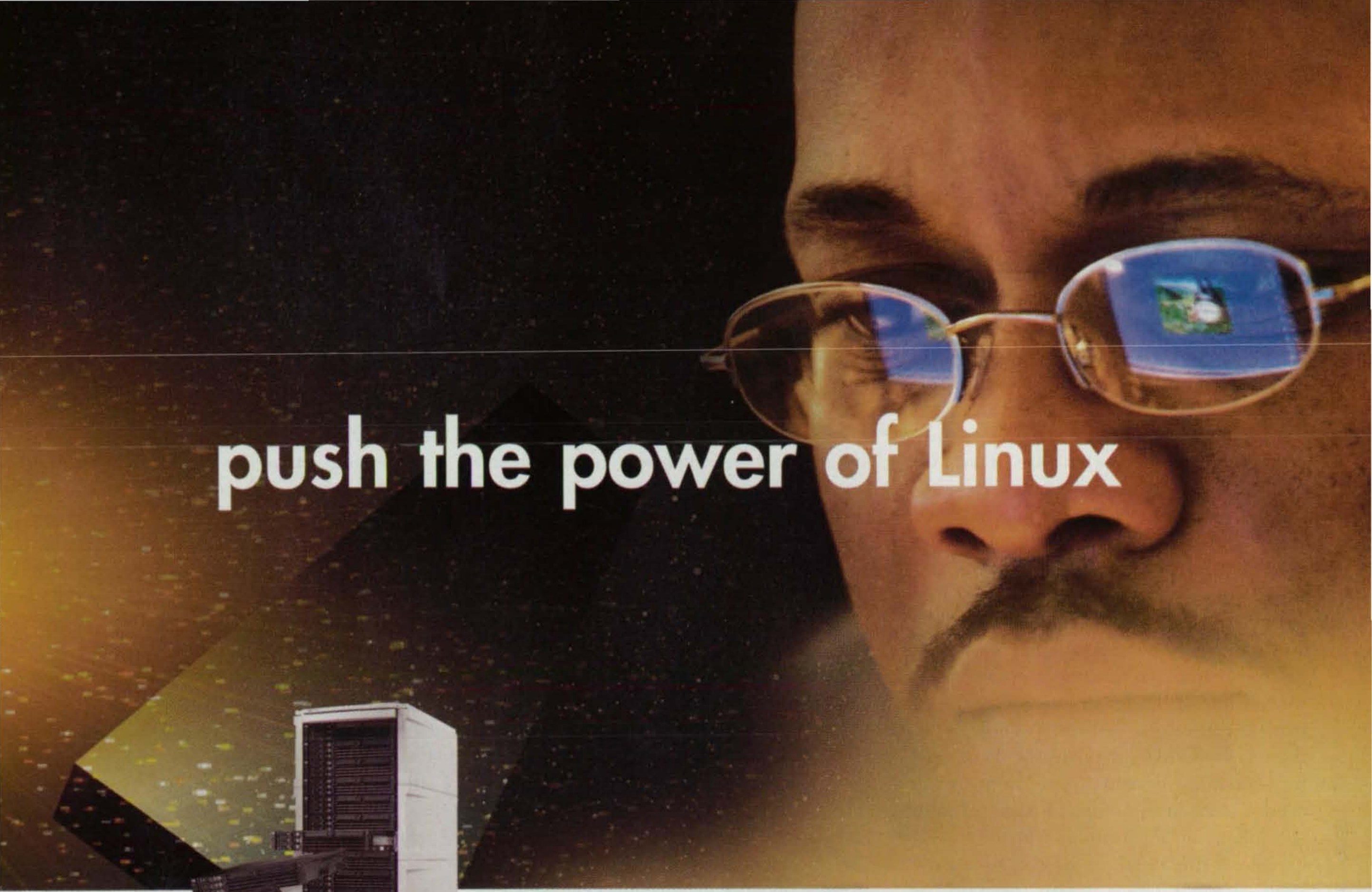
DAC is currently used in most NASA centers and within the U.S. military, and is being employed in the aerospace industry for applications involving high-altitude vehicles. The unique flow-solvers adapted to DAC allow it to be used where the object within the flow field is very small, such as in MEMS (micro-electromechanical systems) and nanotechnology devices.

The Runners-Up

Also receiving mention as award runners-up were:

- Hazardous Gas Detection System (HGDS) 2000 Software from John F. Kennedy Space Center, FL;
- Microgravity Analysis Software System (MASS) from John H. Glenn Research Center, Cleveland, OH; and
- Autonomous Maneuver Control (AutoCon) Flight Software from Goddard Space Flight Center, Greenbelt, MD.

The NASA Software of the Year competition is sponsored by the NASA Chief Engineer, with technical support from NASA's Inventions and Contributions Board. Find more information on the winners and nominees at **http://icb.nasa.gov/swoy2002**.



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Ultrasonic System Tracks Body Movements in Three Dimensions

This system affords centimeter accuracy and overcomes major disadvantages of prior systems.

Lyndon B. Johnson Space Center, Houston, Texas

A system based on ultrasonic sensors has been developed as a means of tracking moving objects with centimeter accuracy. The system is intended especially for tracking pertinent parts of the body of a human subject engaged in control of a remote anthropomorphic robot or immersed in a virtual environment. The system could also be used to track a mobile robot.

There are increasing demands for more sophisticated methods of characterizing the motions of human subjects for the aforementioned purposes. Prior motion-tracking systems have been fairly crude, costly, and tailored for such highly specialized applications as tracking movements of the head or of the eyes only. Whole-body-tracking systems now on the market utilize, variously, expensive optical sensors or magnetic sensors that are susceptible to errors in the presence of nearby metallic objects. To achieve realistic virtual reality, it will be necessary to measure complete body motions by use of systems that are acceptable to human subjects, that interfere minimally with the subjects' motions, and that resist environmental interference. The present system satisfies these requirements.

The present system includes several stationary receiving ultrasonic transducers positioned about the region within which the human subject moves. One or more transmitting ultrasonic transducers are positioned on the parts of the human subject's body that are to be tracked. Putting the transmitters on the human subject minimizes the weight that the subject must carry: the equipment that processes the ultrasonic-signal information is stationary because all such processing is performed in the receivers and in a stationary motion-measurement unit (MMU).

Each transmitter emits a phase-coded waveform at the inaudible frequency of 40 kHz. The outputs of the receivers are sent to the MMU, which performs correlation processing analogous to that performed on microwave signals in the highly successful Global Positioning System. The outputs of the correlation processor are the receiver/transmitter distances; the three-dimensional coordinates of the transmitters are computed from these distances and the known positions of the receivers. No synchronization is needed to enable the receivers and the MMU to distinguish among the signals received from different transmitters because each transmitter uses a unique phase code orthogonal to the phase codes of all the other transmitters.

This work was done by Robert E. Bozek of Genisys Research & Development, Inc., for **Johnson Space Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Electronic Components and Systems category.*
MSC-23028

Cylindrical Shape-Memory Rotary/Linear Actuator

A shape-memory ribbon is wrapped around a cylinder to build up length.

Lyndon B. Johnson Space Center, Houston, Texas

A compact actuator generates rotary or linear motion with a large torque or force, respectively. The original version of this actuator is designed to pull a wedge that, until pulled, prevents retraction of the proposed extended nose landing gear of the space shuttle. The original version is also required to fit into a volume that is severely limited by the size of the landing-gear assembly. The basic actuator design could be adapted to other applications in which there are requirements for compact, large-force actuators with similar geometries.

The transducer portion of this actuator is a ribbon of a nickel/titanium shape-memory alloy. A component made of such an alloy undergoes a pronounced deformation to a "remembered" shape (in the present case, the ribbon becomes shorter) when its temperature rises through a transition value, causing a transformation in its metallurgical structure from a martensitic phase to an austenitic phase. The component resumes its previous shape (in the present case, the ribbon lengthens) when its temperature falls below a lower transition temperature (there is hysteresis in the transformation). In this case, the transition temperatures are somewhat above room temperature.

To obtain sufficient length in order to obtain sufficient stroke, the shape-memory ribbon is wrapped three times around a cylinder. One end of the ribbon is attached to the cylinder, the other to an object that does not move, relative to the axis of the cylinder. The ribbon is heated by passing an electrical current through it. When the temperature of the ribbon rises above the first transition temperature, the resultant shape-memory shrinkage exerts a torque, causing the cylinder to turn. In the original application, the rotary motion of the cylinder is converted to linear motion by use of ramps, attached to the cylinder, that roll along wheels. In a different application, the rotary motion of the cylinder could be the desired output.

The primary difficulty encountered in initial tests was that the sliding friction engendered by wrapping the ribbon three times around the cylinder was so large as to impair actuation. The friction was reduced to an acceptably low level by placing the ribbon on nonconductive roller assemblies to enable the ribbon to move around the cylinder by rolling instead of sliding.

This work was done by Bradley Files and James W. Akkerman of **Johnson Space Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Mechanics category.*
MSC-23211

Program Finds Target-Chemical Signals in Multisensor Outputs

NASA's Jet Propulsion Laboratory, Pasadena, California

A computer program deconvolves the digitized outputs of multiple chemical sensors in an array to extract indications of the identities and concentrations of target chemicals (which could be individual compounds or specified mixtures of compounds). Chemical-sensor arrays — denoted, variously, as electronic noses and electronic tongues — can be used for diverse purposes, including monitoring the quality of air in enclosed spaces, medical diagnosis involving specified chemical compounds or bacteria distinctive of particular diseases or infections, and monitoring the quality of food. The program follows a nonlinear-least-squares approach to the analysis of data from a chemical-sensor array. In experiments, the program was found to be capable of identifying and quantifying both single compounds and mixtures of large numbers of compounds.

This program was written by Hanying Zhou of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Software category.*

This software is available for commercial licensing. Please contact Don Hart of the California Institute of Technology at (818) 393-3425. Refer to NPO-30437.

Pressure-Application Device for Testing Pressure Sensors

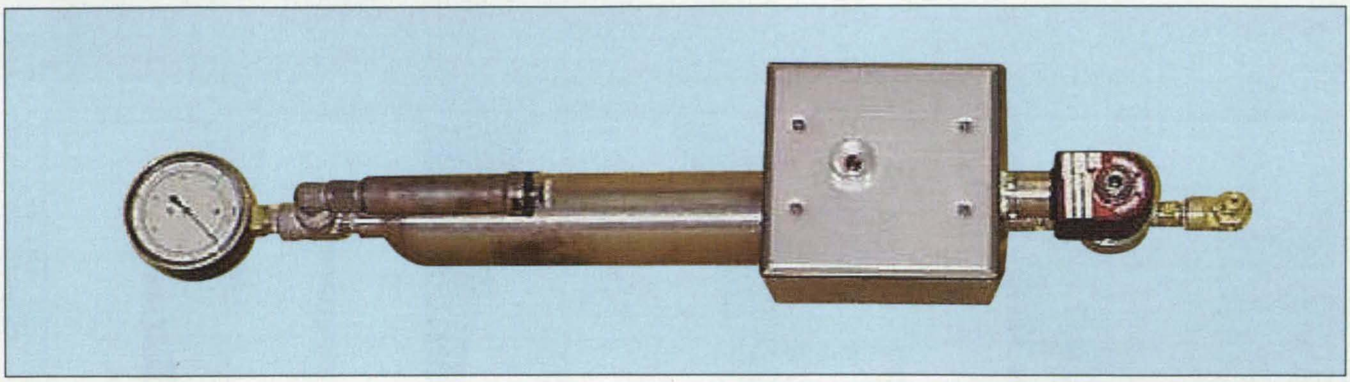
This device generates a pulse of known pressure.

Stennis Space Center, Mississippi

A portable pressure-application device has been designed and built for use in testing and calibrating piezoelectric pressure transducers in the field. The device generates pressure pulses of known amplitude. A pressure pulse (in contradistinction to a steady pressure) is needed because in the presence of a steady pressure, the electrical output of a piezoelectric pressure transducer decays rapidly with time.

The device (see figure) includes a stainless-steel compressed-air-storage cylinder of 500-cm^3 volume. A manual hand pump with check valves and a pressure gauge are located at one end of the cylinder. A three-way solenoid valve that controls the release of pressurized air is located at the other end of the cylinder. Power for the device is provided by a 3.7-V cordless-telephone battery. The valve is controlled by means of a pushbutton switch, which activates a 5-V to ±15-V DC-to-DC converter that powers the solenoid.

The outlet of the solenoid valve is connected to the pressure transducer to be tested. Before the solenoid is energized, the transducer to be tested is at atmospheric pressure. When the solenoid is actuated by the push button, pressurized air from inside the cylinder is applied to the transducer. Once the pushbutton is released, the cylinder pressure is removed from the transducer and the pressurized air applied to the transducer is vented,



Air Is Manually Pumped into a cylinder for storage at a specified pressure. To test a pressure transducer, one presses a pushbutton to activate a solenoid valve that releases a pulse of pressurized air from the cylinder.

bringing the transducer back to atmospheric pressure. Before this device was used for actual calibration, its accuracy was checked with a NIST (National Institute of Standards and Technology) traceable calibrator and commercially calibrated pressure transducers.

This work was done by Wanda Solano of **Stennis Space Center** *and Greg Richardson of Lockheed Martin Corp.*

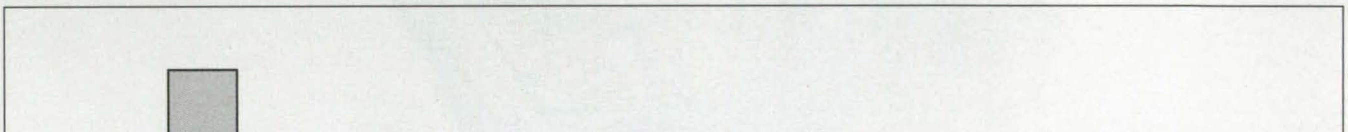
Inquiries concerning rights for the commercial use of this invention should be addressed to the Intellectual Property Manager, Stennis Space Center; (228) 688-1929. Refer to SSC-00142.

Slab-Waveguide Interferometer for Sensing Ammonia in Wet Air

Ammonia changes the pattern of interference between TM_0 and TM_1 waveguide modes.

John H. Glenn Research Center, Cleveland, Ohio

The figure depicts a single-arm, slab-waveguide interferometer that has been demonstrated to be useable as a means of sensing ammonia in wet air. The slab-waveguide portion of this device comprises a 2-µm-thick film of poly(methyl methacrylate) [PMMA] on a substrate of fused quartz. The PMMA layer acts as a waveguide because its index of refraction is greater than the indices of refraction of both the fused quartz on one side and the ambient air on the other side. The PMMA film is doped with bromocresol purple — an indicator dye that causes the index of refraction of the film to vary with the amount of ammonia that diffuses into the film from the ambient air. The remaining basic features of design and operation, as described below, are devoted to enhancing and measuring the change in an optical



This **Slab-Waveguide Interferometer** provides an indication of the ammonia-induced change in the index of refraction of the doped PMMA film.

phase difference attributable to the change in the index of refraction and thus to the presence of ammonia.

At opposite ends of the waveguide, the wide rectangular facets of triangular input and output coupling prisms are pressed against the surface of the PMMA film. The prisms are made of gallium gadolinium garnet. Light from a He-Ne laser (wavelength of 633 nm) is chopped and sent through a single-mode optical fiber to input focusing optics. The design of the input focusing optics and the input coupling prism is such that two transverse magnetic (TM) modes — the ones of zeroth and first order (TM_0 and TM_1, respectively) — are excited simultaneously in the slab waveguide. After traveling along the waveguide, the waves propagating in the two modes encounter the output coupling optics, which are similar to the input coupling optics except that their role is to focus light in the two modes onto an end face of a multimode optical fiber. Because the two modes are coherent, they give rise to an interference pattern. With proper design of the optics and proper placement of the multimode optical fiber, the spatial period of the fringes is several times the diameter of the fiber.

The multimode optical fiber leads to a photodetector. The output of the photodetector is processed through a lock-in amplifier synchronized with the chopper. When index of refraction of the doped-PMMA waveguide film changes upon exposure to wet ambient air containing ammonia, the resulting change in its index of refraction causes a change in the differences between the phases of the TM_0 and TM_1 modes at the output end of the waveguide. This change in phase difference causes the interference fringes to shift with respect to the input face of the multimode optical fiber, thereby further giving rise to a change in the intensity of light arriving at the photodetector. In an experiment, the sensitivity of this device was found to be a phase-difference change of 2π radians (one full oscillation of the intensity of light arriving at the photodetector) per approximately 200 parts per million of ammonia.

The design of this device has not yet been optimized with respect to the laser wavelength, choice of waveguide polymer, and concentration of dopant. In addition, it may be necessary to add a reference interferometer arm isolated from the ambient air to provide temperature compensation, because the single-arm version described above is highly sensitive to temperature (of the order of 2π radians of phase-shift change per 1°C change in temperature).

This work was done by Sergey Sarkisov of Alabama Agricultural and Mechanical University for **Glenn Research Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Physical Sciences category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-17189.

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Intuitive Control System for a Dexterous Robot

The operator and robot acting together can respond with nearly natural, humanlike motions.

Lyndon B. Johnson Space Center, Houston, Texas

The Full Immersion Telepresence Testbed (FITT) is an experimental anthropomorphic-robot remote-control system that is so named because it gives a human control operator some of the sensations of the remote environment as though the operator were in that environment in place of the robot. In comparison with older telerobotic control systems, the FITT provides robotic sensory feedback better suited to the operator's senses and enables the operator and robot acting together to respond, with more nearly natural, humanlike motions, to changes in the remote environment. In particular, correlating the operator's movements (principally of the head, arms, and hands) with movements of the robot creates a more intuitive method of teleoperating robotic manipulators. Moreover, the use of an operator's own movements to control the robot provides the operator with useful kinesthetic feedback. The FITT and other systems like it are expected to reduce training time and costs, task-completion times, and operator workloads and errors. Because the FITT concept mates human intelligence with the durability of robots, it is potentially useful for performing complex tasks in harsh environments; for example, cleaning up radioactive and toxic wastes.

An **Operator Using the FITT** controls a remote robot by a combination of hand, arm, head, and foot motions and vocal commands.

The main component of the FITT is an operator's chair mounted on a rotating base (see figure). By use of foot pedals on the chair, the operator can command direct-drive motors on both the base of the chair and the remote robot. The chair also houses equipment for controlling a video camera unit, manipulators, and end effectors on the remote robot. The operator wears a helmet-mounted video display unit that presents, to the operator, 60°-field-of-view stereoscopic images from the video camera unit on the robot. Stereoscopic imaging creates a perception of depth — one of the most important "immersion" features of the system. The helmet also includes stereophonic headphones for audio feedback and a microphone for operator voice commands. A position-and-orientation sensor on the top of the helmet is the source of commands that control the orientation of the video-camera unit on the remote robot. Other sensors attached to the operator's wrists provide three-dimensional position and pitch, yaw, and roll signals for remote control of positions and orientations of tools held by the robotic manipulators. Instrumented gloves measure the operator's finger-joint angles and the pitch and yaw of the operator's hand, thereby providing signals for dexterous teleoperation of robotic grippers and hands.

Inasmuch as the operator's hands and eyes are "immersed" in the locally synthesized version of the remote environment, they are not available for initiating commands. Therefore, a voice-recognition subsystem provides a convenient way to blend automated commands with direct operator control. To prevent the voice-recognition subsystem from picking up extraneous inputs, the system is set up so that the operator must press a foot pedal to enable the subsystem to receive a spoken command. Once the pedal is released, the command is processed and played back to the operator over a voice synthesizer for confirmation. Motions that can be commanded vocally can vary in complexity from a simple repositioning of a robot arm to a more complex maneuver like grappling and turning a dial.

The software that controls the system is hosted on a UNIX/VersaModule Eurocard (VME) computer workstation and a personal computer with a '486 microprocessor and a voice-recognition circuit board. Data from the position and orientation sensors, instrumented gloves, and foot pedals are sampled at a rate of approximately 10 Hz. The data are sent out over a local-area network, using high-level communication software that enables transfer of data through a C-language program, making low-level driver interfaces transparent.

This work was done by Larry C. H. Li of **Johnson Space Center** *and Myron A. Diftler and Susan S. Shelton of Lockheed Martin. For further information, contact the Johnson Commercial Technology Office at 281-483-3809. MSC-22733*

Noncontact Scanning Surface Profilometers

Position-sensitive detectors are used to measure relative surface heights.

John F. Kennedy Space Center, Florida

A class of optoelectronic noncontact computer-controlled scanning surface profilometers is undergoing development for use in automated or semiautomated inspection of nominally flat surfaces. When fully developed, these profilometers would generate three-dimensional maps of the scanned surfaces for characterization of such defects as pits and scratches.

A profilometer of this type includes a two-dimensional (x,y) horizontal-translation stage, on which the object to be inspected is mounted with the surface of interest facing upward toward a stationary optical head. The optical head contains a laser diode aimed to project a beam of light downward at an angle (22-1/2° in the prototype profilometer) to the perpendicular to the surface of interest. The height of the optical head is set at a nominal vertical distance [0.25 in. (6.35 mm) in the prototype] above the surface of interest. When the vertical distance between the optical head and the surface equals this nominal distance, the spot of light formed on the surface by the laser beam is at a nominal central horizontal position. When the surface lies at a different height, the spot of light is formed at a different horizontal position.

The optical head contains optics that focus the light reflected from the laser-illuminated spot to a corresponding spot on a one-dimensional position-sensitive detector (PSD), which is a photodetector with electrodes at opposite ends of a line. The deviation of the position of the spot of light along this line from a nominal central position depends on the deviation of the illuminated spot on the surface of interest from the nominal vertical distance below the optical head. The spot of light focused onto the PSD gives rise to photocurrents in the two electrodes; the relative values of these photocurrents depend on the position of the spot of light along the line between the electrodes and thus indicate the local deviation of the height of the surface of interest.

Under computer control, the translation stage is actuated to scan the optical head across the surface. For each increment of horizontal position (x,y), the optical head generates photocurrents indicative of the local deviation of the surface from the nominal vertical distance. The computer builds up a three-dimensional map of the surface from the ensemble of vertical-deviation data for all increments of horizontal position.

The prototype profilometer has been tested in scans of several objects, including a shiny new dime and specimens of diffusely reflective materials. The results of the tests suggest that surface deviations could be routinely resolved to within 10^{-4} in. (5 μm).

This work was done by Jeffrey A. Hooker and Stephen M. Simmons formerly of I-NET for **Kennedy Space Center**.

NASA has granted Laser Technology, Inc., an exclusive license for this technology. Inquiries concerning the commercial use of the "Noncontact scanning Surface Profilometers" should be addressed to:

John Newman, President
Laser Technology, Inc.
1055 W. Germantown Pike
Norristown, PA 19403
Tel. No.: (610) 631-5043
Refer to KSC-11759

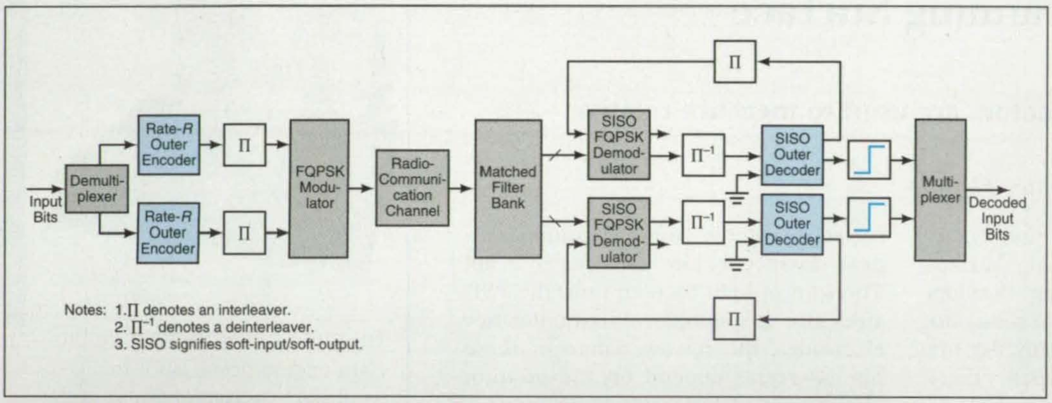
FQPSK With an Outer Code for Greater Efficiency

Coding gains are expected, even for reduced-complexity receivers.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed method of FQPSK modulation and demodulation of a radio signal would incorporate any of a number of relatively simple (short-constraint-length) outer codes. By affording significant coding gains even when using a reduced-complexity (and thus suboptimal) FQPSK receiver, this method would offer the concomitant potential to enhance efficiency in power and spectral width of an FQPSK communication system.

The term "FQPSK" denotes Feher-patented quadrature-phase-shift keying, which is a bandwidth-efficient phase-modulation scheme named after its inventor. Among the notable features of FQPSK is shaping of what would otherwise be square in-phase (I) and quadrature (Q) pulse waveforms, such that the signal envelope (in effect, the power of the transmitted signal) remains nearly constant. The shaping involves, among other things, a cross-correlation between the I and Q channels. The nature of the cross-correlation is such as to effectively incorporate a trellis coding scheme into FQPSK.



This **FQPSK Coding/Modulation and Demodulation/Decoding Scheme** has been shown, in computational simulations, to offer significant gain over FQPSK modulation and demodulation without coding.

According to the proposed method, a short-constraint-length code (in effect, an outer code) would be introduced into a data stream via an interleaver prior to modulation of the carrier signal in an FQPSK transmitter. The combination of this outer code with the trellis or convolutional code inherent in FQPSK (in effect, an inner code) would form a concatenated coding arrangement which allows for iterative decoding. At the receiver, the iterative decoding would be part of the demodulation process.

The figure depicts one of a number of generic coding/decoding schemes, admitted by this method, that includes the use of a reduced-complexity receiver. Computational simulations for this scheme with various outer codes, interleaver block sizes, and numbers of decoding iterations demonstrated the potential to obtain coding gains (in terms of signal-to-noise ratio needed to keep the bit-error rate below a specified value) ranging from 3.75 to 7.7 dB.

This work was done by Marvin Simon and Dariush Divsalar of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Electronic Components and Systems category.*

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

Intellectual Property group
JPL
Mail Stop 202-233
4800 Oak Grove Drive
Pasadena, CA 91109
(818) 354-2240

Refer to NPO-30135, volume and number of this NASA Tech Briefs *issue, and the page number.*

Real-Time Desktop Manager

This program manages other programs and displays.

Lyndon B. Johnson Space Center, Houston, Texas

Real-time Desktop Manager (RDM) is a computer program that manages displays and application programs. RDM was developed for use in connection with NASA's remote manipulator system (RMS) group of flight controllers; it could also be used in chemical plants, laboratories, factories, hospitals, and other settings where it is necessary to monitor many data streams. The RDM displays are data-driven, and color is used to indicate the criticality of a display. There are other programs that perform such functions, but they are very expensive and, unlike RDM, do not afford graphical capabilities.

RDM is written in the ANSI-C computing language, using the Motif widget set, for execution in the UNIX operating system. The sources of input to RDM are a series of input files, the user, and an information-sharing-protocol (ISP) data-acquisition system, which is maintained as an independent program. RDM enables the user to create a data display with the help of previously stored input files that define a main window display, a menu-bar display, and individual display windows. The displays are driven by data received from an ISP server and input from the user. The program reads input files to create easily configurable displays that can be modified before flights and simulations without having to modify and recertify software.

RDM conforms to the Mission Control Center (MCC) Human and Computer Interface guidelines. It utilizes other software already in use in the MCC, plus other software that has, variously, been developed or purchased by NASA. Some investigation of other graphical software tools revealed that display windows are created within programs that must be compiled for each change. In RDM, it is not necessary to compile for each change in a display. The user simply modifies the input files and initiates the execution of RDM that reads the files.

This program was written by Sharon L. Valentine, Charles C. Birkner, and Ronald L. Kerr of Rockwell International Corp. for **Johnson Space Center**. *For further information, contact the Johnson Commercial Technology Office at 281-483-3809. MSC-22727*

Program Analyzes Use of Registers by Another Program

NASA's Jet Propulsion Laboratory, Pasadena, California

Regprof is a computer program that analyzes the use of registers by another program that runs on a PowerPC 750 (or equivalent) computer. Regprof is useful for showing how well compilers make use of registers and for obtaining an indication of the susceptibility of application programs to radiation-induced changes in register bits. Regprof goes through the source code of the program in question, analyzing each instruction to determine what registers it uses and whether the instruction loads a register with a value or uses a value already in a register. A register is marked as being in use between the instruction that loads a value into it and the last instruction in which that value is used. Upon completion of this analysis, a histogram table that shows how many registers are in use at each line of the analyzed program is printed. One limitation of this analysis is that it does not take account of program flow and, instead, is performed as though all lines of the analyzed code were executed in sequence. This is adequate for most compiler code, but in some cases, one might obtain a distorted representation of register usage.

This program was written by Paul Springer of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Software category.*

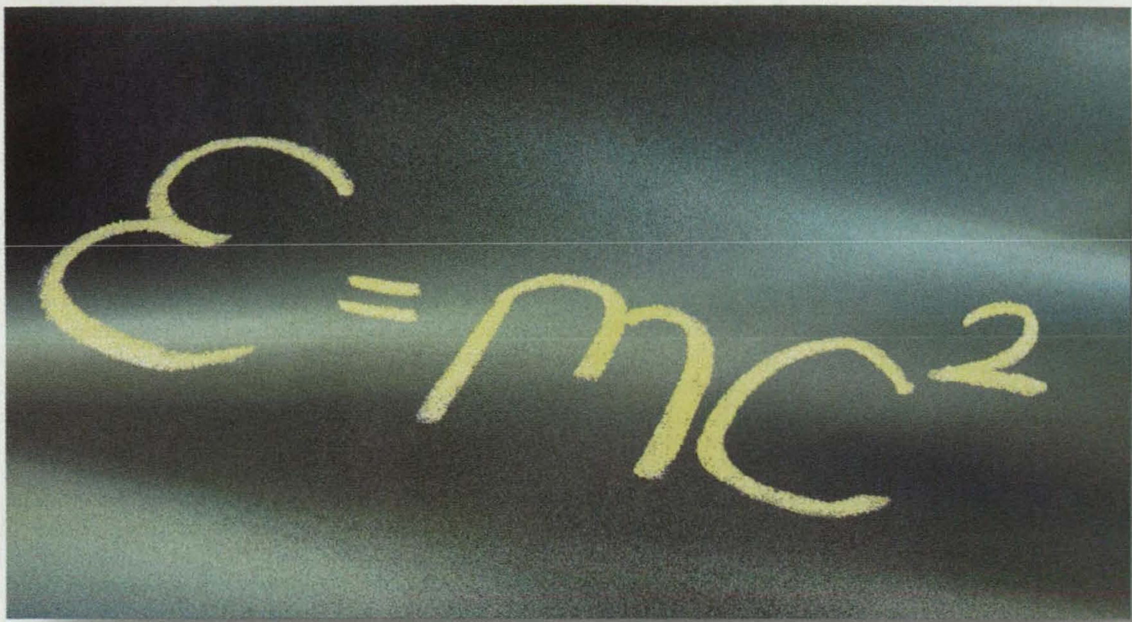
This software is available for commercial licensing. Please contact Don Hart of the California Institute of Technology at (818) 393-3425. Refer to NPO-30347.

Embeddable Fuzzy-Logic-Toolkit Software for Tcl/Tk

Advantages include minimal cost, versatility, and relative simplicity.

Lyndon B. Johnson Space Center, Houston, Texas

A computer program of the fuzzy-logic-toolkit type has been developed as a relatively simple, portable, highly compatible, means of providing fuzzy-logic reasoning capabilities for control and expert-system applications. This program is designed to work with the high-level scripting language Tcl/Tk and to invoke the access-to-data capabilities of an information-sharing protocol (ISP). This program supplies the numerous functions necessary for effective utilization of fuzzy-logic reasoning methods and overcomes many disadvantages of other fuzzy-logic toolkits. The program, written in the C language, is relatively small, portable, efficient, and embeddable. Better yet, this program is flexible in that it includes a source code that can be improved or developed to add further capabilities and features. The most commercially advantageous feature of the


$E=mc^2$

program is that it is available essentially without cost. With the help of this program, users can learn how to write fuzzy-logic programs for real applications.

This software is based partly on the FuzzyCLIPS software, which was developed by the National Research Council of Canada by modifying a prior Johnson Space Center software innovation known as CLIPS (for C Language Integrated Production System). FuzzyCLIPS is written in the C language and contains a source code that is freely available to users. In addition, FuzzyCLIPS was also designed to be embeddable in other application programs, making it most suitable for the development of toolkit-type software.

In the development of the present fuzzy-logic-toolkit program, the FuzzyCLIPS source code was combined with an interface code, thereby registering FuzzyCLIPS functions with Tcl commands while at the same time converting data types between the two codes as necessary. In the end, 13 commands were created to provide access to FuzzyCLIPS from within Tcl.

Other programs were then developed as test cases to demonstrate the capabilities of this fuzzy-logic-toolkit program. In one case, a simple shower-control problem, provided with the original FuzzyCLIPS software, was used to exhibit the ability of the toolkit program to incorporate fuzzy logic into a control application program. Another case, more relevant to NASA's needs, the use of fuzzy-logic control with ISP telemetry data was demonstrated. In this demonstration, ISP data were presented to the user with a graphical display created by use of the Tk software. During each cycle of ISP data, a fuzzy-logic control procedure was invoked, and the results of this invocation were displayed. The degrees of membership of input and output data in fuzzy sets were also presented graphically to users.

In both the aforementioned test cases and in use at NASA, the versatility of this fuzzy-logic-toolkit program has been demonstrated. The main benefit that it affords to NASA is an ability to create more "intelligent" flight-control displays. Beyond NASA, this software can be used to create displays that make background use of fuzzy-logic reasoning while at the same time presenting the results of an expert system (e.g., a diagnostic system) in the foreground.

This program was written by John C. Limroth of Rockwell International for **Johnson Space Center.** *For further information, contact the Johnson Commercial Technology Office at 281-483-3809.*
MSC-22730

Program Computes Outer-Space Heat-Sink Temperatures

John H. Glenn Research Center, Cleveland, Ohio

TSCALC is a computer program that calculates the space sink temperature (T_S), defined as the equilibrium temperature of a spacecraft heat-dissipation radiator or other object nominally isolated except for radiative exchange of heat with the Sun, or any star for which equilibrium sink temperatures are to be evaluated; planets, in the neighborhood of which the thermal environment is of interest; and interstellar space. TSCALC utilizes the gray-body Stefan-Boltzmann equation and the equations for radiant fluxes as functions of distances between, and orientations of, bodies engaged in radiative exchange. Factors taken into account by TSCALC include (1) distances from the spacecraft to the Sun and any planets in the neighborhood of which a spacecraft has to operate; (2) angles between the radiator surface and lines of sight to the Sun and a neighboring planet; (3) the ratio between solar absorptivity and thermal emissivity of the radiator surface; (4) the "View Factor to Space," which is a function of the solid angle subtended by interstellar space as viewed from the radiator; (5) the luminosity, L, of the stellar heat source ($L = 3.86 \times 10^{26}$ W for the Sun); and (6) the albedos of planets, in the vicinity of which a spacecraft will operate. The T_S computed by TSCALC can be used, along with the thermophysical properties of the radiator material and the temperature of a spacecraft heat source, as inputs to spacecraft-radiator design code that computes the area of a radiator needed to dissipate a given heat load while operating at a given temperature $>T_S$.

This work was done by Albert J. Juhasz of **Glenn Research Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Software category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16852.

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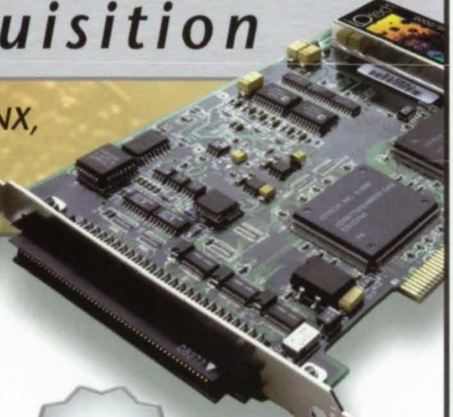

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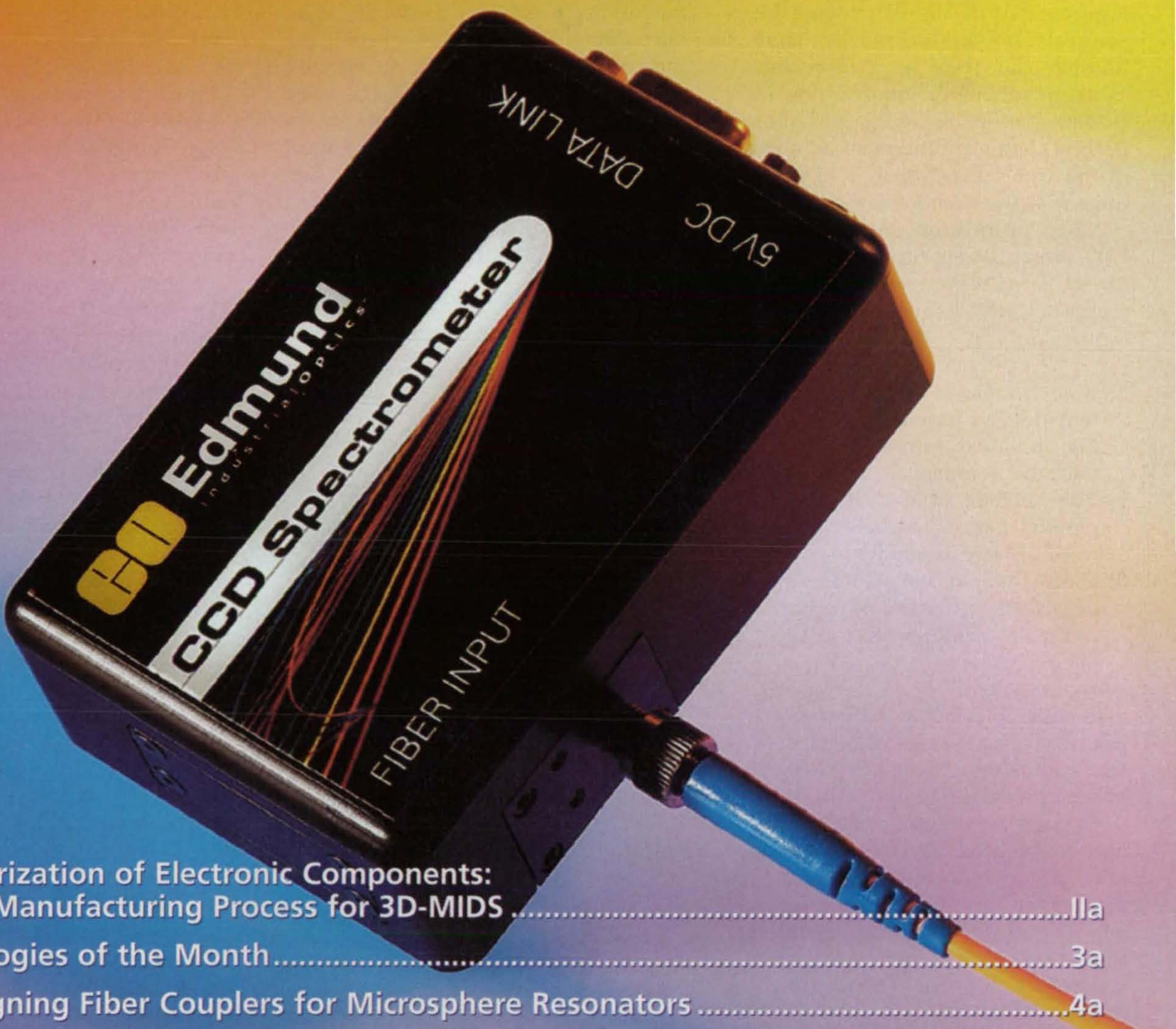

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Miniaturization of Electronic Components: A New Manufacturing Process for 3D-MIDS

A large step towards a significant miniaturization of electronic components is the integration of electrical and mechanical functions as implemented in 3D-MID (Mould Interconnect Device) technology. Here a housing can serve as a three-dimensional circuit board. A more rational fabrication, design flexibility, and shorter process chains are the main advantages of this technology, which is of growing interest to the circuit board industry.

A new production process — LPKF-LDS (Laser Direct Structuring) — for 3D-MIDs has been developed and comprises merely three steps (see figure 1):

1) A thermoplastic part is injection molded based on a granule modified with an organometallic complex.
2) The surface of the thermoplastic part is partially activated by laser irradiation.
3) Circuit tracks are selectively deposited on activated areas using an additive electro-less plating process.

In addition to being highly flexible relating to changes in the electrical circuit design, the LPKF-LDS process provides high throughput, lines and spaces down to 20 µm, and is above all an environmentally friendly technology. This method is now ready-for-market and is currently being adapted for several materials of interest to the electronics industry. This article further describes the process, system technology, and results.

Granule & Organometallic Complexes

The fundamental concept of the LPKF-LDS process is to modify an electrically isolating polymer matrix while maintaining its non-conductive property and to set free seeds on the surface of the polymer via laser irradiation of a certain energy density level. These seeds enable a selective wet-chemical reductive metal precipitation. The polymer is modified by incorporating dispersive organometallic complexes into the matrix, which are designed in a way that they can be activated by the laser irradiation.

On one hand laser irradiation induces a physio-chemical reaction, specifically the cracking of chemical bonds. On the other hand it makes a strong adhesion of the forming metal layer possible by ablating polymer material, i. e. roughening the surface and thus providing an effective anchoring for the forming metal layer. Optimum cavities are produced, providing a mechanical anchoring for the metal plating (see figure 2). This effect is supported by incorporating laser irradiation resistant filler particles, which protrude on the surface after the laser treatment.

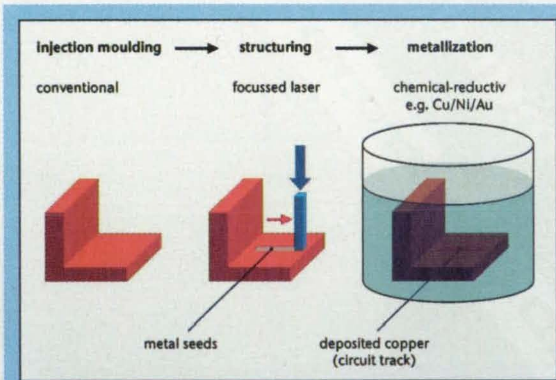

Figure 1: Main technology steps

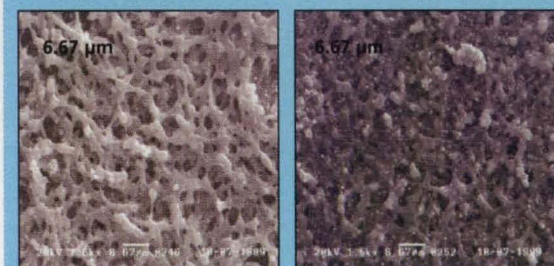

Figure 2: Surface after laser structuring and after beginning metallization

The starting point of the LPKF-LDS process has been the development of organometallic complexes with the following characteristics:

- Electrically non-conducting
- Visual-light-resistant
- Sufficient soluble and/or colloidal dispersible in the polymer matrix
- Good compatibility in the polymer filler material system
- No catalytic activity
- Separable in metal seeds and organic residuals by laser irradiation
- High thermal resistance
- Little toxicity
- Low costs

The organometallic complexes are based on palladium (Pd^{2+}) and/or copper (Cu^{2+}). Due to high palladium prices alternative systems of different transition metals like copper are preferable. The developed organometallic complexes are of an exceptionally high stability.

Pulverized organometallic complexes, inorganic filler materials, the polymer as well as further additives are processed in a heating-cooling mixer combination (fluid mixer, see figure 3) to a homogeneous agglomerate. The next step is the compounding. In an extruder this agglomerate is molten and transported. The result is a homogenized modified thermoplastic. After cooling the extruded thermoplastic is crushed in a granulator to a conventional granule, which is outstandingly well suited for molding three-dimensional parts using conventional injection molding technology.

Laser Radiation & Electro-Less Plating

A string of different technologies is available for coating a plastic surface with a metallic layer, for example PVD coating, laminating with metal foils, spray coating, and electroplating methods. The latter are especially suited for metallizing three-dimensional pieces. When using an electroplating technique, plastic parts are usually metallized in a multi-stage process where the surface is first cleaned and roughened, then given a catalytical nucleation, and finally coated with metal using a chemical and/or electroplating method. In the field of plastics metallization, creating a plastic surface that catalyses a chemical metallization process is called activation.

Selective activation followed by selective metal deposition is an especially promising approach to the problem of metallizing only partial areas of three-dimensional plastic surfaces (e. g. in MID production). When using special substrate materials, laser irradiation can directly trigger such a selective activation. Indirect activation by a laser is possible as well. Here the catalytic plastic surface is not directly created by laser irradiation but rather by deposition of a catalyst in the irradiated areas.

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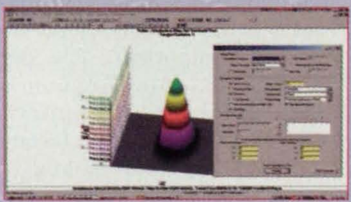

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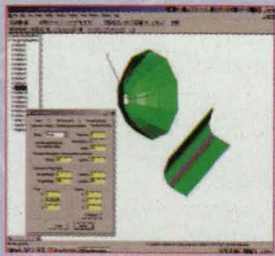

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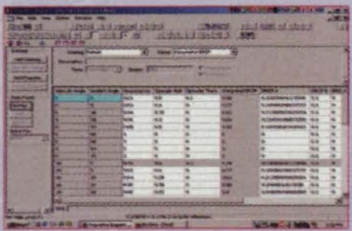

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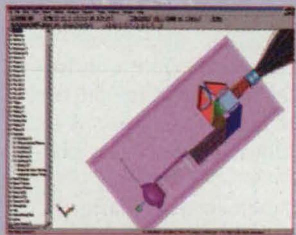

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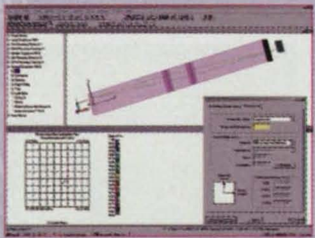

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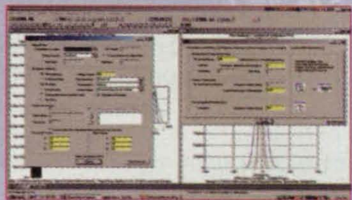

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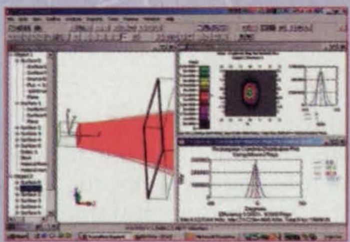

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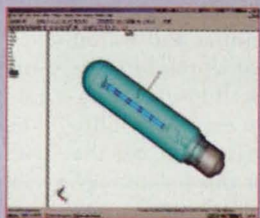

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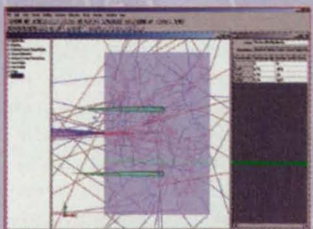

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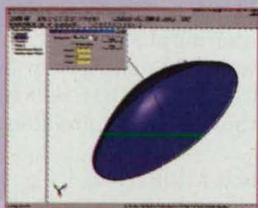

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Surface activation and roughening is achieved by using a UV-laser. With regard to the surface structuring of the thermoplastic, the necessary laser radiation demonstrates high-resolution ablation of material, especially applying to organic materials, and induction of a

Figure 3: LPKF system: Heating-cooling mixer combination, extruder, cooler, and granulator at FH Lippe (from right to left)

physio-chemical reaction. The conductor lines are selectively built up on the thermoplastic in the areas activated by the laser in a following electro-less plating process.

Conventional metallization baths (e. g. Shipley, MacDermid) can be used. An economical plating thickness lies in the range of 5 µm copper, a succeeding Ni-layer of 5 µm, and 0.1 µm gold finish. To achieve a higher copper plating thickness, the part can be placed in an electrolytic bath afterwards.

Basically the process can be applied to many thermoplastics. In a first step polypropylene (PP) was chosen to demonstrate the feasibility of the process. PP is a demanding and within the frame of industrial applications a proven thermoplastic with low temperature characteristics. Its extremely difficult metallization behavior increases the requirement profile for this technology. More recent developments have concentrated on the adoption of the complexes for incorporation into the high performance thermoplastic polybutylene-terephtalate (PBT) and partly aromatic polyamid (PA6/6T MID), which is well suited for microinjection molding.

Laser Technology

The laser system used in this process is comprised of five mechanical and three optical axes. The lateral moving range of the xy-table comprises 200 x 200 mm with an absolute position accuracy of ±4 µm. The z-axis has a positioning range of 300 mm with an accuracy of ±3 µm. An axis of rotation (360°, accuracy ±10°) is mounted on a swivel axis (±90°, 10°) to allow an infeed of parts with multiple planes to be structured.

The initial laser beam is focused, positioned, and deflected within a scanning volume. Three optical axes make it possible to guide the laser focus spot within a plane as well as along complex three-dimensional contours. The laser beam is moved relative to the work piece with two deflecting mirrors in lateral direction. Moving mirrors are synonymous to low moving masses. The result is an extremely high working speed and thus an economical throughput. The mirrors are mounted on a rotational axis of special motors (galvanometer scanner). In addition to high positioning speeds, high accuracies can be provided.

The third optical (a Kepler telescope) axis provides a shift in longitudinal direction. This shift is achieved by moving one of the lenses mounted on a linear translator. At present a scanning volume of 200 x 200 x 50 mm³ can be reached.

Basically the system can be operated with an ultraviolet (λ = 355 nm) or infrared (λ = 1064 nm) laser. Up to now only UV laser radiation has been used for the activation of the thermoplastics. The laser source that has been used for the laser activation process is a frequency-tripled Nd:YAG laser (λ = 355 nm). Increasing absorption characteristics of polymer materials as well as decreasing spot diameters with smaller wavelengths enable the polymer ablation with the desired characteristics of cracking the organometallic complexes and roughening the surface for a metallization of strong adhesion. This is supported by operating the laser in Q-switch mode producing extremely short pulse durations combined with extremely high pulse powers. The small spot sizes also make it possible to achieve finest lines down to approximately 20 µm.

The laser beam is homogenized in order to achieve a constant intensity distribution over a defined cross section. On the other hand a typical laser beam intensity profile is Gaussian. Therefore, less energy is incorporated into the surface of the thermoplastic at the edges of the laser-structured track than within its center. As a result a melting zone is formed at the edges of the track, which should be avoided in terms of a strong metallization adhesion. Thus a clearly defined beam profile with a homogeneous intensity distribution is required. This kind of "Top Hat" beam can be implemented, using fibers for example, a pipe with mirror-glass on the inside or an individual diffractive component.

Current research focuses on a circular Top-Hat intensity profile that is generated using diffractive lenses. At present, diffractive optical elements (DOE) are used in laser technology, fiber technology, communications technology, projection lens technology, and sensor technology.

Material Properties

In connection with the investigations on the characteristics of the developed thermoplastics, measurements of the viscosity in dependence on the shear speed are very important. The dependence does not show any significant difference to standard PP. This proves that high quality components can be fabricated in standard injection molding processes with doped PP. This also applies to PBT and PA6/6T MID.

Apart from impressing electrical and mechanical properties of doped PP and PBT, the exceptional adhesion strength of the plating with values of 13 N/cm for PP-MID, 8 N/cm for PBT-MID and 10N/cm for PA6/6T MID, is important for the circuit board manufacturing industry. Figure 4 shows a complete fabrication of a 3D-MID part, from the molded part to a complete circuit with components.

Figure 4: Complete chain for manufacturing a 3D-MID: molding, activation, plating, and component assembly

Conclusion and Outlook

Laser supported additive metallization of different thermoplastic materials for 3D-MIDs is an environmentally friendly technology for structuring fine lines down to approximately 20 µm for microelectronic applications with a high throughput. At present three modified thermoplastic materials are available that can be injection molded in standard processes with exceptional mechanical and electrical properties. Applications are foreseen within the areas of telecommunication, sensors, and automotive systems.

This article was composed by M. Hüske and J. Kickelhain of LPKF Laser & Electronics AG, Germany; J. Müller the Chair of Manufacturing Technology, University of Erlangen-Nuremberg, Germany; and G. Eßer of the Bavarian Laser Center, Germany. For more information contact Stephan Schmidt of LPKF Laser & Electronics, 28220 SW Boberg Rd., Wilsonville, OR 97070 at (503) 454-4000 or sschmidt@lpkfusa.com. Visit LPKF online at www.lpkfusa.com.

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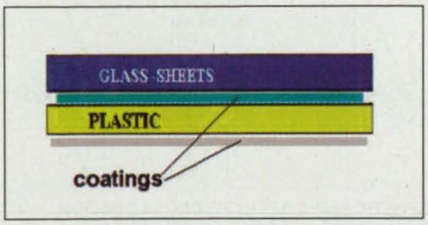
Thin, Flexible Laminate for Support of Electronic and Other Devices

AGFA



Flexible transparent plastic is used as a support for a number of applications. This technique shows how to combine the advantages of a glass layer (i.e. dimension stability, high density, hardness, and barrier properties against moisture, solvents and oxygen) with the properties of a polymer layer (i.e. flexibility) by laminating a glass layer together with a polymer layer. Applications include acting as a barrier layer for photomasks and flat panel displays or as a packaging material for electronic chips.

An improved glass laminate is provided with low specific weight, which enables the use of a continuous web for applying a functional layer by utilizing a borosilicate glass substrate having a thickness in the range from 10 to 450 µm preferentially between 50 and 200 µm. Thickness can go up to at least 700 µm. The bonding between the borosilicate substrate and the polymer support can be done by vacuum lamination or with a temperature sensitive, pressure sensitive, or ultraviolet light curable adhesive layer. The functional layer may be web coated on the glass substrate or the polymer support, or sandwiched between the two, as illustrated.

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Optical Pickup Employing VCSEL

This technology overcomes problems of conventional light out apparatus employing a Vertical Cavity Surface Emitted Laser (VCSEL). Widely used in optical applications such as optical pickup apparatuses and computers, the light emitted from a VCSEL is almost circular, highly dense, and operates in a single mode. Because of these emission characteristics, it is difficult to install a monitoring photodetector outside the light path of the VCSEL that can still receive the emitted light and control the VCSEL's output. This is due to the fact that the VCSEL emits light in a direction vertical to the upper surface of the monitoring photodetector. The lower surface is mounted on a semiconductor base. The following devices overcome these problems.

The housing incorporates a projector window for transmitting most of the light emitted from the VCSEL and reflecting some of the light back onto the base. The monitoring photodetector is installed on the base for receiving some of the light emitted from the VCSEL and reflected from the projector window, and converting the light into an electrical signal. In addition to the above, the optical pickup apparatus includes an object lens for concentrating the light on an optical recording medium by collecting light emitted from the VCSEL, a light path changing unit for changing the path of light reflected from the light record medium, and another photodetector for receiving the reflected light and converting it into an electrical signal to be fed to an error detection circuit.

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Self-Aligning Fiber Couplers for Microsphere Resonators

Critical relative positions would be maintained through contact of precisely dimensioned features.

NASA's Jet Propulsion Laboratory, Pasadena, California

Fiber-optic couplers for spherical, toroidal, and other, similarly shaped microscopic optical resonators that operate in whispering-gallery (WG) modes would be fabricated with integral alignment features, according to a proposal. These alignment features would facilitate coupling adjustments, which, heretofore, have been difficult and complex, as explained below.

Microsphere and similar resonators have been described in several previous *NASA Tech Briefs* articles. The couplers in question were described in "Simple Fiber-Optic Coupling for Microsphere Resonators" (NPO-20619), *NASA Tech Briefs*, Vol. 25, No. 5 (May 2001), page 70. To recapitulate: In the WG modes of a transparent microsphere, light orbits inside the sphere, where it is confined by total internal reflection. The high degree of confinement results in high Q (where Q is the resonance quality factor). Light is coupled into or out of the microsphere by exploiting the overlap of (1) the evanescent field of the WG modes with (2) the evanescent field just outside an angled end face of a single-mode optical fiber.

For efficient transfer of energy, it is necessary to align the microsphere with the fiber such that they are in the correct relative position and orientation for optimum overlap of their evanescent fields:

- The intersection of the core of the optical fiber with the angled end face of the fiber must lie at the point of closest approach of the fiber to the sphere;
- The axis of the fiber must lie in the plane of symmetry of the a circumferential "belt of light" into which the WG modes are concentrated; and
- The gap between the sphere and the angled end face of the fiber must be maintained stable within the range of the evanescent fields — typically between 0.5 and 1.5 µm.

It should be apparent that coupling adjustment between the microsphere and the angled end face of the optical fiber is critical and difficult. Heretofore, it has been necessary to rely on bulky external mounts and translation mechanisms to establish and maintain the correct alignment. The proposed alignment features would ensure the mechanical stability of the gap while reducing the number of adjustment degrees of freedom from five to two, thereby reducing the difficulty of the coupling adjustment and the amount of bulky equipment needed.

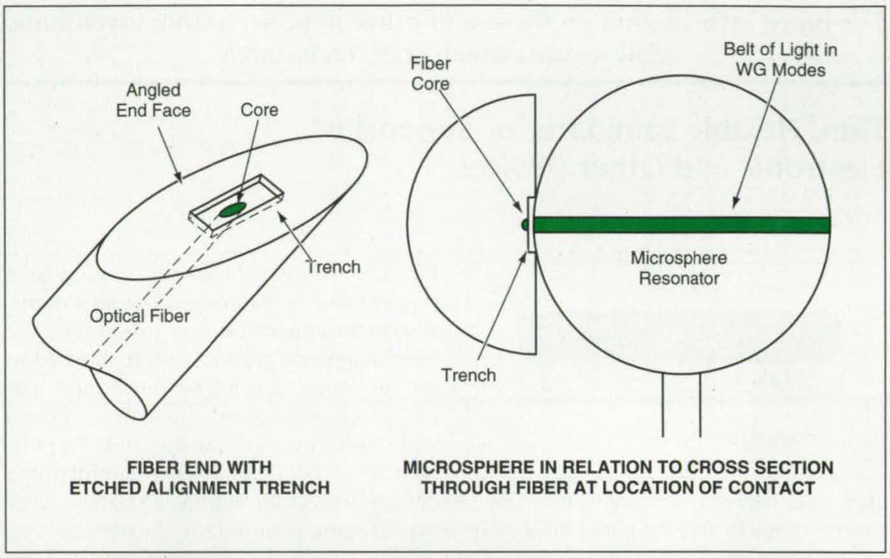

Figure 1. The **Trench on the Angled End Face** of the optical fiber would be placed in contact with the sphere, astride the belt of light of the WG modes. The depth and width of the trench would establish the desired gap between the fiber core and the sphere.

The simplest integral alignment feature according to the proposal would be a trench etched into the angled end face of the optical fiber, coincident with the major axis of the face and centered on the end face of the fiber core (see Figure 1). The sphere would be brought into mechanical contact with the long rims of the trench. In this configuration, the depth and width of the trench would determine the size of the evanescent-field coupling gap between the sphere and the end face of the fiber. The contact between the rims and the sphere would not appreciably affect the performance of the microsphere as a resonator because the trench would be made wide enough that the points of contact would lie outside the belt of light.

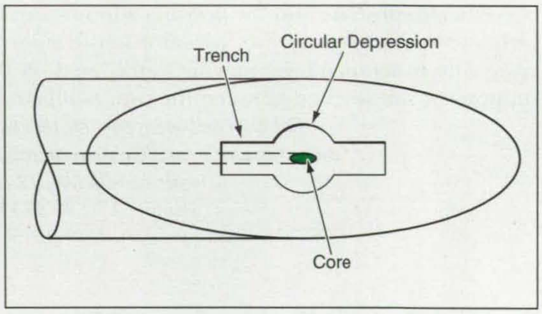

Figure 2. A **Circular Depression** of depth and width chosen to establish the desired gap could be superimposed on a narrower trench. The circular depression would make it unnecessary to perform an along-the-trench adjustment to place the end of the fiber core at the point of closest approach to the sphere.

To eliminate the need for an adjustment along the trench, one could replace the trench with a circular depression centered on the fiber core. As in the case of a trench, the depth and diameter of this depression would be chosen to obtain the desired gap size. Alternatively, as depicted in Figure 2, such a circular depression could be superimposed on a narrower trench.

This work was done by Vladimir Iltchenko of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Physical Sciences category.*

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Relatively Inexpensive Unobscured Large-Aperture Laser-Beam Expander

All of the reflecting and refracting surfaces are spherical.

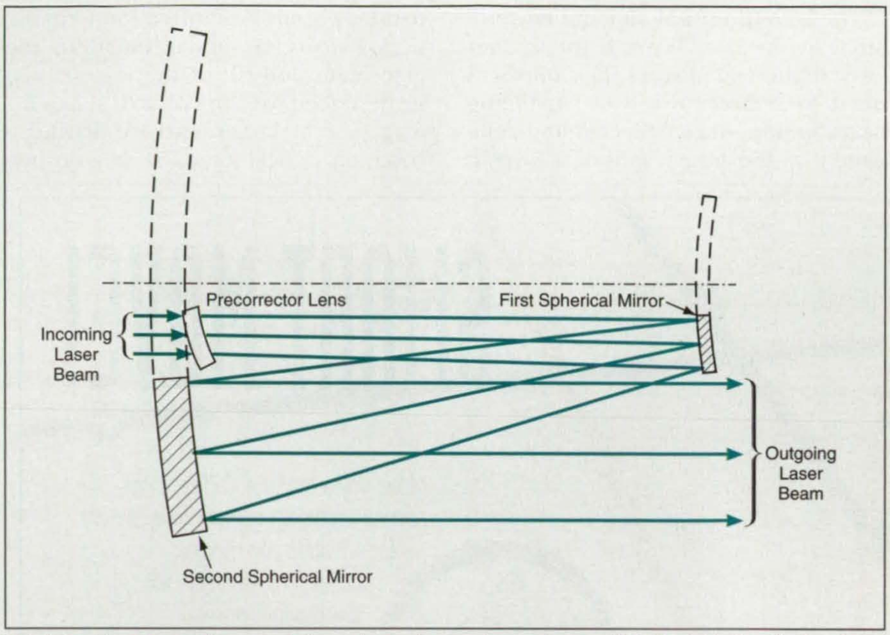
NASA's Jet Propulsion Laboratory, Pasadena, California

A design for an unobscured, large-aperture but otherwise compact laser-beam expander relies solely on spherical reflecting and refracting surfaces, yet provides a reasonably well corrected wavefront suitable for most applications. This design results from a tradeoff among compactness, cost, and performance.

The classical approach to the design of such a laser-beam expander typically involves the use of off-axis, aspherical mirrors and/or large lenses, which are expensive to fabricate. Spherical-surface mirrors and small spherical-surface lenses can be fabricated at substantially lower cost, but a beam-expander design based on such spherical-surface optics involves a tradeoff between compactness and performance.

The approach taken to arrive at the present design starts from an understanding that the design of a laser-beam expander need not afford all the performance characteristics of the classical telescope designs from which most beam-expander designs are derived. One consideration is that a laser-beam expander is not required to perform well over a wide field-of-view. A second consideration is that a laser-beam expander is required to perform well at only one wavelength. A third consideration is that limitations of fabrication capabilities make it impossible to achieve the maximum theoretical performance of a classical design in real hardware and that, in practice, a beam expander fabricated from a suboptimum design that calls for a small number of spherical (only) surfaces can be made to perform as well if not better, while costing much less.

The foregoing reasoning led to the present design (see figure), which calls for a minimum number of surfaces, all spherical, the largest being mirrors rather than lenses. The first optical element encountered by the incoming laser beam is a precorrector lens, which is so named because the radii of its spherical surfaces are chosen to introduce spherical aberration equal and opposite to that from the mirrors that follow. The lens is centered in the beam and tilted to introduce the correct amount of aberration to compensate for (precorrect) the off-axis aber-



This **Laser-Beam Expander**, containing only one lens and two mirrors with all spherical optical surfaces, offers good performance at relatively low cost.

rations caused by using the spherical mirrors at non-normal angles of incidence. The precise required thickness of the lens, radii of curvature of its surfaces, and angle at which it is tilted, depend on the index of refraction of the lens material, the wavelength of operation, and the mirror configuration.

The second optical element encountered by the laser beam is the smaller of two spherical mirrors. This mirror is tilted to redirect the now expanding beam so that, once collected and collimated by the larger spherical mirror, the beam passes the smaller spherical mirror without being obscured. The third and final optical element encountered by the laser beam is the larger spherical mirror, which is concave and is tilted to redirect the now collimated and expanded outgoing beam parallel to the incoming (unexpanded) beam. As is often found in optical systems of similar function, the placement and tilt of the mirrors can be described as being off-axis segments of a pair of larger mirrors sharing a common optical axis. The key distinction is that the "off-axis segments" in the design presented here are of spherical mirrors, so are themselves spherical, and hence easier (= relatively inexpensive) to fabricate.

The resulting wavefront performance is exceptionally well-corrected, with a nominal residual error so low as to be negligible in comparison with the effects of fabrication and assembly effects. The only aspect of performance that might be considered adverse is that the beam expansion is slightly anamorphic: the cross section of the output beam is elliptical, the minor axis being between 0.90 and 0.95 times as long as the major axis. If necessary, the anamorphism could be corrected by use of a more complex precorrector lens, still at an overall cost much less than that of a classical beam expander.

This work was done by Jeffrey Oseas of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Physical Sciences category.*

NPO-30432

Fiber-Optic Probe Uses Evanescent Waves To Sense Biofilm

Biofouling can be detected in less time than that needed in conventional culture-plate counting.

Lyndon B. Johnson Space Center, Houston, Texas

A compact instrument includes a fiber-optic probe that utilizes the evanescent-wave interaction to measure the accumulation of a biofilm. This instrument is a prototype of instruments that could be used to effect continuous monitoring and provide early warning of biofilms associated with bacterial contamination in diverse water systems, including potable-water supply systems, industrial heat-exchanger systems, and heating and cooling systems for buildings. The instrument makes it possible to detect biofouling of such systems sooner than the ends of the 24-to-48 hour incubation periods needed for conventional detection of bacteria by culture-plate counting.

The instrument has overall dimensions of 4 by 17 by 1.5 in. (about 10 by 43 by 4 cm) and is made from inexpensive optoelectronic components. One of the components is a light-emitting diode (LED). Modulated light from the LED is launched into the fiber-optic probe, which includes an unclad length of optical fiber that serves as a sensory element. Light travels along the fiber, past the sensory element, to a photodetector. The output of the photodetector is processed by a digital-interface circuit board connected to the parallel input port of a computer. In essence, what one seeks to compute is the proportion of light reaching the photodetector as an indication of the amount (if any) of biofouling on the sensory element.

Any biofilm attached to the sensory length of fiber affects the evanescent wave of the light propagating in the fiber. The effect is primarily a result of (1) a change in the index of refraction to which the evanescent wave is subject and (2) increased scattering of light. The evanescent wave is shallow enough that the instrument exhibits a significant response to as little as a monolayer of bacteria.

The design of the instrument was guided by a mathematical model that assisted in the optimization of the instrument performance and the prediction of the response of the instrument to specified changes in the index of refraction of the medium surrounding the sensory element. The overall response of the instrument to a change in the index of refraction is characterized by, among other things, a time of less than 1 minute. In tests in which bacterial cultures were added to, variously, distilled water or plant-nutrient solutions, peak first-stage responses occurred within 1 to 6 hours and peak second-stage responses took place after 3 to 10 hours.

This work was done by Ron Michaels of Polestar Technologies, Inc., for **Johnson Space Center**. *For further information, contact the Johnson Commercial Technology Office at (281) 483-3809; commercialization@jsc.nasa.gov*
MSC-22880

Spotlight Radiometer

The principal use of this instrument would be remote sensing of gases.

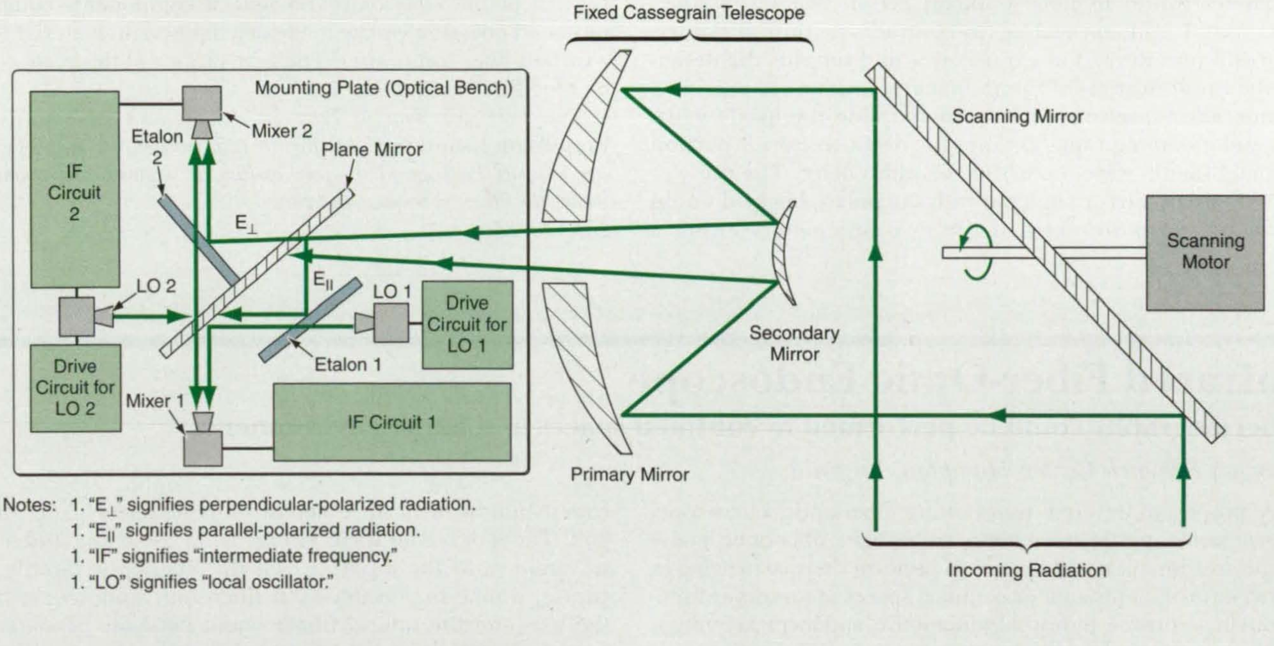
NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed radiometric instrument denoted the spotlight radiometer (SLR) would operate in a frequency band centered at ≈557 GHz and would scan in a conical or circular pattern. The SLR was conceived for use in obtaining spatially and spectrally resolved indications of CO and H_2O molecules in the Martian atmosphere. The basic SLR design is also adaptable to terrestrial use and to operation in different submillimeter-wavelength bands.

Although the SLR would include a Cassegrain telescope, the telescope would not be moved to effect scanning. Instead, the telescope would be fixed and scanning would be effected by simply turning a lightweight, flat mirror in front of the telescope. The entire instrument would fit inside a cylindrical envelope or canister, the diameter of which need not exceed that of the primary reflector of the telescope. The advantages afforded by the foregoing design features include light weight, convenient placement of the electronic and optical components, and simple, compact construction.

The angle between the flat scanning mirror and the optical axis of the telescope would determine the cone angle of the scan pattern. This angle could be set, for example, to enable scanning of the horizon or of an annular region of the sky. The flat mirror could be constructed easily and, because it could be very lightweight, a low-torque scanning motor would suffice and it would be possible to scan at a high rate. At one or more angular positions of the scan, the viewing of the exterior scene could be blocked out for radiometric calibration.

After reflection from the scanning mirror and passage through the Cassegrain telescope, incoming radiation would pass through a polarizing



Notes: 1. "$E_\perp$" signifies perpendicular-polarized radiation.
1. "$E_{\parallel}$" signifies parallel-polarized radiation.
1. "IF" signifies "intermediate frequency."
1. "LO" signifies "local oscillator."

The **Scanning Mirror** and its motor would be the only moving parts in this instrument.

beam splitter in the form of a wire grid tilted at an angle of 45° to the optical axis. From this beam splitter, each of the two polarization components of the radiation would travel to one of two heterodyne radiometers. Hence, the SLR would provide simultaneous readings of both perpendicular- and parallel-polarized radiation.

In addition to a local oscillator, each heterodyne radiometer would include a silicon etalon beam combiner. The use of a silicon etalon (in contradistinction to the use of a different device) as a diplexer would simplify the design of the input portion of the radiometer and would provide a temperature-insensitive means of coupling the local-oscillator and incoming radiation into the down-converter portion (submillimeter-wave mixer) of the radiometer. The use of a double-sided mirror coplanar with the polarizing grid would facilitate the positioning of the two radiometers within a confined space. Even if polarization measurements were not required in a given application, the use of both polarization channels would make it possible to increase the signal-to-noise ratio slightly.

The mixer and local oscillator of each heterodyne radiometer would be conveniently situated near their respective drive elements and within the shadow of the primary telescope mirror. All of the electronic and optical components could be mounted on a single plate made of a lightweight material (e.g., a carbon-fiber composite). The rear surface of this plate could be used for heat sinking.

This work was done by Peter Siegel of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Physical Sciences category.*

NPO-30183

Infrared Fiber-Optic Endoscope

Thermography could be performed in confined spaces and harsh environments.

Langley Research Center, Hampton, Virginia

A proposed infrared transmitting fiber-optic endoscope, which would partly resemble a visible-light fiber-optic endoscope, instrument could be used to perform thermal imaging in harsh environments and/or confined spaces in a variety of situations in aerospace, industrial, automotive, and medical settings.

Like a typical visible-light fiber-optic endoscope, the proposed instrument would include a coherent fiber-optic infrared bundle with an objective lens attached to its distal end. The lens would focus energy from the scene under observation onto the input face of the fiber-optic bundle. Of course, unlike in a visible-light fiber-optic endoscope, both the lens and the optical fibers would be made of materials that transmit a substantial proportion of the infrared energy in a wavelength range useful for observing at the temperature range of interest.

Another infrared-transmissive lens at the proximal end of the coherent fiber-optic bundle would focus the infrared image of the scene from the output face of bundle onto a planar array of infrared photodetectors. The outputs of the photodetectors would be processed by electronic circuitry to generate a temperature map of the scene and/or a visible analog of the infrared image of the scene. In the processing, the photodetector outputs would be converted to temperatures at corresponding locations in the scene on the basis of a photodetector calibration and radiative properties that may be known or assumed in accordance with physical conditions in the scene.

The main advantage of this instrument is that the relatively compact, rugged viewing optic could be inserted in the confined and/or inhospitable environment containing the scene to be observed, while the rest of the instrument could be accessible and located in a hospitable environment. The instrument would be tailored for the temperature range of interest through the choice of lens and fiber-optic materials as mentioned above plus the choice of photodetectors suitable for the wavelength range corresponding to the temperature range. For example, one could choose a PtSi-based detector array for shorter wavelengths corresponding to higher temperatures or an HgCdTe-based array for longer wavelengths corresponding to lower temperatures.

This work was done by Stephen E. Borg and Christopher E. Glass of **Langley Research Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Physical Sciences category.*

LAR-16149

Adjusting Polarization To Reduce Error in an Interferometer

There is no need for additional equipment, signals, or signal processing.

NASA's Jet Propulsion Laboratory, Pasadena, California

An unconventional and highly effective technique has been devised to reduce cyclic errors that arise in the operation of a displacement-measuring heterodyne optical interferometer. The cyclic errors are attributable largely to undesired small exchanges of power between light beams that are nominally in mutually orthogonal polarization states (such exchanges are denoted generally as polarization leakage). Unlike some prior techniques for reducing cyclic errors, the present technique does not require additional optical or electronic signals, additional signal processing, or use of optical components other than those of the interferometer itself. Optionally, the present technique can be used in conjunction with the prior techniques to reduce errors further.

The figure schematically depicts a heterodyne optical interferometer that includes a target retroreflector and a fiducial retroreflector, the purpose of the interferometer being to measure displacements between these two retroreflectors. The beam from a single laser is split into two that are shifted in frequency by different amounts. Beam 1, having frequency ν_1, is designated the target beam; beam 2, having frequency ν_2, is designated the local or reference beam. The beams are collimated and then polarized orthogonally to each other: beam 1 is given s (out-of-plane) polarization, while beam 2 is given p (in-plane) polarization. The beams are combined at the injection polarizing beam splitter. A small fraction of the power of both beams is picked off at the reference beam splitter, combined at the reference polarizer, and mixed by the reference photodetector, which generates the reference heterodyne signal at the beat frequency ν_1–ν_2.

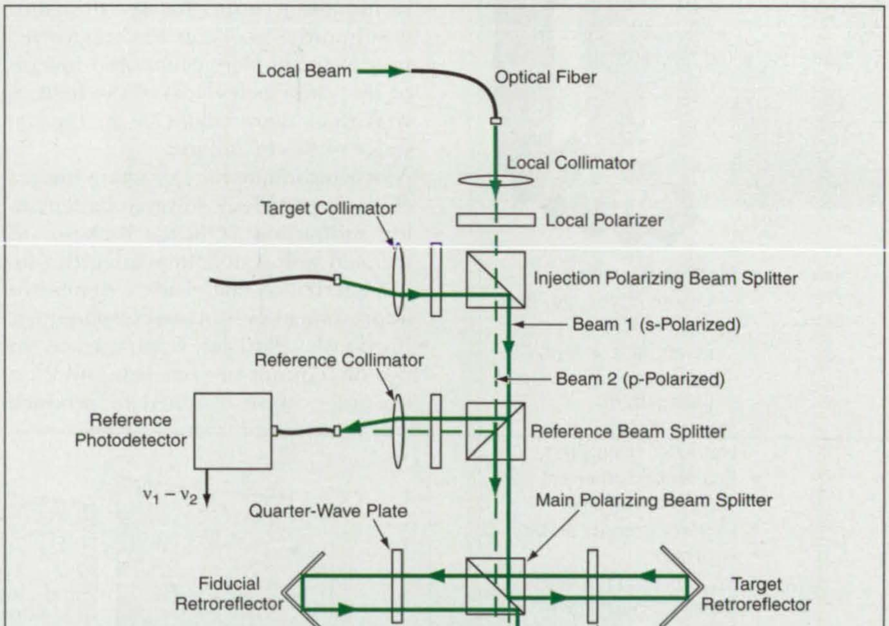
Most of the light propagates to the main polarizing beam splitter. Beam 2 (the p-polarized reference beam) passes through this beam splitter to the signal photodiode. Beam 1 (the s-polarized target beam) is reflected by this beam splitter onto the target path, where it makes a round trip between the target and fiducial retroreflectors and is then reflected into the signal photodiode, wherein beams 1 and 2 are mixed to obtain the target heterodyne signal at the beat frequency. Nominally, the phase of the target heterodyne signal relative to that of the reference signal varies linearly by 2π radians per half wavelength of the target/retroreflector displacement. Hence, the variation of this phase is measured to determine the displacement.

In practice, the variation of phase with displacement deviates from perfect linearity because of a number of leakages, which give rise to the aforementioned cyclic errors. The main leakage is the passage of a small portion (≈0.1 percent) of s-polarized power from beam 1 directly through the main polarizing beam splitter to the signal photodetector.

In the present technique, one makes no attempt to reduce this main s-polarized leakage, because it cannot be stopped without also blocking the desired signal. Instead, one takes advantage of the fact that for complex reasons that involve the amplitude and phase relationships among the various polarization components, it is possible to compensate for the effects of the s-polarized leakage by deliberately introducing some additional p-polarized leakage from beam 2 onto the target path. First, one refines the alignments of all relevant optical components to minimize leakages other than the main one. Then, in a multistep procedure, one iteratively adjusts the polarizers and quarter-wave plates to introduce the correct amount of compensatory p-polarized leakage. The procedure can be alternatively characterized as one of seeking the optimum adjustment of the optical components. When optimum adjustment is achieved, the cyclic displacement-measurement error caused by the main and other leakages can be reduced by a large factor (≈10), without nulling the desired signal.

This work was done by Oliver Lay of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Physical Sciences category.*

NPO-30380



This Is a Typical Heterodyne Optical Interferometer for measuring displacement. Cyclic errors in displacement measurements can be reduced through optimal adjustment of the beam splitters and polarizers to minimize the net deleterious effect of polarization leakage.

General-Purpose Stereo Imaging Velocimetry

This method enables three-dimensional quantitative characterization of flow fields.

John H. Glenn Research Center, Cleveland, Ohio

An improved and expanded method of stereo imaging velocimetry (SIV) for diagnosing three-dimensional flows of gases, liquids, and other fluids involves the use of standard charge-coupled-device cameras positioned orthogonally to each other. In addition to providing a full-field, quantitative, three-dimensional map of any optically transparent flow seeded with tracer particles, this SIV method incorporates a camera-calibration technique, in which rotation and translation of camera lenses and optical distortion generated in the lenses are taken into account by use of an accurate two-dimensional-to-three-dimensional mapping function.

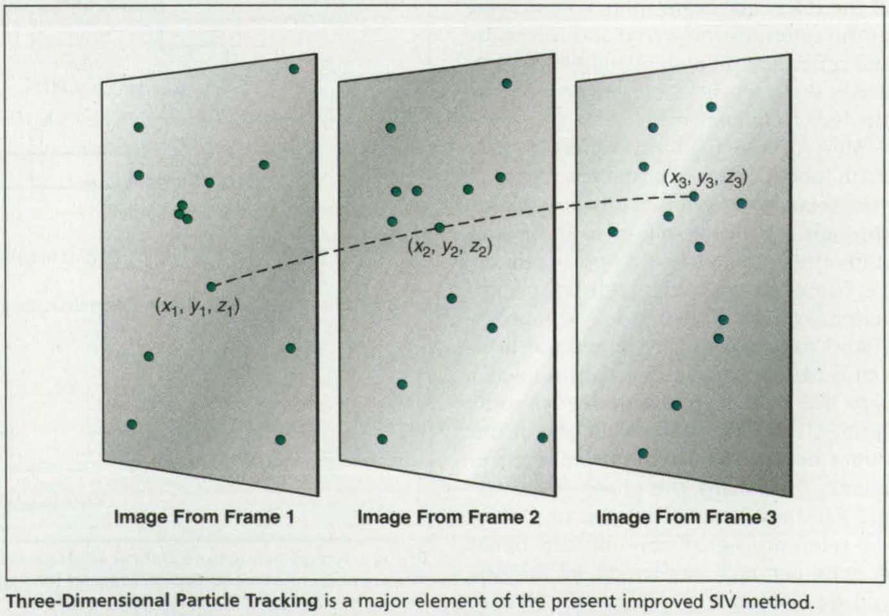
Other improvements over the basic SIV method incorporated into the present method include the following:

- An additional image-reconstruction technique accounts for severe distortion in order to enable the reconstruction of incomplete calibration images so that there is less loss of the field of view than there would be in the absence of this technique.
- A new technique for extracting images of tracer particles involves nonattenuating subtraction of image background coupled with a nonattenuating threshold alternative that yields a significant improvement over previous techniques.
- Previously, particles were tracked in two dimensions in each view and then the tracks were matched to produce approximate three-dimensional vectors. A new technique for tracking particles in three dimensions provides true three-dimensional velocity vectors from two orthogonal views or from any set of three-dimensional data. This is a significant advancement in SIV.
- Color image processing has been added, making it possible to analyze flows of multiphase fluids, thereby expanding capabilities and applications beyond those of SIV as practiced heretofore.

While there is a patent on SIV (U.S. Patent 5,905,568), the present method goes beyond the patent, making possible experiments that were previously impossible. In particular, true three-dimensional particle tracking has not been done in SIV until now. The present method makes it possible to perform quantitative, three-dimensional, full-field analyses of flow fields in any fluids that can be seeded with tracer particles.

This work was done by Mark McDowell of **Glenn Research Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Physical Sciences category.*

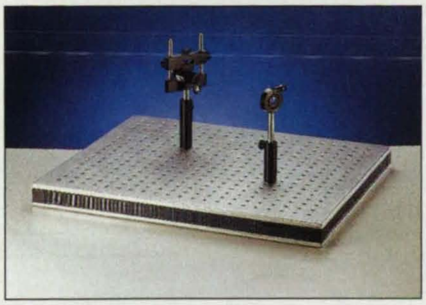
Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-17241.



Three-Dimensional Particle Tracking is a major element of the present improved SIV method.

Product Guide: Breadboards

Edmund Industrial Optics
Barrington, NJ
www.edmundoptics.com



Composite
Size: 19x23 to 35x47 in.
Thickness: 2 in.
Material: Ferromagnetic stainless steel with honeycomb core
Flatness: ±0.005 in.

Kinetic Systems, Inc.
Boston, MA
www.kineticsystems.com

VIBRALITE™
Series 5500
Size: 12x12 to 24x48 in.
Thickness: 1 or 2 in.
Material: Aluminum
Flatness: ±0.004 in.

5600 & 6100 Series
Size: 12x12 to 48x96 in.
Thickness: 1 or 2 in.
Material: Ferromagnetic stainless steel with aluminum core
Flatness: ±0.004 in.

5700 & 5800 Series
Size: 12x12 to 48x96 in.
Thickness: 2 or 4 in.
Material: Ferromagnetic stainless steel with honeycomb core
Flatness: ±0.004 in.

Melles Griot
Carlsbad, CA
www.mellesgriot.com

UltraLight™ Series
Size: 12x12 to 48x72 in.
Thickness: 1 or 2.2 in.
Material: Aluminum alloy with honeycomb core
Flatness: ±0.006 in.

Performance™ Series
Size: 12x12 to 48x96 in.
Thickness: 2.4 or 4.3 in.
Material: Magnetic stainless steel with honeycomb core
Flatness: ±0.004 in.

PerformancePlus™ Series
Size: 12x12 to 48x96 in.
Thickness: 2.4 or 4.3 in.
Material: Magnetic stainless steel with double honeycomb core
Flatness: ±0.004 in.

Thorlabs, Inc.
Newton, NJ
www.thorlabs.com

Aluminum
Size: 4x4 to 48x48 in.
Thickness: 1/2 or 3/4 in.
Material: Aluminum

Lightweight Honeycomb
Size: 12x12 to 48x120 in.
Thickness: 0.8, 1.3, 2.3 or 4.3 in.
Material: Stainless steel with honeycomb core
Flatness: ±0.005 in.

Optical
Size: 12x24 to 36x72 in.
Thickness: 2 in.
Material: Magnetic stainless steel
Flatness: ±0.004 in.

Technical Manufacturing Corp. (TMC)
Peabody, MA
www.techmfg.com

75 Series
Size: 19x23 to 35x47 in.
Thickness: 2 in.
Material: Ferromagnetic stainless steel with honeycomb core (Aluminum and Carbon steel available)
Flatness: ±0.005 in.

77 & 78 Series
Size: 12x12 to 48x96 in.
Thickness: 2 or 4 in.
Material: Ferromagnetic stainless steel with honeycomb core
Flatness: ±0.005 in.

Vere Inc.
New Kensington, PA
www.vere.com

Optical
Size: 1x1 to 118 x240 in. for single unit, any dimensions for joined structures
Thickness: 0.8, 1.3, 2.3, 4.3, 8.3, 12.3, 16.3, 20.3 in., up to 96 in.
Material: Ferromagnetic steel with composite honeycomb core (Plastic, Composites, Ceramic, Aluminum and Titanium skins available)
Flatness: ±0.01 in.

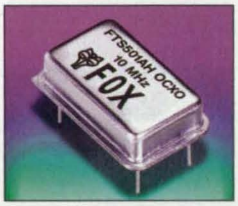
New Products

Product of the Month

Precision Tunable Laser Sources

ILX Lightwave's (Bozeman, MT) TLS 8800 Series Precision Tunable Laser Sources enable fast, high-resolution, low-noise wavelength dependent measurements at an affordable price. The TLS-8801 C-band and TLS-8802 L-band Tunable Laser Sources feature an integrated wavelength reference and monitor, offer + 13 dBm of power with excellent stability, and come equipped with an intuitive user interface and standard GPIB remote interface for easy incorporation into automated production test systems or computer controlled laboratory tests. The integrated power monitor maintains a power flatness of ±0.05dB over the full tuning range. These compact instruments measure 88mm x 212mm x 269mm, offer absolute wavelength accuracy of ±1pm, and can be use in one of three modes: swept, step-lock-measure, or discrete wavelength operation. The instrument can tune or sweep in either direction, increasing or decreasing wavelength.

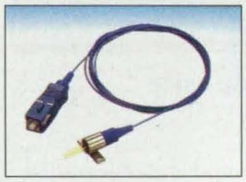
For Free Info visit www.nasatech.com/ilx



Crystal Oscillators

Fox Electronics (Fort Myers, FL) has added a new line of OCXOs (oven compensated crystal oscillators) to its line of frequency control products. The new FTS501AH OCXO meets stratum level accuracy requirements for telecommunications applications, offers a frequency stability of ±250 ppb over the standard temperature range of 0°C to 70°C (32°F to 158°F), and an overall accuracy of ±4.6 ppm for all conditions over 10 years. Frequency range of the new OCXO is 10 to 40 MHz. Supply voltage is 5.0 V, with 3.3 V available, and control voltage is 0.5 V to 5.0 V.

For Free Info visit www.nasatech.com/fox



InGaAs Avalanche Photodiode

The G8930 InGaAs avalanche photodiode (APD) from Hamamatsu (Bridgewater, NJ) has the performance and reliability necessary for design into a variety of optical communications applications. Features include high-speed response, typical sensitivity of -31dBm at its maximum response of 2.5 Gb/s, and typical overload of -5 dBm. Typical photosensitivity is 11 V/mW at both 1.31 μm and 1.55 μm bands. The APD also features a pigtail that can have a variety of connectors, including SC/SPC, FC/SPC, MU, and LC.

For Free Info visit www.nasatech.com/hamamatsu

CCD Based Spectrometer

Edmund Industrial Optics' (Barrington, New Jersey) CCD Based Spectrometer is available in three standard configurations for UV (200-400nm), VIS (400-700nm), and NIR (700-1050nm) wavelengths. All three spectrometers plug directly into a computer's RS-232 port with the included cable, or to a USB port by way of a converter. The 10mm Cuvette holder is useful for transmission, absorption, or fluorescence applications, and has three SMA905 connections to illuminate a sample or detect light from it. The reflectance probe illuminates samples via two 200 micron fibers and captures reflected light through a 200 micron fiber.

For Free Info visit www.nasatech.com/edmund

Color & Monochrome Megapixel Cameras

JAI A/S (Copenhagen, Denmark) has enhanced the CV-M7 (color) and CV-M4 (monochrome) megapixel camera series to include higher resolution (increased from 1.3 to 1.45 million pixels), increased sensitivity (by 6dB), and reduced smear (by 2dB). The new cameras also feature the new JAI serial interface protocol, based on short ASCII commands, and LVDS or Camera Link interface for ease of system integration. The cameras provide 1392 × 1040 pixel resolution and utilize proprietary sample/hold and correlated double sampling (CDS) techniques to achieve double-speed readout without sacrificing dynamic range or image fidelity.

For Free Info visit www.nasatech.com/jai

Proximity Sensors

Madison Company's (Branford, CT) P Series Proximity Sensors provide a variety of ways to sense the relative position of specific machine elements requiring continuous monitoring. Offered in both plastic and metal housings, these sensors incorporate reed switch-based technology, which will remain reliable for up to 5 million cycles, and have no moving parts. Operating times are as short as 0.6 mSec. and release times are as short as 0.05 mSec. These sensors are interchangeable with other sensors of similar characteristics. Engineered designs available for individual application requirements.

For Free Info visit www.nasatech.com/madison

High Index, Optically Clear Gel

Fiber Optic Center (New Bedford, MA) now offers Optical Gel LS-3252, manufactured by Lightspan™. This soft encapsulation material is designed to protect sensitive photonics and flat panel display assemblies from mechanical and thermal shock, dust, and moisture. LS-3252 is optically clear from the near UV to the near IR, has a refractive index of 1.52 for index matching to BK7 glass and acrylic plastics, and features an 8-hour pot life. It cures in 24 hours at room temperature without the need for UV exposure or high temperature bake.

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Materials

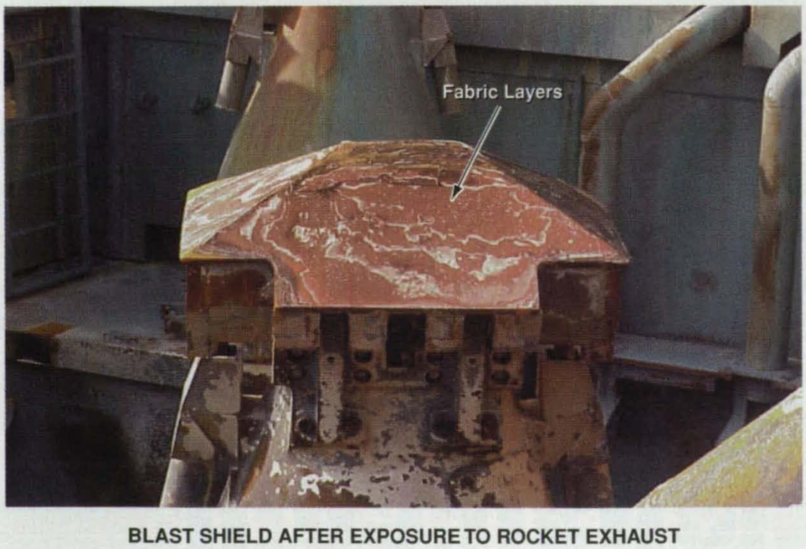
Ablative Coat Protects Against Brief, Intense Heating

A substrate can be protected against a rocket blast for a short time.

John F. Kennedy Space Center, Florida

An ablative composite coating has been developed to protect a steel substrate against a short-duration exposure to supersonic stream of hot gases and molten ceramic particles. In the original application, the short-duration hot, abrasive flow is resultant from the shuttle solid-fuel rocket motor exhaust during launch. The steel substrate to be protected is a holddown-post blast shield on a space-shuttle mobile launcher platform. The maximum temperature in the rocket blast exceeds 5,500 °F (≈3,000 °C), and the heat load on the blast shield can exceed 8,000 Btu/ft^{2}s (≈91 MW/m^{2}s). Other components and launch accessories exposed to similar intense, short-duration, heat loads could also be protected by use of similar composite coatings.

NEWLY COATED BLAST SHIELD



BLAST SHIELD AFTER EXPOSURE TO ROCKET EXHAUST

Some of the Layers of Fabric and silicone rubber were removed from the laminated coat by exposure to rocket exhaust. However, enough of the laminate remained (except at the corners) to prevent excessive heating of the substrate.

The basic architecture of this ablative composite coating is a high-density, room-temperature-cured silicone (RTV), reinforced with layers of glass fabric. By chemically preparing the substrate and fabric laminates and by use of vacuum consolidation during cure, a coating is created that not only provides the known ablative properties of silicone resins, but also provides the physical strength to withstand the enormous pressures and shear forces encountered during exposure with delamination or debonding from the substrate.

In this application, the substrate is prepared by sandblasting an application of a hydrolyzable silicone primer. If necessary, the thick trowelable putty is made from RTV and a ceramic powder. Layers of glass fabric are preprocessed to remove the sizing and chemically treated to ensure a strong resin-to-fiber bond. The laminate is then built up to the required thickness by applying alternating layers of fabric and silicone resin. After sufficient layers have been applied, caul plates are applied and the entire blast cover cured under moderate vacuum pressure to squeeze out excess resin and ensure a strong coating-to-substrate bond.

The figure shows a newly coated blast shield and a blast shield after an exposure to the rocket exhaust. The average thickness of the ablative coating when new was 0.542 in. (≈13.8 mm); the average thickness after exposure was 0.165 in. (≈4.2 mm). The thickness of the coating was found to be adequate everywhere except at two corners. Ceramic particles in the rocket exhaust did not adhere to the silicone rubber. The silicone rubber at the steel substrate and the laminate exhibited no visible signs of deterioration. This observation was interpreted as signifying that the ablative coat succeeded in keeping the temperature at the bond surface below 600 °F

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forward engineering

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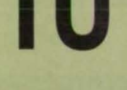
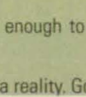
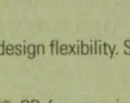


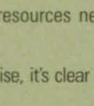
withstand wear. High-performance engines built with bushings, vanes, and wear strips that endure high temperatures and provide low friction. Exceptionally clean retainer rings, chamber liners, and in-process components, durable enough to resist chemical attacks. But before you go setting the design world on its edge, you need a range of materials versatile enough to make these visions a reality. Good thing DuPont™ Vespel® Parts and Shapes are equal to the task. In fact, our expanded new lineup consists of five families of material solutions that



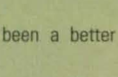
provide a unique combination of physical properties, while offering you the ultimate in design flexibility. Starting as the Vespel® S line, the family has grown significantly to include the introduction of Vespel® TP for maximum geometric flexibility, Vespel® CP for superior heat resistance and strength, Vespel® CR for maximum chemical resistance, and Vespel® ASB, which combines materials for specific applications.



Now more than ever, we have the resources necessary to help you realize your vision from start to finish. With the culmination of our expanded line of products and in-depth technical expertise, it's clear that Vespel® Parts & Shapes are the perfect complement to the mindset of an engineer focused on not only meeting customer requirements, but breaking



new ground as well. After all, making things stronger, faster, lighter, and, subsequently, more efficient is what Vespel® Forward Engineering is all about. All things considered, there's never been a better time to think Vespel® Parts & Shapes early on in the design process. An idea more and more engineers are waking up to. For more information on what our expanded line of material solutions can do for you, go to www.dupont.com/vespel or call 1-800-972-7252. If you can dream it, we can make it.



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(below approximately 320 °C). Except for a minor surface crack at one corner, the blast shield was undamaged.

This work was done by Robert C. Dyer, Martin J. Wilson, Jean M. Charvet, and Burton J. Pelkey, Jr., of United Space Alliance for **Kennedy Space Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Materials category.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Technology Programs and Commercialization Office, Kennedy Space Center, (321) 867-4879. Refer to KSC-12285.

Insertion of Reactive Material for Treating Groundwater

There is no need to remove most of the overlying soil.

John F. Kennedy Space Center, Florida

An improved method of inserting reactive material in the ground for treating groundwater contaminated with chlorinated solvents has been devised. An older method involves the removal of a significant portion of soil overlying the treatment volume, and consequently the expensive off-site disposal of the large amount of removed soil (some or all of which is contaminated). In the improved method, only a relatively small amount of soil need be removed.

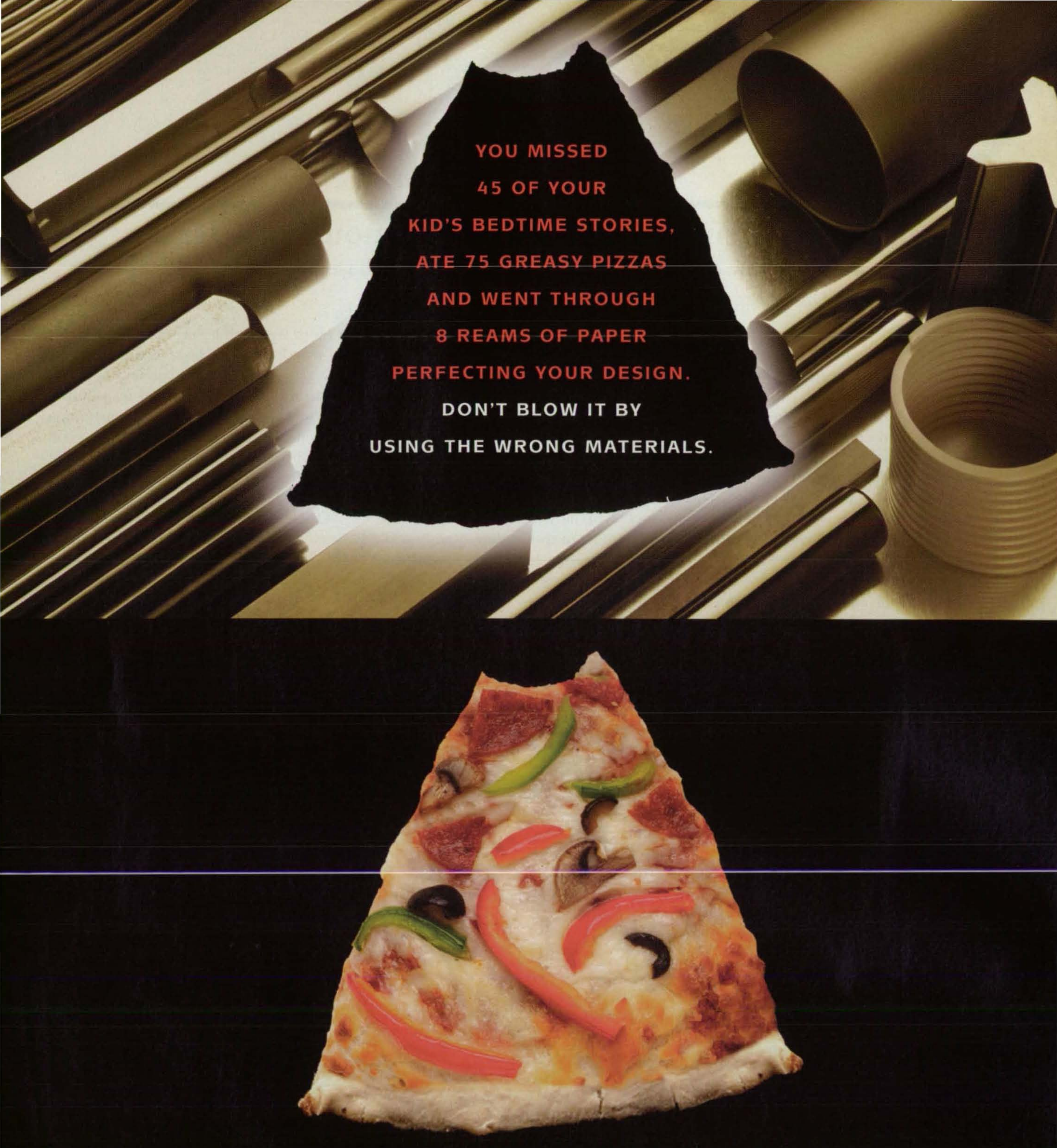
The first step in the improved method is to remove approximately the first 4 ft (1.2 m) of soil from above the water table where the reactive material is to be placed. Hollow casings are inserted in the ground surface over the treatment site, then hammered down to the required placement depth. [The placement depth in the original application at Kennedy Space Center was 40 ft (12 m).]

Once each casing reaches the required depth, a gravity-fed hopper is used to fill the casing with the reactive material plus, if needed, bulking material to increase permeability. The casing is then removed, leaving behind a column of treatment material. In this manner, several such columns are positioned throughout the treatment volume.

An *in situ* deep-soil-mixing rig is then used to mix the reactive columns with the adjacent soil. Thorough mixing is achieved by up-and-down motion of the rig. The rig includes paddles, the turning of which acts in combination with the up-and-down motion to help increase the permeability of the soil.

This work was done by Jacqueline Quinn of **Kennedy Space Center** *and Debra R. Reinhart, Christian A. Clausen III, Manoj B. Chopra, and Cherie L. Geiger of the University of Central Florida. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Materials category.*

This invention has been patented by NASA (U.S. Patent No. 6,207,114). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Technology Commercialization Office, Kennedy Space Center, (321) 867-8130. Refer to KSC-11957.


YOU MISSED
45 OF YOUR
KID'S BEDTIME STORIES,
ATE 75 GREASY PIZZAS
AND WENT THROUGH
8 REAMS OF PAPER
PERFECTING YOUR DESIGN.
DON'T BLOW IT BY
USING THE WRONG MATERIALS.

Formation Alignment of Multiple Autonomous Vehicles

Alignment is achieved by use of lasers, optical sensors, and rule-based controls.

NASA's Jet Propulsion Laboratory, Pasadena, California

A table-top experiment on formation alignment of three air-levitated robotic vehicles has been performed to demonstrate the feasibility of a more general concept of controlling multiple robotic vehicles to make them move in specified positions and orientations with respect to each other. The original intended application of the concept is in the control of multiple spacecraft flying in formation, as described in "Synchronizing Attitudes and Maneuvers of Multiple Spacecraft" (NPO-20569) on page 64 in this issue of *NASA Tech Briefs*. In principle, the concept could also be applied on Earth to control formation flying of aircraft or to coordinate the motions of multiple robots, land vehicles, or ships.

The experimental system is, of course, much simpler than a fully developed multiple-robot formation-alignment system would be. In this system (see figure) the three vehicles are levitated over a flat table by air bearings generated from internal supplies of compressed air. Each vehicle is equipped with valves that can be opened momentarily under electrical control to allow jets of compressed air to escape in order to control horizontal translation of the vehicle and/or rotation of the vehicle about a vertical axis.

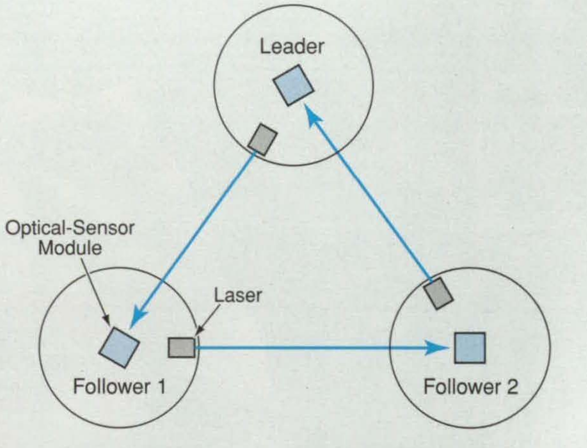
The problem chosen for the experimental demonstration is to make the three vehicles position and orient themselves at the corners of an equilateral triangle. Even in this simple system, the formation-alignment scheme is highly complex; the most that can be done to describe it in this article is to do so indirectly by summarizing the major features of the equipment and the formation-alignment scenario as follows:

The formation-alignment scheme chosen to solve the triangle problem involves the use of lasers, optical sensors, and control subsystems that implement rule-based motion-control algorithms in response to optical-sensor readings. The control subsystems of the vehicles also communicate with each other via radio transceivers.

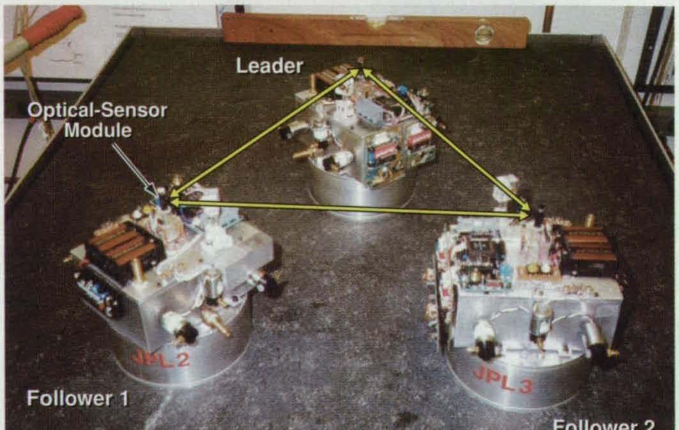
Each vehicle is equipped with a laser and with an optical-sensor module with an optical axis at an angle of 60° with the laser axis. One of the vehicles is designated the leader, while the others are designated follower 1 and follower 2. The leader initiates the alignment process by activating its laser and rotating to look for follower 1. When the optical sensors of follower 1 detect the laser beam from the leader, follower 1 sends a radio signal to the leader to cause the leader to stop rotating. Follower 1 then performs fine adjustments of its attitude relative to the laser beam from the leader.

Once follower 1 has completed its fine alignment, it turns on its laser and sends a radio signal that commands follower 2 to search for the laser beam from follower 1. This search involves a sequence of prescribed rotations and translations. Follower 2 terminates its search as soon as its optical sensors detect the laser beam from follower 1. Follower 2 then performs fine adjustments of its attitude with respect to the laser beam from follower 1.

Once follower 2 has completed its fine alignment with the laser beam from follower 1, follower 2 turns on its laser and begins a final alignment mo-



BASIC GEOMETRY OF THE EXPERIMENT



PHOTOGRAPH OF THE THREE VEHICLES IN EQUILATERAL-TRIANGLE FORMATION

Three Autonomous Vehicles levitated on air bearings and propelled horizontally by air jets locate each other optically and align themselves in an equilateral triangle.

tion in which it translates along the laser beam from follower 1. When an optical sensor on the leader intercepts the laser beam from follower 2, the leader sends a radio signal that tells follower 2 to stop. At this point, alignment is complete.

This scheme causes the three vehicles to lie at the corners of an equilateral triangle, with the laser of each vehicle aimed at an optical sensor on another vehicle. However, in this scheme, no attempt is made to control the size of the triangle; this is because of the difficulty of optically measuring short distances typical of the intervehicular distances in this experimental system.

This work was done by Fred Y. Hadaegh and Kenneth Lau of Caltech and Paul K. C. Wang and John Yee of the University of California for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Mechanics category.*

NPO-20599

Microfabricated Flow Controllers and Pressure Regulators

John F. Kennedy Space Center, Florida

Efforts are underway to develop microfabricated flow controllers and pressure regulators that contain as few discrete components as feasible and that are cheaper, more robust, and orders of magnitude smaller than are currently commercially available devices that have similar capabilities. The developmental devices are designed to interact with electronic sensing and control circuits that include microprocessors that, in turn, communicate with host computers of digital feedback control systems. An example of the prototype devices constructed thus far is a hybrid device that includes a flow sensor, a valve containing a TiNi-alloy microribbon shape-memory actuator, and a temperature sensor, with wire-bonded leads for connection to electronic circuits. Windows™-based software for interaction between host computers and the microprocessors associated with these devices has been written. Contemplated further development efforts would be devoted to advancing from the concept of a flow controller on a ceramic substrate to that of a flow controller on an assembly of two or more semiconductor chips. In principle, fabrication on a semiconductor chip could be accomplished without need to assemble discrete components.

This work was done by A. David Johnson of TiNi Alloy Co. for **Kennedy Space Center.**

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

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Refer to KSC-12104, volume and number of this NASA Tech Briefs *issue, and the page number.*

Growing Carbon Nanotubes Aligned With Patterns

Positions and orientations of individual nanotubes could be tailored.

NASA's Jet Propulsion Laboratory, Pasadena, California

A process has been proposed for growing carbon nanotubes aligned substantially parallel with the nominal planar surfaces of substrates and further aligned with patterns on the substrates. Prior to growth, the patterns would be formed by micromachining the substrates, which could be silicon or silicon-on-insulator (SOI) wafers. By making it possible to tailor the positions and orientations of individual carbon nanotubes grown on pre-patterned substrates, this process would enable advances in nanotube-based electronic and electromechanical devices.

The process would include chemical vapor deposition (CVD) of the carbon nanotubes on patterned catalysts on the substrates. In each case, the CVD gas would consist of a source of carbon (such as methane, ethylene, or carbon monoxide) either by itself or in a mixture with other gases. Carbon nanotubes grow when a substrate with patterned catalyst is heated and exposed to this CVD gas mixture under appropriate conditions [which can include enhancement by RF (radio frequency) plasmas and/or hot filaments].

The basic process admits of three main variants, each involving a different technique or combination of techniques to position and orient the growing carbon nanotubes. In the first variant (the basic process), the desired alignment would be enforced by use of in-plane pointed silicon cantilevers protruding from an undercut silicon layer on an SOI substrate (see Figure 1). Part of the upper surface of each cantilever would be coated with a thin film of a suitable catalyst (e.g., Ni, Co, or a suitable metal alloy or compound).

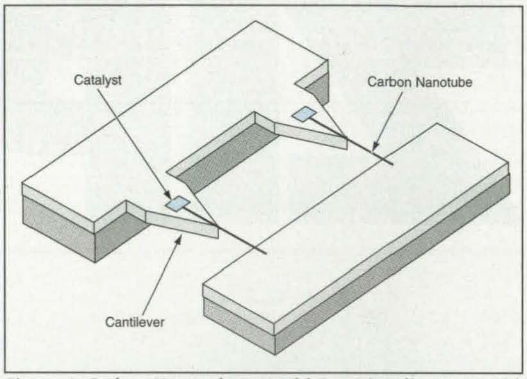

Figure 1. **Carbon Nanotubes Would Grow in Alignment** with the tips of micromachined cantilevers on an SOI wafer.

On the basis of prior experiments on the growth of nanotubes, it is expected that (1) the nanotubes will tend to nucleate at random times and locations, such that multiple tubes may grow out of each catalyst film, and (2) because of attractive van der Waals forces, the nanotubes will tend to grow along the cantilever surfaces and edges. It is also anticipated that if the tip of a growing nanotube reaches the tip of the cantilever, further growth would likely cause the nanotube to protrude from the tip because strain-energy cost of bending the nanotube to the small tip radius would exceed the energy of van der Waals attraction (see Figure 2).

In the second variant of the process, the micromachined patterns would comprise narrow, etched trenches in silicon wafers. Enhanced van der Waals forces at the edges of the trenches would preferentially align the growing nanotubes.

In the third variant of the process, electric fields would be used to align the growing nanotubes. In this case, each substrate would be prepared by microfabrication of (1) pointed cantilevers similar to those of the first variant of the process and (2) on-chip elec-

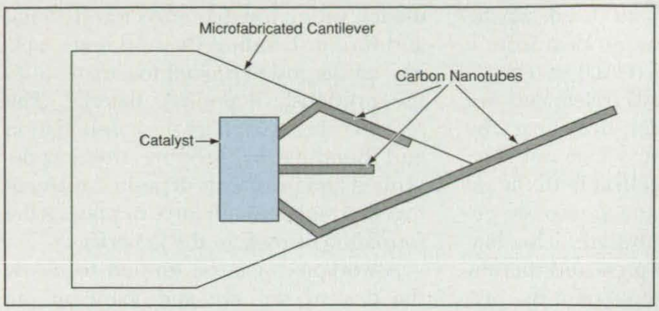

Figure 2. **Nanotubes Would Tend To Grow Along Surfaces and Edges** because of van der Waals attraction, but could not follow sharp bends. The growing nanotubes tubes would therefore be expected to grow toward the sharp tip of the cantilever. One of the growing nanotubes could be expected to end up protruding from the tip in a predetermined direction.

trodes. A bias potential applied during growth would result in a high local electric field between an electrode on the tip of each cantilever and a nearby electrode. The bias circuitry would be designed to prevent the large surges of current that would destroy the growing nanotubes as the interelectrode gaps became bridged by growth of the nanotubes (e.g., by incorporating a large series resistor in the circuit). It may be necessary to adjust the pressure of the CVD gas and/or electrode spacing to prevent electrical discharges between the biased electrodes.

This work was done by Brian Hunt, Daniel Choi, Michael Hoenk, Robert Kowalczyk, and Flavio Noca of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Manufacturing category.*

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

Intellectual Property group
JPL
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4800 Oak Grove Drive
Pasadena, CA 91109
(818) 354-2240

Refer to NPO-30205, volume and number of this NASA Tech Briefs *issue, and the page number.*

Process for Rapid Prototyping in Ceramic-Matrix Composites

Precursors of continuous-fiber-reinforced CMCs are deposited in patterned layers.

Marshall Space Flight Center, Alabama

The ceramic-composite advanced tow-placement (CCATP) process is a means of laying down continuous-fiber-reinforced, ceramic-matrix composite (CMC) materials in patterned layers to form objects that could have complex three-dimensional shapes. The CCATP process is a member of the growing family of solid-freeform processes in art of rapid prototyping.

In preparation for CCATP, tows of fibers (of which the main ingredients are typically graphite or silicon carbide) are first coated with an interfacial material (e.g., pyrolytic graphite or boron nitride) to prevent damage in subsequent processing.

The fibers are then coated with a mixture of a ceramic matrix material in powder form plus a thermoplastic or other low-temperature binder. The resulting tows of coated fibers are wound on spools.

The CCATP process is effected by use of advanced tow-placement (ATP) equipment that includes, among other things, a robotic head that is moved to deposit the tows in the specified patterned layers. As the robotic head moves, the tows are paid out from the spools, heated, and pressed onto the surface of the object to be formed. The process parameters and the motion of the robotic head can be controlled by use of output data from a computer-aided design (CAD) system.

The head includes two rollers and two hot-nitrogen-gas torches that heat the rollers and the deposited material. The first torch and roller preheat both the incoming material and the previously deposited material or substrate. The first roller serves further to press and thereby tack the incoming material onto the previously deposited material or substrate. The second torch provides through-the-thickness heating to facilitate both consolidation of the just-deposited tow material and further bonding (beyond mere tacking) of the just-deposited tow material to the previously deposited material. The second roller completes the consolidation and bonding by pressing the just-deposited and previously deposited material together with enough force to prevent the formation of voids in the material.

A workpiece can be formed to nearly the desired net size and shape in the CCATP process. The size and shape can include allowances for small changes that occur in the next processing step, in which the workpiece is heated to burn out the binder and sinter the ceramic matrix to complete the synthesis of the composite material.

This work was done by Michael R. Effinger of **Marshall Space Flight Center**; *Ranji K. Vaidyanathan, Mark Fox, Mark J. Rigali, and Anthony C. Mulligan of Advanced Ceramics Research, Inc.; and John W. Gillespie, Jr. and Shridhar Yarlagadda of The Center for Composite Materials, University of Delaware. For further information, contact the company at (520) 573-6300 or access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Manufacturing category.*

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

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3292 E. Hemisphere Loop
Tucson, AZ 85706

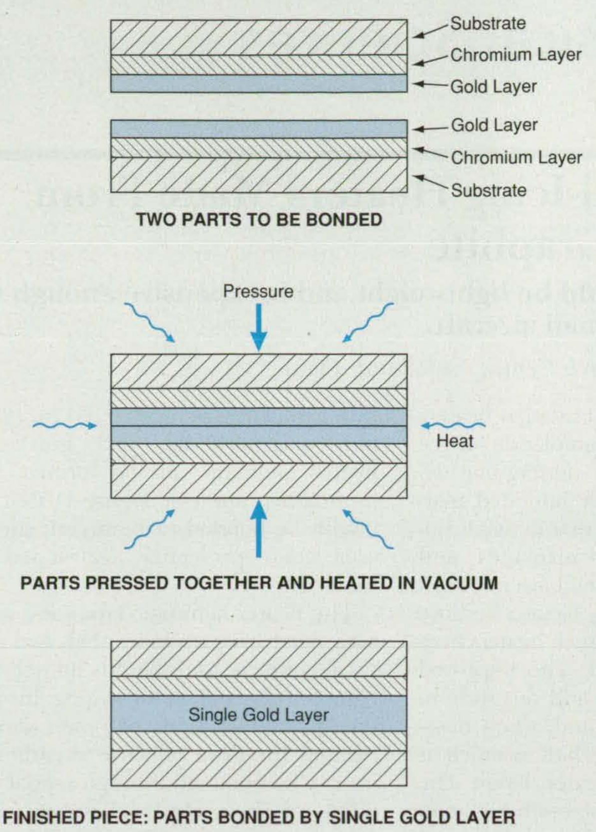
Refer to MFS-31597, volume and number of this NASA Tech Briefs *issue, and the page number.*

Low-Temperature Thermocompressive Au-to-Au Diffusion Bonding

This technique is suitable for fabrication of microelectromechanical structures.

NASA's Jet Propulsion Laboratory, Pasadena, California

A technique of thermocompressive gold-to-gold diffusion bonding at relatively low temperature has been devised to provide stable, uniform, strong bonds between structural components of microelectromechanical systems. The technique can also be used for vacuum sealing of microscopic cavities. Unlike some



The **Two Parts Are Pressed Together** and heated in a vacuum, causing diffusion and mixing of gold atoms. As a result, the two gold layers become one.

other metal-to-metal diffusion bonding techniques, this technique does not entail significant outgassing or the formation of intermetallic compounds. The technique is suitable for bonding of parts made of silicon, quartz, low-thermal-expansion glass, and other materials that can withstand the relatively mild rigors of a low-temperature thermocompressive-bonding process.

Two parts to be joined by this technique must have faying surfaces that are either flat or shaped to fit each other. In preparation for bonding, each of the faying surfaces is coated with a layer of chromium, then with a layer of gold (see figure). The coating is done by electron-beam evaporation. The coated substrates are cleaned, then clamped together with their gold layers touching in the desired final configuration in a press in a vacuum chamber.

The chamber is evacuated to a pressure of about 10^{-5} torr (about 1.3×10^{-3} Pa). While maintaining the clamping force and the vacuum, the coated parts are heated to a temperature in the approximate range of 100 to 350 °C for about 1 hour. The combination of heating and clamping pressure in the vacuum causes atoms to diffuse and mix between the touching gold layers of the two parts, forming a single gold layer that bonds the two parts together.

This work was done by Tony K. Tang and Roman Gutierrez of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Manufacturing category.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Management Office–JPL (818) 354-7770. Refer to NPO-20076.

Aircraft Anti-Icing Heaters Made From Expanded Graphite

These heaters could be lightweight and inexpensive enough to be practical for small aircraft.

John H. Glenn Research Center, Cleveland, Ohio

Improved electrical resistance heaters for preventing the accumulation of ice on aircraft surfaces are undergoing development. The primary intended market for these heaters is that of small single- and twin-engine airplanes and helicopters, most of which have not been equipped with anti-icing heaters because the weights and costs of such heaters have made them impractical. The improved heaters are expected to add very little to the weights of aircraft and, when mass-produced, to cost about half as much as do anti-icing systems of prior design. The aircraft could be equipped with high-output alternators to supply the additional electric power needed for the heaters.

In the previously developed electrical anti-icing heaters used on larger aircraft, the resistance heating elements are metallic. Power densities are zoned by use of multiple elements and multiple electrical terminations. A concomitant of multiple heating zones is cold spots and the consequent need for complex control mechanisms: most such systems include multiple timers.

In the present developmental systems, the heating elements are made of expanded-graphite foil, which is flexible, has an electrical resistivity between 6×10^{-4} and 10×10^{-4} Ω·cm, has a thermal conductivity approaching that of brass, and is available in a variety of thicknesses. Typically, the foil in a heater of this type is laminated between (1) an insulating rubber or plastic sheet in contact with an aircraft surface and (2) an outer thermally conductive and protective layer of polyurethane or polyamide with a thickness between 0.001 in. (≈0.03 mm) and 0.010 in. (≈0.25 mm). The heater laminate can be formed as a monolithic tape (see Figure 1) that can readily be bonded to an aircraft surface area where protection against icing is needed.

The heater laminate/tape for a given area need have no more than two electrical contacts, and there is no need for complex controllers for zoning: instead, the spatial variations of power density needed for most effective shedding of ice can be obtained through spatial variations of sheet electrical resistance effected by use of different thicknesses and/or different densities of expanded-graphite foil. For example, one preferred design calls for a heater laid out along the leading-edge area of a wing (see Figure 2). The heater would contain a single foil heating element comprising (1) a central parting strip of greater thickness along the stagnation line wherein the power density would be high enough to keep the temperature above freezing and (2) shedding zones on both sides (downstream) of the parting strip where the thickness of the graphite foil and power density would be lower by an amount that would make the power density at least 3 to 5 times lower than in the parting strip.

Icing-wind-tunnel tests have demonstrated the efficacy of the parting-strip/shedding-zone concept. Icing-wind-tunnel tests have also shown that in comparison with metallic anti-icing heaters, experimental expanded-graphite-foil heaters are 3 to 5 times more efficient.

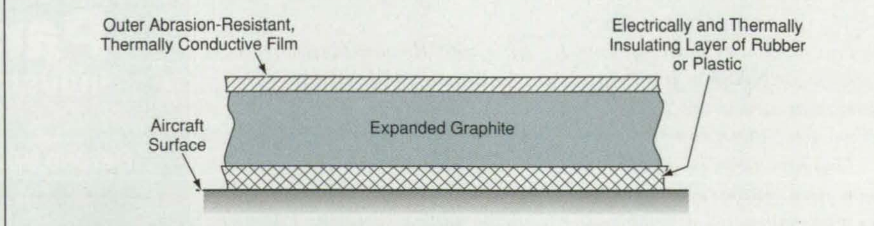


Figure 1. A **Foil of Expanded Graphite** is laminated between an insulating inner layer and a thermally conductive, protective outer layer to form a heater tape that can be bonded to an aircraft surface.

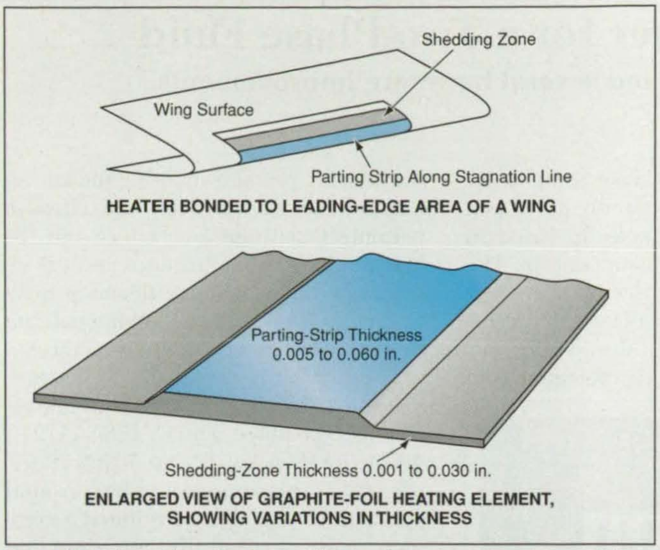


Figure 2. A **Three-Zone Heater** for the leading edge of a wing contains a single electrical-resistance heating element made of expanded-graphite foil with zone-to-zone variations of thickness.

This work was done by Robert Rutherford of EGC Enterprises, Inc., for **Glenn Research Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Physical Sciences category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16895.

Regulating Pressure-Volume Control of a Gas Blanketing Liquid R-124

John F. Kennedy Space Center, Florida

A system for storing and circulating a refrigerant liquid [R-124 (chlorotetrafluoroethane)] includes a reservoir and a subsystem that regulates the pressure of nitrogen gas in the head space of the reservoir. The purpose of the pressurization is to prevent cavitation in a pump that circulates the liquid. It is necessary to keep enough nitrogen in the system to keep the pressure high enough to prevent cavitation even when the liquid is at its coldest and thus at its smallest volume. It is also necessary to satisfy a competing requirement to, when the refrigerant is at its warmest and thus at its greatest volume, prevent the pressure from exceeding the level at which a relief valve opens and vents the head-space gaseous mixture of refrigerant vapor and nitrogen to the atmosphere. The pressure-control subsystem includes a supply of nitrogen at a pressure of 80 psig (gauge pressure of 552 kPa), a commercial electronic pressure regulator, a programmable-logic controller, and pressure and temperature sensors in the reservoir. The pressure-control subsystem adjusts the nitrogen pressure to the optimum value for the sensed temperature, thereby preventing both cavitation and venting.

This work was done by Michael Katz and Charles Walker of United Space Alliance for **Kennedy Space Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Physical Sciences category.*
KSC-12167

Improved Capacitive Quality Meter for a Two-Phase Fluid

Features include a better electrode configuration and several hardware improvements.

John F. Kennedy Space Center, Florida

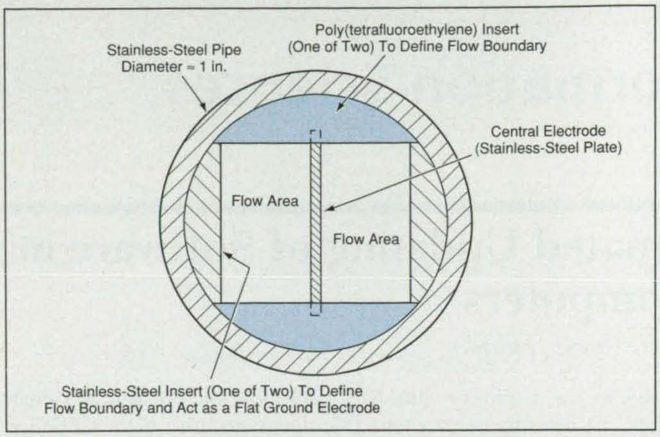
A previously developed quality/flow meter has been redesigned to improve its performance as a device for measuring the quality (but not the flow) of two-phase (liquid + vapor) oxygen or nitrogen flowing in a pipe. As used in engineering disciplines concerned with two-phase flows, "quality" denotes, loosely, volume fractions of liquid or gas. Like some other quality meters, the previously developed meter and the present meter are based on a capacitance-measurement concept: The fluid flows through a space between electrodes, the capacitance between the electrodes is measured, and the volume fractions of liquid and gas are estimated from the effective permittivity, using the known relationships (a) between the effective permittivity and the capacitance and (b) between the volume fractions and the effective permittivity. The estimate of quality can be refined by use of additional data from pressure and temperature sensors.

The previously developed quality/flow meter was described in "Quality/Flowmeter for Two-phase Fluid" (KSC-11725), *NASA Tech Briefs*, Vol. 21, No. 7 (July 1997), page 62. That instrument was built around a section of pipe that constituted a common outer electrode for two capacitive sensors. The other electrodes for the capacitive sensors were metal rods mounted coaxially within the pipe on electrically insulating radial spacers.

A major difference between the previously developed and present instruments lies in the shapes of the electrodes and the flow cross section. The present instrument contains flat electrodes in a square flow cross section (see figure). In comparison with the previous configuration of concentric round electrodes in a round flow cross section, the present configuration should afford greater accuracy in the measurement of quality because the sensing electric field generated by flat electrodes is more nearly uniform across the flow path.

The design of the present instrument also incorporates a number of hardware improvements to minimize leakage, provide a rugged connection between an electrical-feedthrough pin and the central plate electrode, position the feedthrough to minimize condensation, and facilitate assembly and disassembly. In addition, the design ensures compatibility of the instrument with liquid oxygen: for this purpose, all parts in contact with liquid oxygen are made of either stainless steel, poly(tetrafluoroethylene) or (in the feedthrough) ceramic.

The technique used to measure the capacitance is somewhat complicated but offers more stability and accuracy than do simpler techniques. First, a circuit that includes timer integrated circuits is used to convert a change in capacitance to a change in the duration of a digital pulse. The duration is then measured by use of an oscillator and a counting circuit. These circuits yield a 12-bit digital counting signal, which is fed to a digital-to-analog converter to generate an analog signal indicative of the measured capacitance and thus the quality. The circuit parameters are chosen so that if, for example, the fluid is



Flat Electrodes give rise to a nearly uniform sensing electric field across the flow area. While the electric field becomes highly nonuniform in the regions above and below the flow area, the poly(tetrafluoroethylene) inserts keep the fluid out of those regions.

a mixture of liquid and gaseous nitrogen, the analog output potential ranges from ≈1 V when only vapor is present to ≈4 V when only liquid is present. The circuitry is capable of sampling the capacitance about 2,000 times per second, but the speed of response is limited by the 0.03-second time constant of a filter in an operational amplifier that process the output of the digital-to-analog converter. This time constant is acceptably short in the original intended application of the quality meter.

This work was done by Rudy J. Werlink of Langley Research Center and Robert C. Youngquist, Robert B. Cox, and William D. Haskell of Dynacs Engineering Co., Inc., for **Kennedy Space Center**. *For more information contact the Kennedy Commercial Technology Office at 321-867-8130.*
KSC-12080/09

Ellipsoidal Collecting Horns for Ultrasonic Leak Detectors

John F. Kennedy Space Center, Florida

Ellipsoidal reflectors have been proposed as collecting horns for ultrasonic leak detectors. Exploiting the classical focusing characteristics of ellipsoids, these reflectors would facilitate and enhance the detection of leaks in situations in which it is possible to bring leak-detecting sensors to within distances of the order of centimeters from leaks, but not closer. Leak detectors based on this concept could complement commercially available ultrasonic leak detectors equipped with paraboloidal reflectors for focusing over much longer distances. In a typical application, an ultrasonic receiving transducer would be positioned at one of the two foci of an ellipsoidal reflector. At the end opposite the transducer, the reflector would be truncated to provide an opening for the entry of sound and for positioning the reflector near a leak. When the reflector-and-transducer assembly was positioned to make the leak (or, for that matter, any other small source of ultrasound) lie at the other focus of the ellipsoid, the maximum amount of radiated ultrasound would be focused onto the transducer, resulting in maximum detector response. The principle of operation has been verified in experiments.

This work was done by Robert C. Youngquist and Robert Cox of Dynacs Engineering Co. Inc. for **Kennedy Space Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Physical Sciences category.*
KSC-12082

Information Sciences

Flash Automated Updating of Software in Multiple Computers

John F. Kennedy Space Center, Florida

Program and data files in the Unified Control Modules (UCMs) of the Operational Television system at Kennedy Space Center are updated rapidly and automatically in a scheme that exploits unique features of the UCM design. Each UCM includes a VersaModule Eurocard (VME) chassis, in which are installed several single-board central processing units (CPUs) and a board that holds 8MB of flash electrically erasable, programmable read-only memory that is accessible to all the CPUs via the VMEbus. This flash memory can be erased and reprogrammed without removing the memory circuitry from the UCM. The CPUs utilize the VxWorks real-time operating system, which provides, among other things, interprocessor communication via the VME backplane, support for networking, and support for MS-DOS file systems. A VxWorks driver program creates an MS-DOS file system in the flash memory and provides for access to, and manipulation of, the files. Each time the UCM is rebooted, one CPU, designated the main CPU first determines whether a designated host computer is available in a network to which the UCM is connected. If so, the main CPU obtains a list, stored in the host computer, of files that should be in the flash memory. If it finds that the modification date and time of a given file in the host differs from those in the flash memory or if the file does not exist in flash memory, then the file is copied to the flash memory. Once flash-memory files have been thus updated, the main CPU signals the other CPUs to complete their booting and gain access to the files in the flash memory card via the VMEbus.

This work was done by Charles H. Chapman of Dynacs Engineering Co., Inc., for **Kennedy Space Center**. *For further information regarding this technology, contact Mr. Charles Chapman at (321) 232-8141 or via e-mail at charles.chapman-1@ksc.nasa.gov. KSC-12120*

Algorithm Plans Motion of Robot With Limited Field of View

NASA's Jet Propulsion Laboratory, Pasadena, California

The RoverBug algorithm plans the motion of a robotic vehicle (rover) equipped with a CCD (charge-coupled device) camera or comparable sensor that has a limited field of view. The algorithm produces locally optimal (shortest-distance) paths across unbounded, previously unknown terrain; utilizes gaze control to minimize the amount of sensing; and avoids unnecessary robot motion. Because this algorithm is based on a local and simple mathematical model of terrain, it does not entail the bookkeeping of a global model (with all of the attendant issues of registration of local maps with global ones and with each other), and does not require the large memory that would be required by a global model. The algorithm is amenable to varying levels of autonomy, ranging from single-subpath execution under tight operator guidance to completely autonomous traverses to distant goals. In addition to being useful for exploration of distant planets via rovers, the algorithm could be applied in such terrestrial scenarios as cleanup of environmental hazards or military surveillance. A version of the algorithm has been implemented on NASA's Rocky 7 prototype microrover.

This work was done by Sharon Laubach of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Information Sciences category.*

This software is available for commercial licensing. Please contact Don Hart of the California Institute of Technology at (818) 393-3425. Refer to NPO-30241.

Initialized Fractional Calculus

Initialization functions are essential to a revised formulation suitable for engineering and scientific applications.

John H. Glenn Research Center, Cleveland, Ohio

The fractional calculus (which admits of integrals and derivatives of non-integer order) dates back almost to the origin of the better-known ordinary (integer-order) calculus, but thus far has been treated more as a mathematical curiosity than as a scientific and engineering tool. Increasingly many physical processes are found to be best described using fractional differential equations. These processes include: viscoelasticity, rheology, electrochemistry, fractal processes, and many diffusion processes. The application of the fractional calculus to scientific and engineering problems has been inhibited by difficulties that arise from the basic definitions given heretofore for integrals and derivatives of arbitrary order. These difficulties are associated with the initialization problem, which is explained below.

Consider a function $f(t)$, where t could be time or any other independent variable, and let ${}_cD_t^{\nu}f(t)$ denote the νth-order derivative of f with respect to t (where ν is a positive real number and not necessarily a integer). One of the properties that must be preserved to make the fractional calculus compatible with the ordinary calculus is the composition of the index law, which is represented by the following equation:

$${}_cD_t^{u}\,{}_cD_t^{v}f(t)={}_cD_t^{v}\,{}_cD_t^{u}f(t)={}_cD_t^{u+v}f(t).$$

The initialization problem arises as follows: One of the requirements of prior formulations of the fractional calculus is that in order to preserve composition, $f(t)$ and all of its derivatives must be identically zero at $t = c$. Inasmuch as it is difficult to make all functions and derivatives of interest initially zero in many scientific and engineering problems, this requirement has effectively rendered until now the fractional calculus inapplicable in such cases.

As its name suggests, the initialized fractional calculus is formulated to address the initialization problem. In the initialized fractional calculus, it is not required that $f(t)$ and its derivatives be zero at $t = c$ in order to preserve composition. What enables the elimination of this requirement is the revision of definitions of integrals and derivatives of arbitrary orders to include initialization functions that carry the history of the differintegral. The initialization functions are generalizations of the constants of integration that appear in the ordinary calculus, where they are used to represent initial conditions.

Other major topics addressed in the development of the initialized fractional calculus include the following:

- Heretofore, Laplace transforms have been the primary tools for solving fractional differential equations. Therefore, the basic Laplace transforms for the initialized fractional integrals and derivatives were developed.

- The concept of a variable-structure or variable-order differintegral was introduced. This concept can be represented by the fractional differential equation ${}_cD_t^{q(t)}y(t) = f(t)$ and the companion inferred integral equation ${}_cD_t^{-q(t)}f(t) = y(t)$, where q (the structure or order parameter) is a function of t or y. Some phenomena in viscoelasticity and diffusion appear to be amenable to treatment by fractional differential equations with variable order parameters.

Going beyond viscoelasticity, the initialized fractional calculus can be applied to problems that arise in a variety of scientific, engineering, and purely mathematical disciplines, including creep, percolation, material science, viscous fluid behavior, heat transfer, batteries, electromagnetics, control, communications, filtering, and chaotic systems.

This work was done by Carl F. Lorenzo of **Glenn Research Center** *and Tom T. Hartley of the University of Akron. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Information Sciences category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-17139.

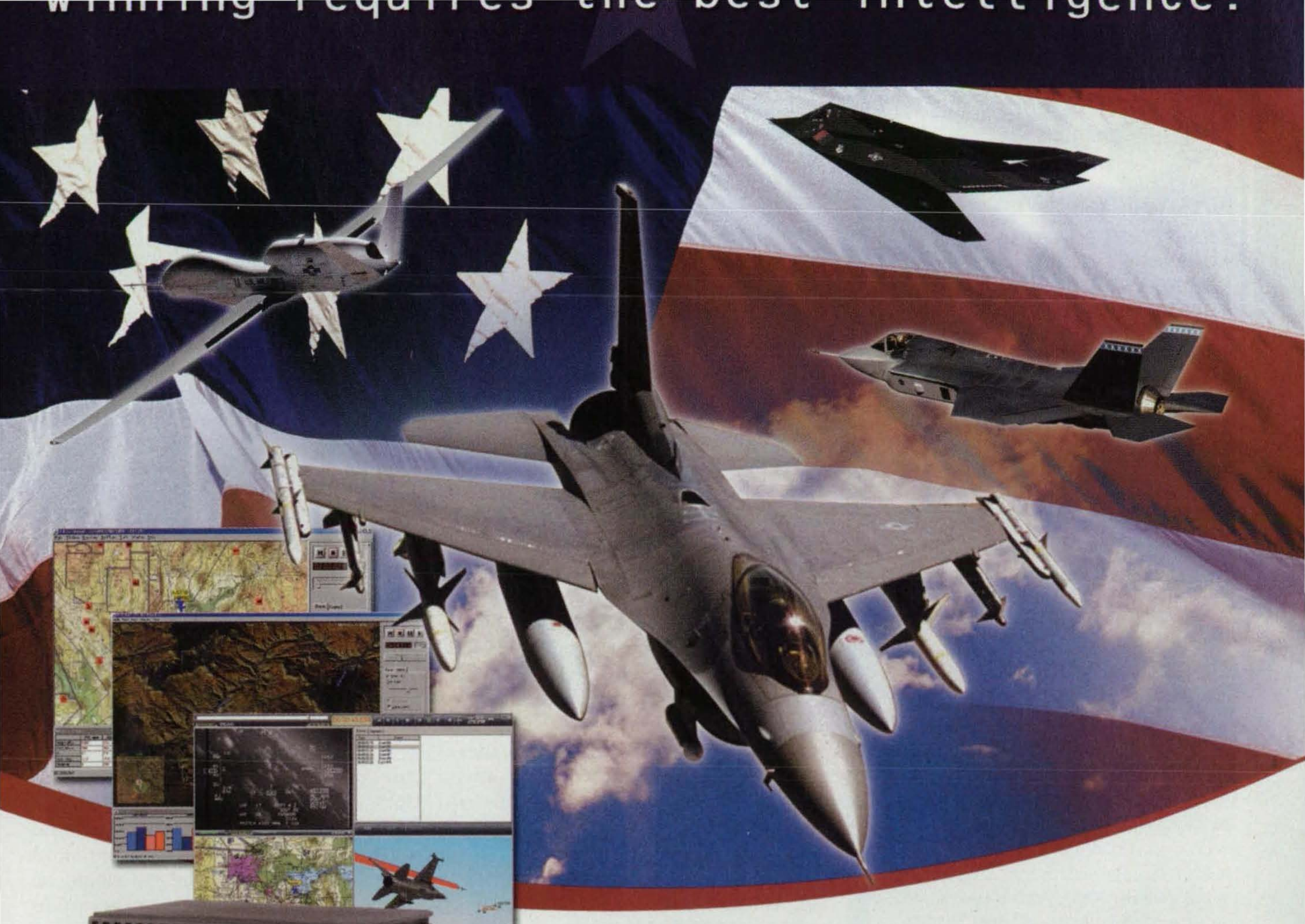
Product Attributes Database

NASA's Jet Propulsion Laboratory, Pasadena, California

Product Attributes Database (PAD) is a computer program that enables a team of engineers, managers, and administrators involved in a product-development project to collaborate more effectively. PAD serves as a single, network-accessible repository for all essential parametric information (the database) that characterizes the project at any phase of implementation. PAD collects and organizes the data into a human-readable format so that any member of the team can gain access to the data and/or link the data to documents, reports, and presentations. The PAD information architecture includes interfaces to several software systems, including programs for engineering design and analysis, estimation of costs, testing and verification of designs, documentation, and display of data. These interfaces support real-time, collaborative engineering. Going beyond prior engineering-database programs, PAD includes both (1) a machine-interface subsystem that enables a variety of engineering and administrative programs to work together through the database over a network and (2) a human-interface subsystem, which provides a simple graphical user interface that enables a team member to read and write data from any network-accessible computer.

This work was done by Thomas Clymer, William Heinrichs, and Joel Sercel of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Information Sciences category.*

This software is available for commercial licensing. Please contact Don Hart of the California Institute of Technology at (818) 393-3425. Refer to NPO-20673.



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Books & Reports

Simulating the Structural Behavior of Laminated Glass

This report investigates the strength of architectural laminated glass and the viability of its use for window glass in commercial buildings. Some researchers recommend that the structural behavior of laminated glass (typically consisting of two glass layers and a plasticized PVB [polyvinyl butyral] interlayer) is equivalent to the structural behavior of monolithic glass (one solid piece of glass) for most common applications. However, if this monolithic equivalency assumption is not valid, its implementation would result in the unconservative design and use of laminated glass, which could lead to failure of the glass at the design load. Using ALGOR Mechanical Event Simulation (MES) software, laminated and monolithic glass plates were modeled and analyzed to compare their response to a wind load. Stress results for the two plates were very different due to shear deformations experienced by the interlayer of the laminated plate. This research may help to ensure the safe use of laminated window glass.

This work was done by Dr. W. Lynn Beason, Associate Professor of Civil Engineering at **Texas A&M University** *in College Station, Texas, using* **ALGOR***'s Mechanical Event Simulation software. To obtain a copy of this report, visit beasonreport.ALGOR.com.*

Synchronizing Attitudes and Maneuvers of Multiple Spacecraft

A report discusses the problem of controlling the maneuvers of multiple spacecraft flying in formation and, more specifically, making the entire formation rotate about a given axis and synchronizing the rotations of the individual spacecraft with the rotation of the formation. Such formation flying is contemplated for mission in which the spacecraft would serve as platforms for long-baseline-interferometer elements and the synchronized rotations would be needed for slewing of the interferometers. Starting from (1) a particle model of the dynamics of the spacecraft formation, (2) a rigid-body model of the spacecraft-attitude dynamics, and (3) an assumption that one spacecraft would serve as the reference for the positions and orientations of the other spacecraft, the report presents a mathematical derivation of control laws for formation flying in the absence of gravitation and disturbances. A simplified control law suitable for implementation is also derived. Results of a computer simulation for three spacecraft flying in a triangular formation are presented to show that the control laws are effective.

This work was done by Fred Y. Hadaegh and Kenneth Lau of Caltech and Paul K. C. Wang of the University of California for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Synchronized Formation Rotation and Attitude Control of Multiple Free-Flying Spacecraft," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Mechanics category.*
NPO-20569

Lightweight Solar Sail for a Spacecraft Flying Near the Sun

A report proposes a high-temperature-resistant solar sail with an areal mass density less than 1 g/m^2, for a spacecraft that would approach the Sun to within a distance of 0.2 astronomical unit ($\approx 3 \times 10^7$ km). The sail would be made in multiple segments of a carbon microtruss fabric held in a network of tensioned lines. The segments and network would be designed to minimize tension in the fabric. The porosity of the fabric would be tailored so that to photons, the fabric would behave as though it were solid. Reflective metal surface films could be attached to the fabric. In advanced versions, the fabric could be directly coated with metal, or, alternatively, the fabric surface would be the sail surface and there would be no metal layer. The sail fabric would be wrapped around a sail cylinder and deployed by use of centrifugal force. A separate structure next to the sail cylinder would contain most of the deployment hardware and would be ejected after deployment of the sail to reduce the mass staying with the sail.

This work was done by Charles Garner, Stephanie Leifer, Timothy Knowles, and William Layman of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Solar Sail Design for Interstellar Probe," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Materials category.*
NPO-20854

Technologies for Licensing

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Ultrasonic Nozzle System Improves All Types of Liquid Flow

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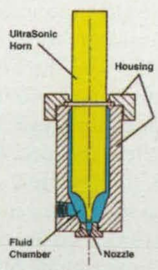


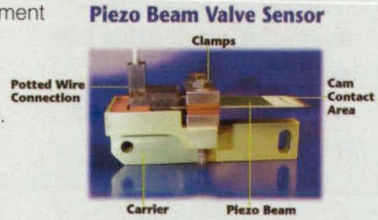
Low Cost, Low Density Ceramic Fibers Perfect Replacement for Costly Superalloys and Ceramics

Bayer AG has developed low cost, low density ceramic fibers exhibiting superior high temperature mechanical properties compared to superalloys and existing ceramic fibers. These fibers are used to manufacture ceramic matrix composites which have major applications in aerospace and power generation, where it is anticipated that significant operational cost reductions can be achieved through weight saving and higher thermal efficiencies. SIBORAMIC is corrosion resistant and lightweight – providing weight reductions of approximately 40% compared to other ceramic fibers and as much as 70% compared to typical superalloys. **http://www.yet2.com/nasatech/210**

Piezo-Beam Sensor Ideal Low Cost, Hi Rel Solution For Critical Position Indicator Systems

Honeywell is offering cutting edge technology for position sensing systems. Currently used on aircraft to sense valve positions, this unique device utilizes a sensor beam in an instrument which is low cost, lightweight, modular, and able to operate reliably in extreme engine environments. The "piezo-beam" has no electrical contacts--a substantial improvement over conventional position sensors. The device is lightweight and inexpensive, with few parts and an interchangeable, modular design for easy replacement during maintenance. A standardized design enables it to be used in a wide variety of applications, enabling high volume manufacturing with reduced production costs and higher margins. Its potential applications are extensive, including aircraft environmental control system valves, commercial HVAC systems, CNG processing and safety controls, gas and fluid transfer systems, and many more. **http://www.yet2.com/nasatech/211**

Piezo Beam Valve Sensor



Versatile, Super Water Repellent Can be Controlled by Light

Hitachi has invented a robust, fluorine-containing compound that could provide superb water-repellency for a wide range of materials and products while remaining active for longer periods of time. This organic surface treatment utilizes commercially available chemicals applied in a relatively straightforward process.

The flexibility and versatility of this technology make it suitable for a broad range of applications, including anti-corrosion coatings, electronics packaging, architectural coatings, anti-icing treatments, fabric coatings, heat exchange surfaces, low-friction coating for machine parts and as a protective layer for recording media, to name a few. A variation of the technology enables the degree of water repellency to be controlled by exposure to light. **http://www.yet2.com/nasatech/212**

Super Water Repellent Application

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(Continued from page 82)

To test the skates' performance on the ice, the new polishing tool was brought to the Pettit National Ice Center in Milwaukee, WI, for glide tests in September 2001. The tests showed a nearly 15% improvement in unassisted glide over conventionally sharpened speedskates. Further research continued over the next few months.

"It wasn't until about three weeks before the Olympics started that we finally hit on the design that worked well and we rushed out to Salt Lake City to work with Finn (Halvorsen) and the skaters," said Lyons. With the Olympics just a few weeks away, it was time to let the skaters use the polishing tool. Speedskater Chris Witty, who won the only two speedskating medals in Nagano, was willing to try the new polishing tool.

U.S. short-track skaters benefited from the grip provided by their polished skates. (Jerry Search, SCSSA, Copyright ©2001)

"When I tried the polishing tool for the first time, immediately you could tell that it made a difference in your skates," she said. "I knew I was skating faster. It's hard to say how much, but mentally, I knew my skates were ready to go."

On February 17, Chris Witty used her newly-polished blades to skate the 1,000-meter race, which she finished in world-record time, winning the gold medal. In subsequent races, American short- and long-track speedskaters who used the new polishing tool also stood on the winner's podium.

Said Witty, "I think we had the intimidation factor going at the Olympics. The other countries were saying, 'NASA's helping you? What's going on?' It created a little wave in speedskating that the Americans had something nobody else had."

Jim Lyons has since started Competitive Edge Co., another small business that will keep developing the polishing technology for use on skis and in other ice sports. His company represents the latest in a series of startup ventures fostered by NASA's technology transfer program.

For more information, contact the Technology Commercialization Office at NASA's Goddard Space Flight Center at 301-286-5810; e-mail: techtransfer@tco.gsfc.nasa.gov; http://techtransfer.gsfc.nasa.gov.

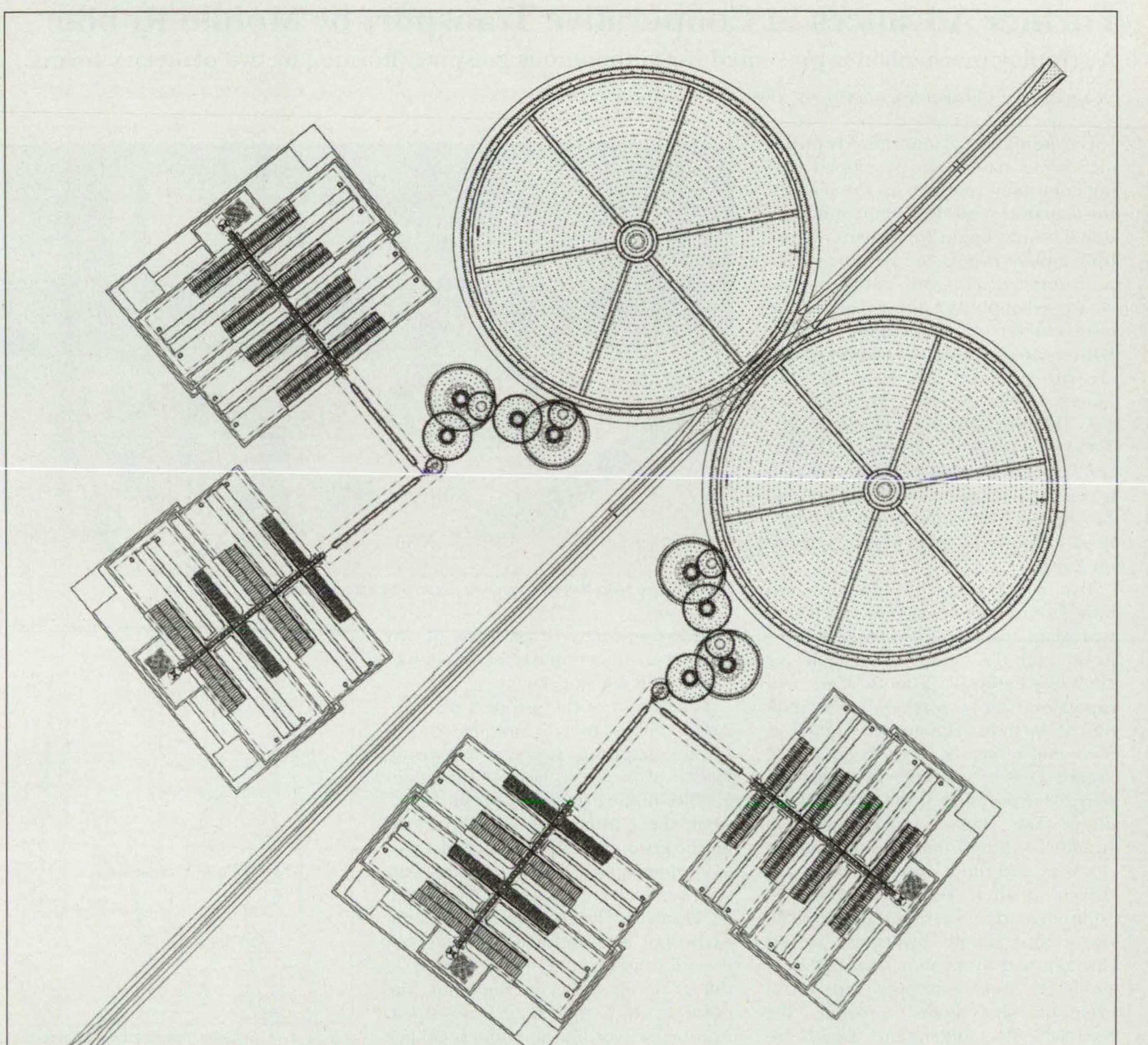
Mesoscopic Winch for Precise Extension and Retraction

A cable could be drawn in submicron steps over a range of ≈1 m.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed lightweight, micromachined winch would have microscopic structural details and mesoscopic overall dimensions and would be capable of generating bidirectional macroscopic motion (maximum cable extension or retraction ≈1 m) with submicron increments. Winches like this one could be useful for actuating small mechanisms in scientific instruments and robots: examples of such mechanisms include translation stages; slide shutters and filters for imaging photodetector arrays; pan, tilt, or zoom actuators for cameras; mechanisms for dragging sampling scoops; and steering mechanisms for small robotic vehicles.

The proposed winch (see figure) would be fabricated in a four-layer poly-



This **Micromachined Winch** would include comb actuators and reduction gears for retracting or extending a miniature cable.

crystalline-silicon surface-micromachining process. Electrostatic comb actuators would be the prime movers, generating motion in increments that gear trains would reduce to submicron values. The final gears in the gear trains would pinch and retract (or extend) a miniature cable, thereby generating the submicron increments of translation.

In one example design, the electrostatic comb drives would operate in four-phase cycles. For each such cycle, a 19-tooth pinion gear would undergo one revolution. The pinion gear would be meshed with a 12.57-μm-pitch winch gear, so that one revolution of a pinion would result in a 238.83-μm translation. The thrust of each comb drive would be ≈1 μN and could be applied rapidly enough to sustain rotational speeds up about 4,000 revolutions per second. Two tandem gear trains would reduce the translation to 1.66 μm per pinion rotation or, equivalently, 0.415 μm per phase step of an electrostatic comb drive, and would increase the torque proportionally. Given the foregoing parameters, the maximum speed of retraction or extension of the cable would be ≈6 mm/s.

Assuming design rules and fabrication based on a fundamental design-rule length of 1 μm, the gear backlash per mesh would be ≈1 μm. For the purpose of precise positioning, it would be necessary to measure the aggregate backlash prior to operation and thereafter, during operation, correct for the aggregate backlash at each cable-draw reversal.

This work was done by Frank T. Hartley of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Machinery/Automation category.*
NPO-20979

Further Advances in Cooperative Transport by Mobile Robots

A gripping mechanism is presented for autonomous grasping/hoisting by two planetary rovers.

NASA's Jet Propulsion Laboratory, Pasadena, California

Hardware and decentralized-control algorithms have been developed during continued research on the sensors, the actuators, and the design and functional requirements for systems of multiple mobile robots cooperating in the performance of tightly coupled tasks — for example, grasping and lifting long objects on challenging terrain. [Different aspects of the hardware and algorithms were described in "Advances in Cooperative Transport by Two Mobile Robots" (NPO-30376) *NASA Tech Briefs*, Vol. 26, No. 8 (August 2002), page 60. Although this research is oriented toward developing robotic capabilities for exploration of Mars, these capabilities could also be utilized on Earth.

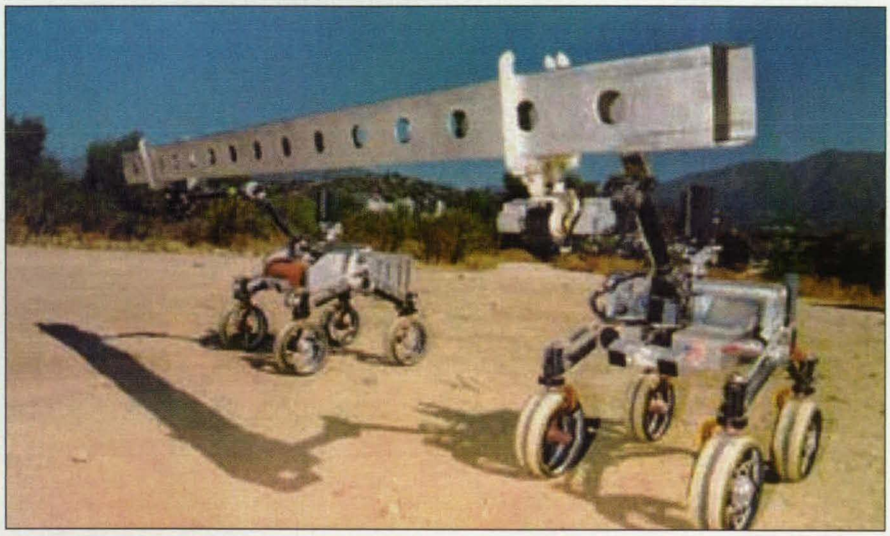


Figure 1. **Two Mars Rovers** cooperate in carrying a long payload.

Two robots used in this research have been rovers designed for prototype Mars missions: the Sample Return Rover and the Sample Return Rover 2000 (see Figure 1). Robotic arms (manipulators) on both rovers were modified to include grippers redesigned as their end effectors. Each gripper (see Figure 2) is of a simple yet novel design, incorporating three interlocking digits: Two fingers facing one side straddle a thumb that faces the opposite side, and these opposing digits are driven at their respective bases by counterrotating, parallel pivots. The finger and thumb pivots are driven through a transmission actuated by a single DC motor equipped with an incremental-shaft-angle encoder for feedback. The fingers and thumb are hooked at their tips to provide positive retention against slippage of a grasped payload. The finger geometry accommodates a variety of payloads of any general cross section narrow enough to fit between the fingers.

The design of the grippers provides passive compliance to simplify control of the gripping process: A spring-loaded pivot at the base of each digit enables flexing to "open up the grip," when the payload exerts an overload on the gripper. In the absence of a payload, mechanical hard stops and limit switches arrest the gripper and signal its closure. The compliant joint on each digit also includes a switch that provides limited feedback related to the gripping force, by signaling the point at which each digit flexes open. Another sensor that provides feedback is located in the "palm" of the gripper: a compliant bumper on a switch provides information related to the loca-

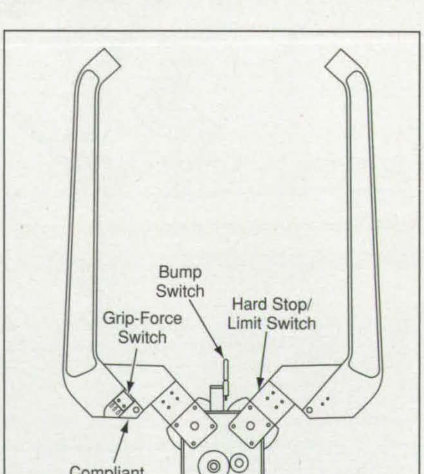


Figure 2. A **Gripper** includes two fingers that straddle and oppose a thumb. The fingers and thumb are connected at their bases to compliant pivots counterrotated by a motor and transmission.

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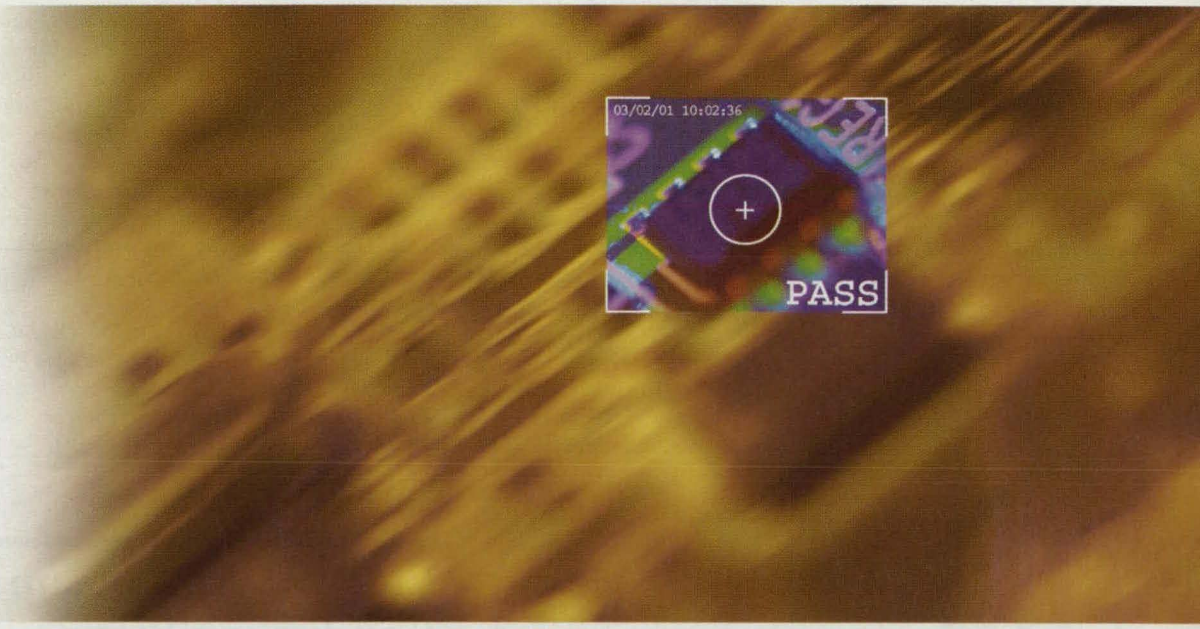

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tion of the payload; that is, whether or not the payload has been grasped.

The cooperative grasping and lifting behavior of the robots is characterized as being partitioned into the following four distinct phases:

1. *Visual Target Search Phase*

In this phase, cameras on the rovers are used to search and capture images of unique patterns placed at specified positions on the payload. From the images, estimates of the Cartesian coordinates of the point of grasp and of an approach unit vector are computed for each rover. Estimates of the distance each rover must travel and the orientation that each rover must assume to place the payload within the work space of its manipulator are also computed. Synchronization occurs between the rovers, and both rovers proceed to position and orient themselves within their respective manipulator work spaces. The rovers then proceed to the approach phase.

2. *Approach Phase*

The gripper of each rover is moved along the approach unit vector toward the point of grasp computed during the visual target search phase, until the palm contact switch is triggered. If contact is made as indicated by the thumb or finger switch during the approach, the gripper is moved away from the payload until thumb or finger switch is reset and the approach phase aborted. This completes the approach phase. Synchronization occurs between the rovers before proceeding to the grasp phase.

3. *Grasp Phase*

The digits are moved in such a manner as to ensure that the finger and thumb contact switches are triggered, confirming a firm grip of the payload. The gripper is not equipped with force and torque sensors; instead, the spring preloads of compliant joints are adjusted manually ahead of time to set the approximate value of the gripping force or a prescribed amount of overtravel is used to give an estimated gripping force.

An "intelligent" heuristic, rule-based compliance-control algorithm is implemented by use of the limited feedback provided by the contact switches during grasping. If the thumb contact switch is closed independently of any finger contact switch, the arm is moved perpendicular to approach unit vector until the thumb contact switch is reset to the open condition. A similar maneuver is performed if either or both of the finger contact switches are triggered independently of the thumb contact switch. These compensatory maneuvers have been demonstrated to guarantee a firm grasp with rover positioning errors of as much as 5 cm.

4. *Payload Lift Phase*

In this phase, the payload is lifted about 20 cm in two stages: 5 cm in the first stage and 15 cm in the second stage.

It is easy to develop control algorithms that use the information provided by the switches on the fingers and thumb, along with the information from the bump switch in the palm, to deduce whether the payload is within grasp; that help to center the gripper about the payload; and that deduce minimal information about the orientation of the payload. For example, by determining which finger is flexing, such an algorithm can help to determine the angle of the payload.

This work was done by Ashitey Trebi-Ollennu, Hari Das Nayar, and Anthony Ganino of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Machinery/Automation category.*

NPO-30511

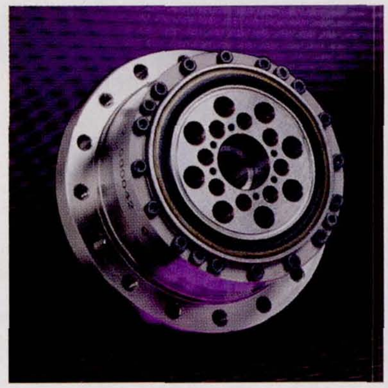
Electrohydrodynamic Conduction Pumps

Pumping is achieved without moving parts and without direct charge injection.

John H. Glenn Research Center, Cleveland, Ohio

Electrohydrodynamic (EHD) conduction pumps have been investigated in theoretical and experimental studies. In general, EHD pumps contain no moving parts. They generate pressure gradients and/or flows in dielectric liquids via any of a variety of interactions between (1) applied electric fields and (2) free and/or bound electric charges in the liquids. Like a related prior device denoted an EHD ion-drag pump, an EHD conduction pump exploits interactions with free charges in liquids, but unlike an ion-drag pump, a conduction pump functions without direct injection of electric charges into the liquid. In the absence of direct injection, EHD conduction pumps are the only EHD devices that can pump isothermal liquids. EHD conduction pumps could be suitable for use as compact, low-power-consumption pumps to enhance flows and thus heat-transfer rates in heat pipes and capillary-pumped loops.

In an EHD conduction pump, an electric field is applied to a dielectric liquid through electrodes that are made either flat or else rounded with large curvatures and without sharp points so that there are no electric-field concentrations large enough to give rise to direct injection of charges. Figure 1 depicts salient aspects of the theory of operation in simplified form. Instead of free charges intro-



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This design is made possible by developing a ring gear that can flex in the radial direction, while maintaining high torsional stiffness. The result is a planetary gearhead that provides consistently low backlash, high efficiency, and high output speeds.

This planetary gearhead is available in 3 frame sizes from 60mm to 120mm. Rated torque ranges from 53 in-lb to 956 in-lb. Peak torque ranges from 496 in-lb to 5753 in-lb. Gear Ratios 5:1 to 45:1. Flange or shaft output available.

HD Systems, Inc.
(800)231-HDSI (631)231-6630

For Free Info Enter No. 657 at www.nasatech.com/rs

NEW, Hollow Shaft Actuators

The FHA Series of actuators features a through-bore up to 45mm in diameter and provides high torque and exceptional positioning accuracy. This performance is achieved in a compact design using a patented "S" tooth harmonic drive gear coupled to a DC brushless pancake motor with integral electronic commutation and a high resolution encoder. Rated torque up to 1730 in-lb and positional accuracy better than 1 arc-minute can be achieved. The FHA Series is available in five frame sizes, ranging from 128 to 300mm in diameter, and 116 to 248mm in length.

HD Systems, Inc.
(800)231-HDSI (631)231-6630

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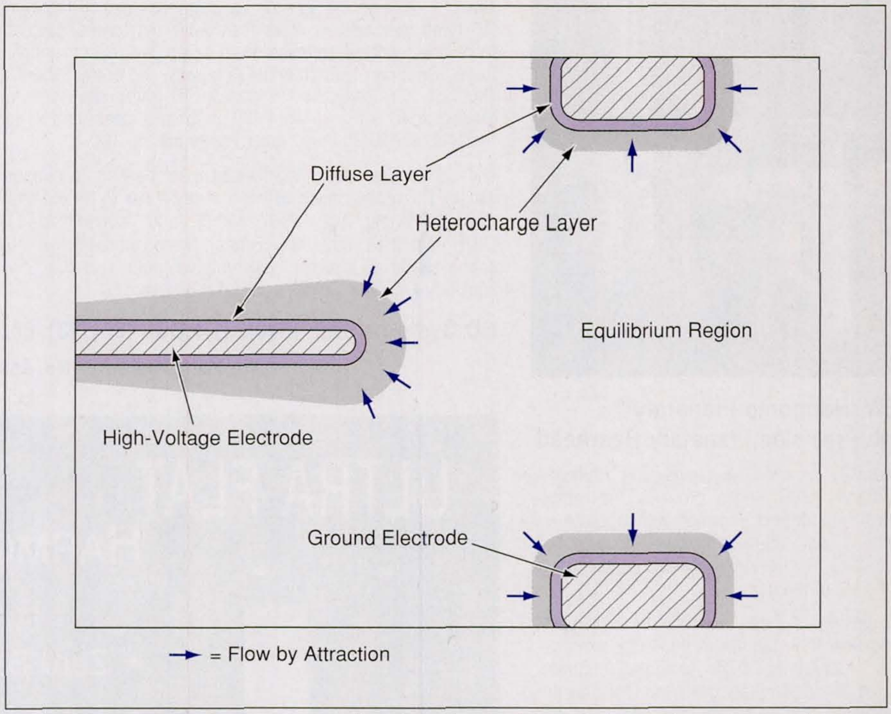


Figure 1. An **EHD Conduction Pump** utilizes free electric charges in heterocharge layers adjacent to electrodes.

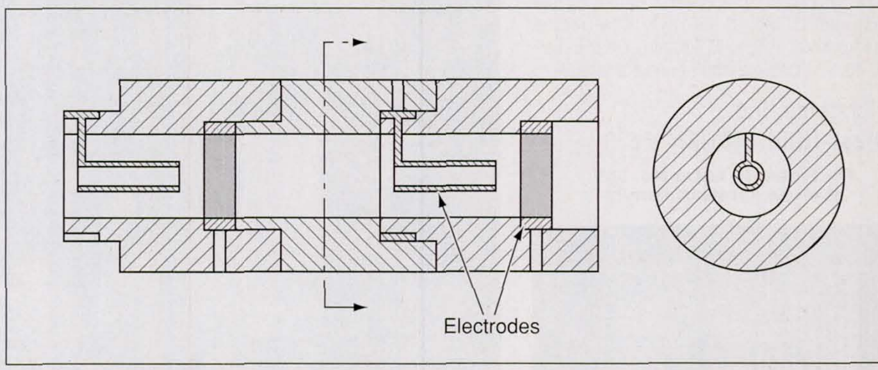


Figure 2. **Tube/Ring Electrode Pairs** were shown in experiments to be effective for EHD conduction pumping.

duced through direct injection, an EHD conduction pump utilizes free charges in thin heterocharge layers formed in the vicinities of the electrodes through dissociation of molecules within the liquid and recombination of the resulting ions. In order to take advantage of the pumping effect of the heterocharge layers, an EHD pump must also utilize the residual small electrical conduction through the bulk of the otherwise nominally purely dielectric liquid.

Experiments on static-pressure EHD conduction pumps containing three different electrode configurations, using refrigerant 123 (dichlorotrifluoroethane) as the working fluid, have demonstrated the feasibility of this pumping concept. The best performance, observed in the case of a pump containing five hollow-central-electrode/ring-outer-electrode pairs similar to the pair shown in Figure 2, was characterized by a maximum static pressure of 1,034 Pa at an applied potential of 20 kV and a maximum power consumption of 0.57 W.

This work was done by Jamal Seyed-Yagoobi, James E. Bryan, S. I. Jeong, and Y. Feng of Texas A & M University and P. Atten and B. Malraison of LEMD, CNRS (Grenoble, France) for **Glenn Research Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Physical Sciences category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer LEW-17142.

NEW PRODUCTS

Incremental & Absolute Encoders

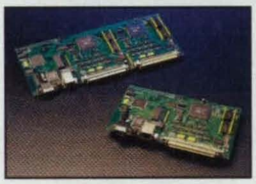
The CoreTech™ encoder line from Stegmann (Dayton, OH) combines custom designed OPTO-ASIC technology with a modular mechanical concept. A large variety of incremental and absolute encoder solutions with different mechanical interfaces, housing styles, resolutions, and new electronic features are available. CoreTech™ encoders offer incremental counts from 1 to 8,192. Absolute encoders offer resolutions between 2 and 32,768 steps. Both types are supplied in a variety of solid, hub, and hollow shaft versions.

For Free Info Visit www.nasatech.com/stegmann

Digital Linear Actuator

The bi-directional digital linear actuator (DLA) from Thomson Airpax Mechatronics (Port Washington, NY) provides high liner resolution as fine as 0.004" per pulse. The Series K923 DLA is suitable for precise, measured control of fluids and gases. Weighing 5.5 oz. with a pull-in rate of 300 step/sec, the 12 models in Series K923 feature a linear force up to 23 lbs., maximum travel rate of 0.95", and maximum linear force (2 phases energized) of 370 oz (103N).

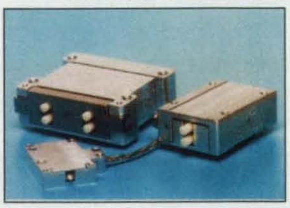
For Free Info Visit www.nasatech.com/thomsonam



Motion Controllers

Galil Motion Control's (Rocklin, CA) Econo Series of DMC-21x2 motion controllers come in 1-8 axis formats, each with a 10Base-T Ethernet port and a 19.2 KB RS232 port. The card-level DMC-2182 measures just 4.25" x 10.75". In addition to controlling both step and servomotors in any combination of axes, the DMC-21x2 can handle various modes of motion including point-to-point positioning, jogging, linear and circular interpolation, electronic gearing, ECAM, and contouring. Features include a homing input and forward/reverse limits for each axis and encoder inputs up to 12MHz.

For Free Info Visit www.nasatech.com/galil



Piezoelectric Motors

Nanomotion's (Ronkonkoma, NY) family of HR-V and HR-UV series motors are for use in vacuum environments. With a size range from a single element (providing 0.45kg of force) to an 8 element motor (providing 3.6kg of force), the HR series is capable of driving both linear and rotary stages. The HR-V vacuum series is rated up to 10-7 Torr and the HR-UV is rated up to 10-10 Torr. Both configurations are suitable for bake out and operate without magnetic field.

For Free Info Visit www.nasatech.com/nanomotion

Torsionally Stiff Couplings

The X Series by Helical Products Company (Santa Maria, CA) is a new stainless steel, flexible coupling designed to meet the exacting positioning requirements of servomotor applications. The coupling features high torsional stiffness, low radial loads, one-piece integrity, and zero backlash. A substantial parallel misalignment capability reduces the need for high precision alignment during assembly operations. Created for high performance motion control systems, the X Series combines greater end-to-end rotational accuracy with radial flexibility in one design.

For Free Info Visit www.nasatech.com/helical10

Optical Component Alignment System

Danaher Precision Systems' (Salem, NH) Photonic Processor™ System is an integrated suite of alignment tools and functions meant to replace traditional search-based peak finding with a synchronous demodulation solution. Teamed with Danaher's compact, frictionless air bearing stages, it delivers high-speed optical alignment over an extended travel range with nanometer resolution. Housing a compact 2U high (3.5") rack mount unit, the system includes low noise optical power meters, laser diode light sources, and rapid first light acquisition. Its open architecture design provides flexible alignment configuration.

For Free Info Visit www.nasatech.com/danaherps

Delta Driver Setup Software

The Delta Driver™ setup software, Delta-View™, by Industrial Indexing Systems (Victor, NY) allows the user to configure and monitor the full line of Delta Servo Drives using a PC. All the setup and tuning parameters can be accomplished with a click of a mouse or from the drive's onboard keypad/display. The software includes a simulation mode that demonstrates the software's capability without having an active Delta drive. The software is compatible with Windos 95/98™ and Windows NT™.

For Free Info Visit www.nasatech.com/industrialis

Optical Linear Encoder

The RGH25F non-contact linear encoder by Renishaw (Hoffman Estates, IL) offers resolutions from 5µm to 10nm. Compact design and self-tuning electronics make the RGH25F suitable for positioning fiber optic splicing equipment in the telecommunications industry. The non-contact design eliminates hysteresis, friction, and wear, while the low mass, compact readhead handles high accelerations and speeds to 300mm/second. The ultra-low profile, low-mass RGH25F readhead measures 36 x 14.3 x 12.5mm and weighs a mere 22g. Patented filtering optics provide immunity to dust, scratches, and light oils on the tape scale.

For Free Info Visit www.nasatech.com/renishaw

New INCH & METRIC Drive Component Catalog Set

Free 1,184-page "Handbook of Inch Drive Components - 790" and 1,060-page "Handbook of METRIC Drive Components - 780" feature over 68,000 off-the-shelf standardized components, including over 3,700 new products including: gears, belt and chain drives, shafts, shaft accessories, bearings, couplings, universal joints, vibration mounts, gearheads and speed reducers, right angle drives, brakes and clutches. (516) 328-3300 • Fax: (800) 737-7436. See them NOW at: www.sdp-si.com/search3

Stock Drive Products/Sterling Instrument

For Free Info Enter No. 609 at www.nasatech.com/rs

NEW Integral Fastening System

Fairloc® the better way! The patented Fairloc® one-piece clamping system is non-marring, easily adjusted and cost effective. Over 3,400 inch and metric drive components featuring this unique system such as couplings, timing belt pulleys, gears, etc. are available in the NEW Fairloc® Components Catalog, D242.

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Web: http://www.sdp-si.com/search3

For Free Info Enter No. 610 at www.nasatech.com/rs

NEW Timing Belts Drive Catalog From Stock Drive Products/Sterling Instrument

The process of selecting timing belt drives for new prototypes or for production application just became easier with the publication by Stock Drive Products and Sterling Instrument (ISO 9001 registered) of a free 480-page catalog, the "Handbook of Timing Belts and Pulleys" catalog D265. The catalog features timing belts and pulleys in the following pitches: MXL, 40DP, XL, L, 3mm HTD, 5mm HTD, T2.5, T5, T10, 2mm GT®2 and 5mm GT®2. Also included is a comprehensive 169-page Technical Reference Section.

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NEW SDP/SI Drive Component Database

You can now easily find over 68,000 SDP/SI drive components at our new eCatalog database. It features interactive quoting, free 2D & 3D CAD drawings, plus complete specs for pulleys and belts, gears, bearings, couplings, linear motion components and much more!

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For Free Info Enter No. 644 at www.nasatech.com/rs

H834 Linear Motion Products

The new 176-page catalog H834 features a large selection of completed X, XY and XYZ linear position systems. This includes gantry tables, belt driven and ball screw driven slides for all types of automation including inspection, dispensing and testing machinery. 4 rotary tables are available handling loads from 50 to 2000 pounds. This new catalog from Techno Inc. also has a complete selection of single and multi-axis conrollers for stepper and servo motors as well as software to program them.

Techno Inc.
2101 Jericho Turnpike, Box 5416, New Hyde Park, NY 11042-5416
(516) 328-3970 • Fax: (516) 358-2576
See our New interactive database at: www.techno-isel.com/search5

For Free Info Enter No. 645 at www.nasatech.com/rs

H860 Linear Motion Components

The new master catalog H860 features linear rails and bearings for all types of automation applications as well as acme and ball screws. These components make it more affordable to design, build or repair linear systems and/or production, dispensing or testing machinery. This new catalog from Techno Inc. also has aluminum extrusions and T-slotted table plates. These plates are ideal for flexible manufacturing platforms.

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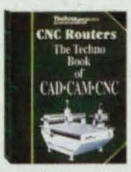


CAD/CAM/CNC - 2nd Ed. "What To Know Before You Buy a CNC Router"

New free 144-page primer (h840) explores topics to know before you invest in CAD/CAM/CNC technology. A comprehensive Technical Section covers: scanning, tooling, fixturing and stepper/servo technology. Application case histories cover: wood, plastic, prototypes, engraving, education and more. Shows how CNC routers can expand business as well as provide quick payback. Includes specifications and descriptions of 15 CNC router systems and 2D and 3D software packages.

Techno Inc.
(800) 948-3246 • Fax: (516) 358-2576
www.techno-isel.com

For Free Info Enter No. 647 at www.nasatech.com/rs

New Bearing Catalog B610

Hundreds of new bearing products have been added to this new 264-page catalog describing a full line of over 12,580 ball bearings, thrust bearings, sleeve bearings, needle bearings, linear ball bearings, aluminum-lined linear bearings and inner and outer ring spacers. Also included is a technical section to help designers/specifiers plan, design and specify bearings.

Quality Bearings & Components
(516) 616-0436 • Fax: (516) 616-0443
See it NOW at: www.qbcbearings.com

For Free Info Enter No. 648 at www.nasatech.com/rs

New on the MARKET

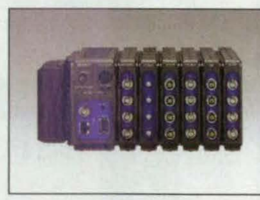
Modeling and Simulation

COMSOL, Burlington, MA, has released FEMLAB v2.3 multiphysics modeling and simulation software featuring new versions of the Structural Mechanics Module, Chemical Engineering Module, and Electromagnetics Module. The software provides new solvers for parametric analysis, modeling of large vector field models and transport processes. Also included are new eigenvalue solvers, and new capabilities in 3D solids, shells, and beams. **For Free Info Visit www.nasatech.com/comsol**

Hybrid Actuators

RB HybroDynamics, Lynnwood, WA, offers Hy-P hydro-pneumatic hybrid actuators that use fluid power technology combining actuation powered by compressed gas with hydraulically governed motion. At shop standard and up to 300 PSI nominal working gas pressure, the actuators provide displacement and positioning between two terminal points. They are interchangeable with conventional pneumatics, and can be regulated pneumatically and hydraulically. **For Free Info Visit www.nasatech.com/rbhybro**

Data Acquisition System



The EX Series data acquisition and analysis system from Sony Precision Technology America, Lake Forest, CA, consists of an i.LINK Interface unit, which interfaces with any PC via i.LINK, and four channel input/output modules. This enables the configuration of any type of system, from a compact, standalone four-channel recorder to a wide, distributed, multi-channel real-time analysis system. The system operates on AC and DC power, and on battery for field or mobile data acquisition. **For Free Info Visit www.nasatech.com/sonypta**

Viewing and Presentation Tool

ALGOR, Inc., Pittsburgh, PA, has released Superview IV, an integrated results environment offering evaluation and presentation options for all ALGOR linear analyses. Features include multiple-window displays, 3D viewing options provided by OpenGL-based displays, clipping planes that enable cross-section viewing of models, controls for customizing the results legend, and pre-defined and user-defined color palettes for result contours. **For Free Info Visit www.nasatech.com/algor**

Touchscreen Interface

The HMI500 Series touchscreen interfaces from Maple Systems, Everett, WA, features 133 MHz processing, 5 MB standard Flash and Operating RAM, 256 colors, graphics and animations, and the ability to place an unlimited number of touch objects on each screen. The series supports 20 brands of controllers and protocols. **For Free Info Visit www.nasatech.com/maple**

New LITERATURE

Temperature Measurement

OMEGA Engineering, Stamford, CT, has released the 2,000-page Volume MM™ Temperature Handbook describing 40,000 products for process measurement and control. Product selections include connectors, wire, and temperature sensors for thermocouples, RTDs, thermistors, probes, meters, handhelds, transmitters, controllers, and recorders. **For Free Info Visit www.nasatech.com/omegaoct**

Spiral Retaining Rings

Smalley Steel Ring, Lake Zurich, IL, offers a product catalog covering spiral retaining rings. Included are light, medium, and heavy-duty rings, as well as shims and WaveRings®. Load and rotational capacity, a materials selection guide, and other spring products are included. **For Free Info Visit www.nasatech.com/smalley**

Switches

A 217-page catalog from E-Switch, Brooklyn Park, MN, describes rotary, detector, leaf, keylock, tactile, DIP, and slide switches. Also included are snap-action switches available in standard, miniature, and sub-miniature series. Applications range from office equipment to control functions in industrial test and measurement uses. **For Free Info Visit www.nasatech.com/eswitch**

Servo Gearheads

A brochure from Neugart USA, Bethel Park, PA, provides an overview of the PLS and PLE series in-line planetary servo gearheads, and the WPLS and WPLE series right-angle bevel planetary servo gearheads. **For Free Info Visit www.nasatech.com/neugart**

Tools and Instruments

Jonard Industries Corp., Tuckahoe, NY, offers a product catalog on force gauges, telecommunication tools, wire wrap tools, connector tools, burnishers, alignment tools, and tool kits. All instruments are applicable for telecom, computers, and electronics industries. **For Free Info Visit www.nasatech.com/jonard**

Sealed Components

A 376-page product guide from Ceramaseal, New Lebanon, NY, includes temperature, pressure, current, and voltage rating specifications for feedthroughs, multipin connectors, coaxial connectors, thermocouples, isolators, viewports, and vacuum hardware. The components support optical, gas, liquid, power, instrumentation, and sensing applications. **For Free Info Visit www.nasatech.com/ceramaseal**

LITERATURE & WEB SITE SPOTLIGHT

Free catalogs and literature for NASA Tech Briefs' *readers. To order, enter the corresponding number on the Online Reader Service Page at* www.nasatech.com/rs.

2002 PRODUCT DESIGN GUIDE ON THE WEB

Pulizzi Engineering, manufacturer of AC power distribution and control systems, has announced its 2002 Product Design Guide that includes standard units, new products, engineering specifications, and a sampling of custom systems. The Web site has a new product search engine that searches the extensive engineering database and submits a list of products to the customer that will meet specific needs. Pulizzi Engineering, Inc.; Tel: 714-540-4229 or 800-870-2248; email: sales@pulizzi.com; www.pulizzi.com

Pulizzi Engineering, Inc.

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STOCKED BELLOWS CONTACT SPRINGS

New brochure presents Servometer's lines of miniature, gold-plated, bellows-type spring contacts and flexible interconnect contacts, which range from ODs of 0.037" to 0.125". Servometer contacts insure electrical continuity where vibration, tolerance build-up, and thermal expansion are a problem. Lifetime spring repeatability and reliability. Visit our homepage: www.servometer.com. Servometer® Precision Manufacturing Group, LLC, 501 Little Falls Rd., Cedar Grove, NJ 07009-1291; Tel: 973-785-4630; Fax: 973-785-0756.

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WIRING DUCT SYSTEM

Internationally approved wiring duct system in white, gray and now black. A manufacturer of dinosaur "coverless" duct as well as DIN rail and accessories including the new aluminum 2 inch high step rail. IBOCO CORPORATION®, 10 Alvin Court, Suite 100, East Brunswick, NJ 08816; Tel: 732-238-0200; Fax: 732-238-0304; e-mail: iboco@worldnet.att.net

IBOCO Corporation

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POROUS CERAMIC VACUUM CHUCK

PhotoMachining offers a porous ceramic vacuum chuck for use with thin films and other flat samples. Pore sizes under 25 microns assure uniform suction and holding power for even the smallest parts. PhotoMachining also provides contract laser-manufacturing services, and designs and builds custom laser-based manufacturing equipment. PhotoMachining, Inc., 4 Industrial Dr., Unit 40, Pelham, NH 03076; Tel: 603-882-9944; Fax: 603-886-8844; rschaeffer@photomachining.com; www.photomachining.com

PhotoMachining, Inc.

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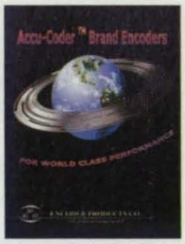
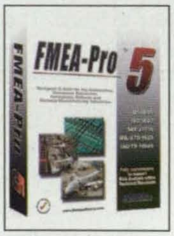


PRECISION ENCODERS

New 98-page catalog gives in-depth specifications and descriptions of Accu-Coder™ brand encoders by Encoder Products Company. Catalog features a full line of Cube™, industry-standard size 15, size 20, size 25, size 58mm, C-face, NEMA mount and hollow shaft encoders, with a wide selection of configuration options, suitable for a wide variety of industrial counting, motion, and motor control applications. Encoder Products Company; Tel: 800-366-5412; Fax: 208-263-0541; www.encoderproducts.com

Encoder Products Company

For Free Info Visit www.nasatech.com/680 or Enter No. 680 at www.nasatech.com/rs



FMEA SOFTWARE

Failure Modes and Effects Analysis using FMEA-Pro™ 5 empowers automotive, consumer, electronic, aerospace, defense and general manufacturing industries to improve the quality, reliability and safety of their products. This fully customizable software helps companies comply with QS 9000, ISO 9000, SAE J1739, MIL-STD-1629, ISO/TS 16949 and other regulations. FMEA-Pro™ 5 contains extensive libraries and data protection features. The report generation tools support a variety of file formats, including HTML and PDF. Download a free trial: www.fmeasoftware.com

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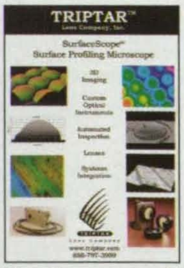
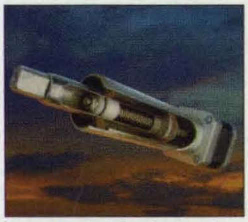


SURFACE PROFILING TOOL

Triptar's surface profiling tool, SurfaceScope™, renders 3D images of surfaces. It is combined with a standard OEM microscope to extract height information throughout the field of view. Acquisition is extremely fast. Resolution is limited only by the microscope and the electronic camera used to capture the images. Triptar Lens Company, Inc.; www.triptar.com/surfacescope.htm

Triptar Lens Company, Inc.

For Free Info Visit www.nasatech.com/672 or Enter No. 672 at www.nasatech.com/rs



LINEAR ACTUATORS

Ideal for robotics, pick-and-place, packaging, medical equipment, clean room, testing, processing, and positioning, the "Digit-HS" (High Speed) linear actuators are available in stroke lengths to 8 in. Offering speeds to 14 in/sec, force to 190 lbs, repeatability to 1.5 microns. Totally enclosed, these actuators are available in a variety of drive screw combinations. Ultra Motion; Tel: 631-298-9179; Fax: 831-298-6593.

Ultra Motion

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DIGITAL DELAY/PULSE GENERATOR

DEI's PDG-2510 is a precision digital delay and pulse generator providing two output channels with independent delay and pulse width adjustable from 0 to 99.9 seconds with 25 nanoseconds resolution. With a standard RS-232 interface, it is well suited for laser timing, automated testing and precision pulse applications. See our Web site for data sheets and additional product information. Directed Energy; Tel: 970-493-1901; Fax: 970-493-1903; e-mail: deiinfo@directedenergy.com; www.directedenergy.com

Directed Energy, Inc. (DEI)

For Free Info Visit www.nasatech.com/660 or Enter No. 660 at www.nasatech.com/rs

ECONOMICAL LINEAR MOTION SYSTEM

The Econo Rail linear bearing system consists of a single piece bearing core that is ground all over and two recirculating ball bearing circuits with 3.5mm diameter steel balls. Two bearing elements are mounted on a specially machined plate to provide precision alignment. The bearing is preloaded to eliminate play and provide smooth and accurate motion along the track. This system provides a high level of accuracy, maintaining parallelism at 0.0005 inch per foot, yet can be fabricated without precision machining, reducing the cost to the purchaser. Tusk Direct; Tel: 800-447-2042 or 203-790-4611; www.tuskdirect.com

Tusk Direct

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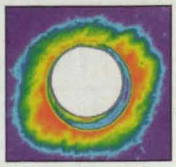

PRESSURE INDICATING SENSOR FILMS

Pressurex force indicating sensor films enable you to quickly, accurately and inexpensively measure pressure distribution and magnitude between any two contacting surfaces. Ideal QC and R&D applications include evaluation of bolted joints and gasketed surfaces, lamination presses, nip impressions, heat seals, composite material tests and machine calibration. FREE samples. Sensor Products Inc. USA; Tel: 973-884-1755; Fax: 973-884-1699; e-mail: sales@sensorprod.com; www.sensorprod.com

Sensor Products Inc. USA

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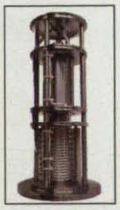

IEC CORPORATION INTRODUCES FIBER OPTIC SLIP RING LINE

IEC has a catalog of their standard line, but pride themselves in stating that they only sell about 10% standard. Meaning that 90% of their business lies in modified and custom designs. The fiber optic rotary joint, or FORJ, is offered from 1 to 7 channels, single or multimode. The standard options available on the electrical component are: 2-60 rings, current to 90 amps, voltage to 6000V, signal to 250 MHz. IEC Corporation, 3100 Longhorn Blvd., Austin, TX 78758; Tel: 512-836-0547; Fax: 512-834-1082; e-mail: info@ieccorporation.com; www.ieccorporation.com

IEC Corporation

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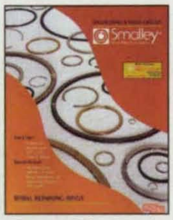

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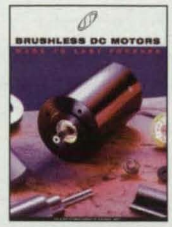

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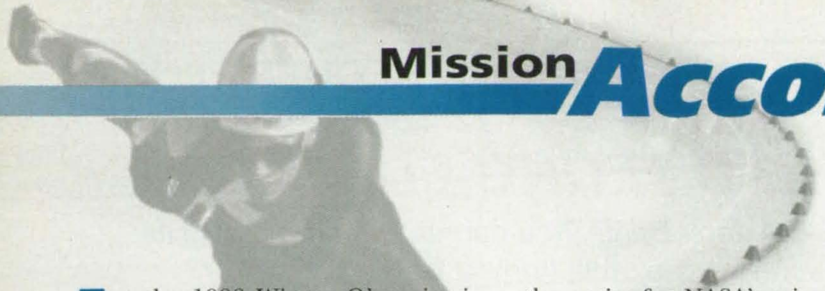


At the 1998 Winter Olympics in Nagano, Japan, U.S. speedskaters took home just two medals — a silver and a bronze — both of which were won by Chris Witty. At the 2002 games in Salt Lake City, the U.S. long- and short-track teams won 11 medals. How did they make such a drastic improvement in four years? In addition to hard training and new aerodynamic suits, the U.S. team had a competitive edge at the Salt Lake City games. Several of them used a new polishing tool that improved their skate glide 10 to 15%. That innovative tool came from NASA.

During a trip to the U.S. Olympic training facility in Colorado Springs in the summer of 1999, Darryl Mitchell of NASA's Goddard Space Flight Center's Technology Commercialization Office met with the U.S. Olympic Committee to offer help in transferring NASA technologies that had application in the various Olympic sports.

The U.S. Speedskating Team took Mitchell up on his offer. "When I heard that NASA was interested in helping athletes, I was very excited," said Finn Halvorsen, long-track program director for U.S. Speedskating. "I mean, it's NASA. If they can put a man on the Moon, surely they can help our skaters."

Halvorsen worked with Mitchell to find NASA technologies that could help address three areas that needed improvement: reducing the weight of the skate, improving their mechanical functionality, and providing better glide and grip for the skate blade. The blade, which is 1 mm wide where it meets the ice, needs to glide with the least amount of friction possible while maintaining a sharp edge to ensure adequate grip in the turns.

"I got a real crash course in speedskating there," said Mitchell, "and as a result of that, we generated a list about two pages long of possible technologies that would fit speedskating's needs. In the end, we thought that maybe the polishing technique could be adapted somehow for use on the skates."

The polishing technology was based on the same principles used to make the optics for NASA's science observatories such as the Hubble Space Telescope. Highly polished optics are needed to obtain sharp, clear images in space. The mirror-polishing technique was developed by Jim Lyons, who had worked at NASA Goddard as an optics engineer before forming his own optical systems company, PROSystems (www.retros.com).

"Polishing aluminum is one particular part of the optics world that's haunted the industry for many years. What we ended up doing was developing what was called aluminum superpolishing. It's a process that allows us to polish a bare aluminum mirror and make a very high-quality aluminum optic that's very lightweight and very user-friendly," explained Lyons.

The new polishing tool is put to use on the skate blades.

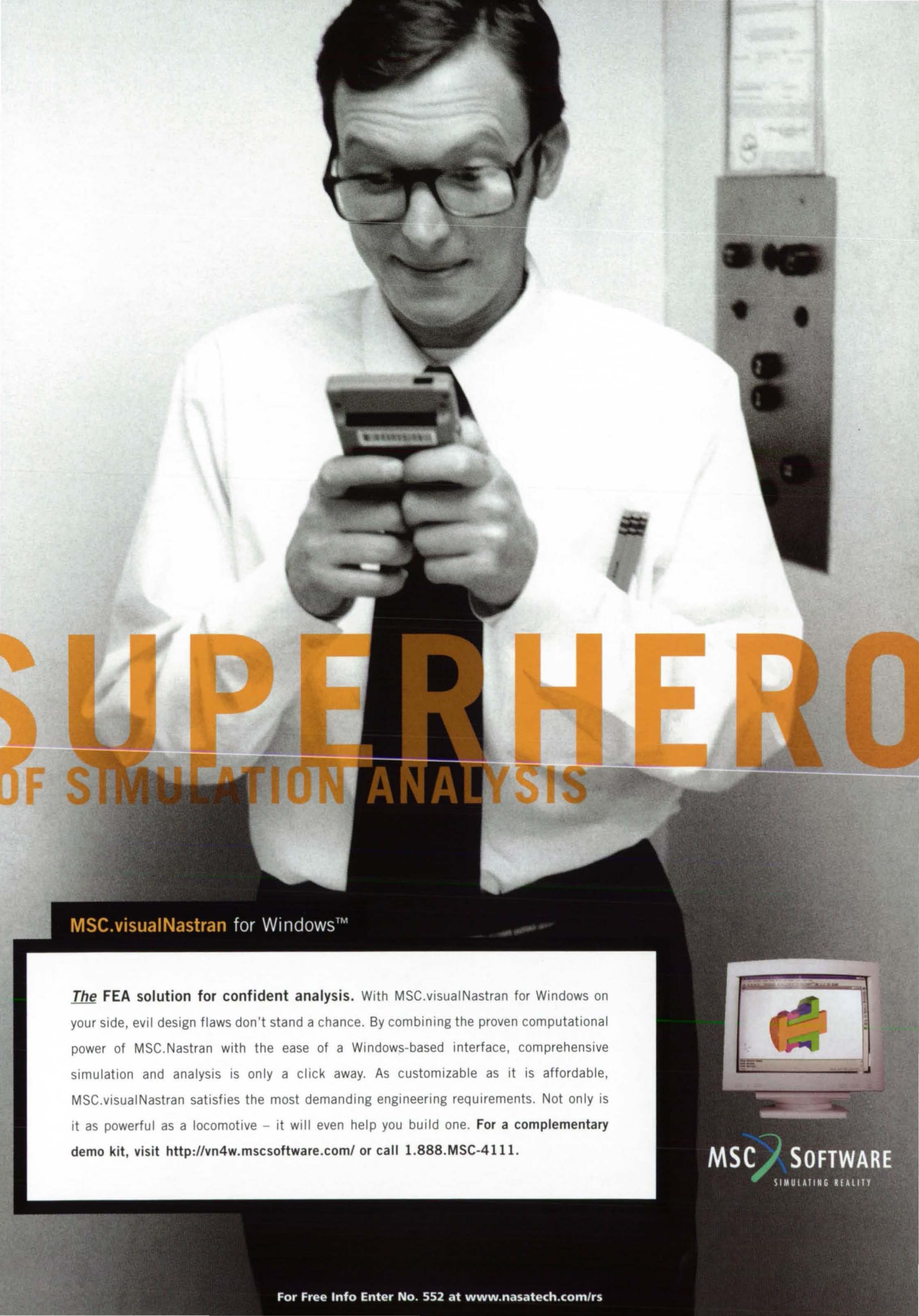
U.S. Speedskater Chris Witty wears her newly polished skates in the Salt Lake City Olympics. (Jerry Search, SCSSA, Copyright ©2001)

Mitchell worked with Joe Famiglietti at NASA Goddard, who had been helping Lyons commercialize his aluminum super-polish technology. "They were the ones that cross-referenced the problem that the speedskating team was having with the possible technologies that could be used," said Lyons. "They handed off a pair of blades to me that didn't even have boots on them, just to see if we could put a shine on the actual edge of the blade."

Lyons took the blades and began to explore how optical polishing technologies could be transferred to the speedskates. "For ice skating, the purpose is to reduce the surface roughness, and therefore, you reduce the coefficient of friction, which gives the skate an improved glide," he explained. The result was a new polishing tool used during blade sharpening.

The new sharpening process begins by securing the skates in a jig. A sharpening stone is run over the blades, followed by other sharpening tools, each with a progressively finer roughness. During the sharpening, a burr begins to form on the edge of the blade. The burr is removed with a special stone. Then, the skates are ready for polishing. To prepare the tool for polishing, a combination of a polishing compound and a standard lubricating oil is used. When injected through the ports, the compound and the oil saturate a polyethylene-impregnated felt pad in the bottom of the polishing tool. It is this pad that touches the 1mm surface of the blade. The tool is then rubbed quickly and vigorously along the blade. It only takes 30 to 60 strokes to improve the blade's surface.

(Continued on page 66)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