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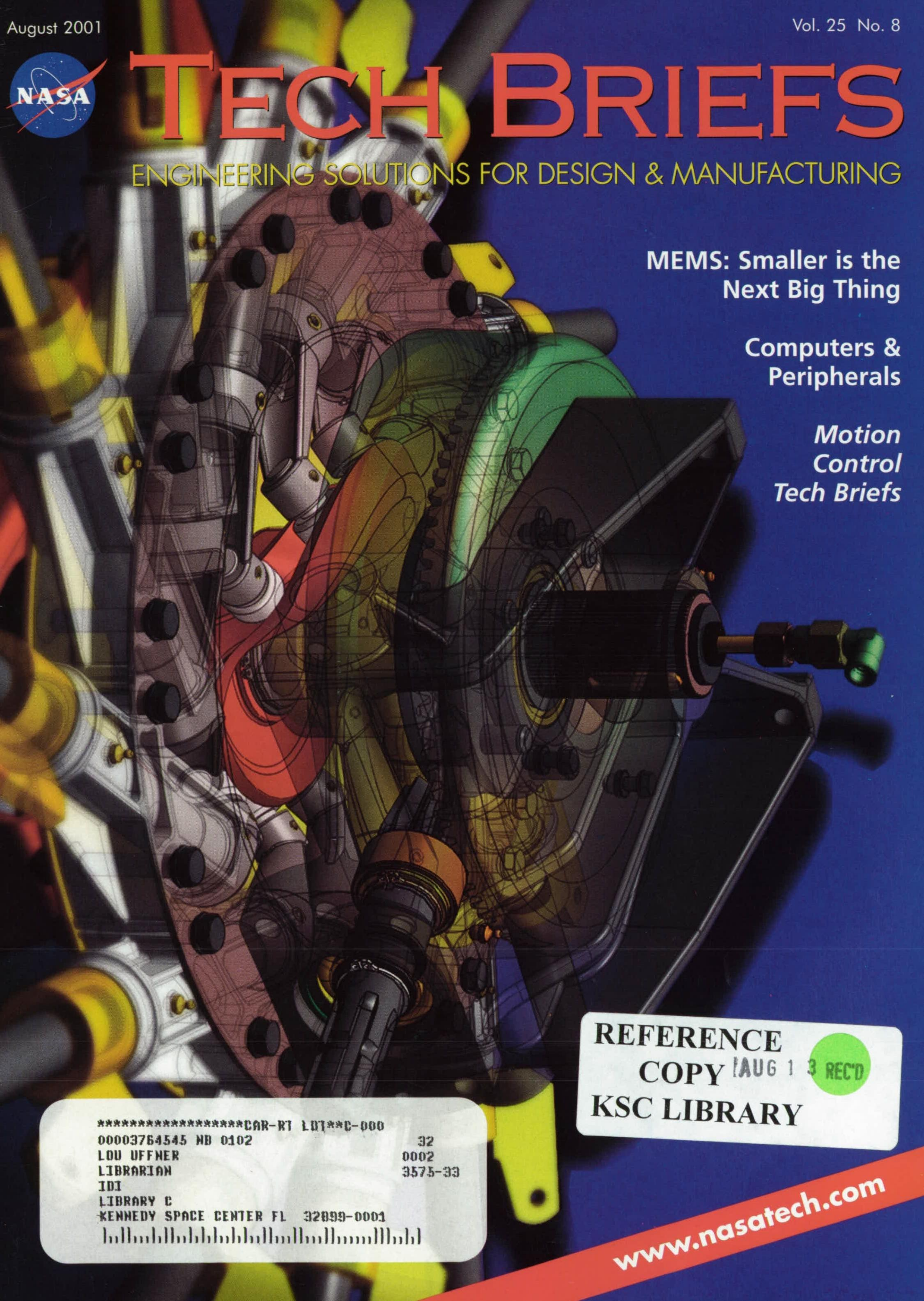
Vol. 25 No. 8

NASA

TECH BRIEFS

ENGINEERING SOLUTIONS FOR DESIGN & MANUFACTURING



MEMS: Smaller is the Next Big Thing

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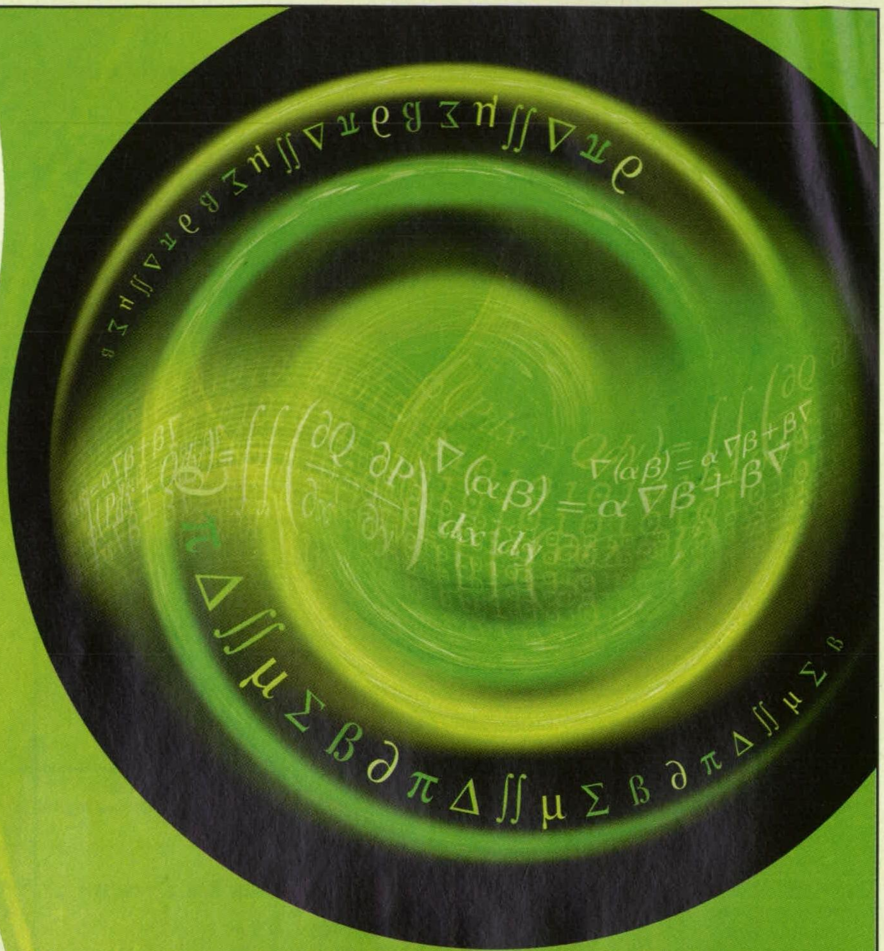

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ENGINEERING SOLUTIONS FOR DESIGN & MANUFACTURING
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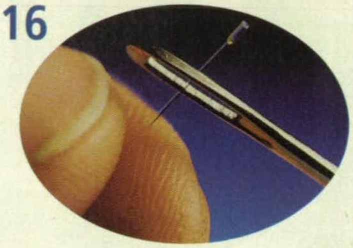
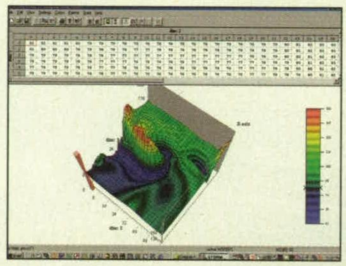


SOLUTIONS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DEPARTMENTS

NEW FOR DESIGN ENGINEERS

SPECIAL SUPPLEMENT

Motion Control Tech Briefs

Follows page 48 in selected editions only.

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PRODUCT OF THE MONTH

VX CAD/CAM Version 5 software from VX Corp., Palm Bay, FL, features automatic healing of imported solid models, and direct import/translation of Parasolids files.

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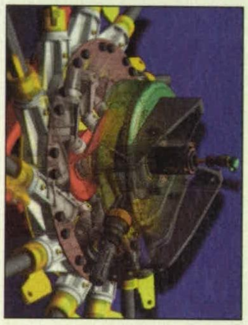
ON THE COVER



German-based Fella-Werke GmbHA used Solid Edge CAD software from UGS (www.solid-edge.com) to design this rotational drive assembly for a piece of agricultural machinery. Version 10 of Solid Edge features enhancements that focus on these types of large-assembly designs, including a drawing view tracker, pipe threading, and part/feature/assembly color options. For more on the latest version of Solid Edge, see New on Disk on page 55.

(Image courtesy of UGS)

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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.

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Langley Research Center
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Marshall Space Flight Center
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Vernotto McMillan
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vernotto.mcmillan@msfc.nasa.gov

Stennis Space Center
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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.

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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.

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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.

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B. Greg Hinkebein
Mississippi Enterprise for Technology
Stennis Space Center, MS
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Joe Becker
Ames Technology Commercialization Center
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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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The medallion, which is embedded in the shape of an Apollo Command Module, has alloyed in it a portion of an artifact flown to the moon and back on Apollo 11

UpFront

PRODUCT OF THE MONTH

VX Corp., Palm Bay, FL, has released Version 5 of VX CAD/CAM, a design-through-manufacturing software package that features new functions and enhancements. Included are manual and automatic healing of imported solid models; direct import/translation of Pro/E, CATIA, and Parasolid files; unified filleting with a single command; lofting for complex shapes; and advanced mold and sheet metal design and manufacturing. New surface creation tools allow users to decide how much attraction or gravity to apply to problem curves, eliminating deformities. The user interface for the new version has been enhanced to comply with Windows standards. The software was designed to integrate product design and manufacturing to eliminate the gap between CAD and CAM packages. Manufacturing planning and CNC machining routines are an integral part of the VX modeling engine.

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NASA Licenses Mapping Software

A new radar mapping technology designed to generate high-resolution 3D maps of Earth beneath foliage and other vegetation has been licensed by NASA's Jet Propulsion Laboratory (JPL) in Pasadena, CA, to EarthData International of Fresno, CA. This is the first system that will be able to map above, through, and below the vegetation canopy to provide information on landslides that are overgrown with vegetation.

This digital elevation model of Los Angeles County, CA, is typical of the data that will be produced with the GeoSAR system. This model is used to identify potential earthquake hazards.

The Geographic Synthetic Aperture Radar (GeoSAR) mapping system uses radar to operate both day and night, under almost any weather condition. JPL designed and constructed the radar systems and the processing software. After the system is fully tested, EarthData plans to provide GeoSAR mapping services to both military and commercial customers.

The system uses interferometric radar remote sensing and combines X-band and P-band (UHF) radar waves. The shorter wavelength X-band radar measures near the tops of trees, and the longer wavelength P-band penetrates the foliage. The system can produce elevation models with vertical accuracies to 1 to 5 meters. Federal, state, and local government agencies, as well as other organizations, may use GeoSAR data to understand seismic changes in forests, assess forest fire damage, measure timber volume, and help in environmental protection and flood plain management.

For more information visit http://southport.jpl.nasa.gov/html/projects/geosar/geosar.html

What's New On-line

- What's new is what's next: the X Internet. The "Executable Internet" adopts the XML standard, and will become the dominant way we interact with the Net by 2005, according to Forrester Research. The X Internet will replace browsers and static Web pages with a much richer, interactive experience. And speaking of interactive experiences, you can access the full story on the X Internet by visiting the *NASA Tech Briefs* Web site at **www.nasatech.com/features**. There, you'll find out about the first and second stages of the X Internet, how it will affect all aspects of business, which types of vendors will be the biggest winners in developing applications, and what your company can do to prepare for the X Internet.

- If you enjoyed this month's feature story on MEMS and nanotechnology, you'll want to visit **www.nasatech.com/features** for more information on this subject. Each month, we include an on-line feature story that picks up where the print feature leaves off. Additional comments from industry leaders, hot links to related companies, and other supporting information not included in the print piece are highlighted in the on-line feature. You can even access archived on-line stories based on feature articles that appeared earlier this year in *NASA Tech Briefs*.

- Don't forget to visit **www.nasatech.com/25letters** and enter our 25th Anniversary Reader Contest. Simply fill out the brief profile and tell us in 200 words or less how *NASA Tech Briefs* has helped you in your business or daily life during the past 25 years. If your letter is selected, we'll publish it in our December commemorative anniversary issue and you'll be eligible for some great prizes.

Reader Forum

Reader Forum is dedicated to the thoughts, concerns, questions, and comments of our readers. If you have a comment, a question regarding a technical problem, or an answer to a previously published question, post your letter to Reader Forum on-line at **www.nasatech.com,** or send to: Editor, *NASA Tech Briefs*, 317 Madison Ave., New York, NY 10017; Fax: 212-986-7864. Please include your name, company (if applicable), address, and e-mail address or phone number.

The February issue of *NASA Tech Briefs* included a tech brief on page 52 entitled "High-Performance POSS-Modified Polymeric Composites." One of the authors, Joseph Lichtenhan, has been working closely with my company on the development of conformal coatings for use in the electronics industry. The article concludes with the fact that the concept has not been reduced to practice. However, recent tests have been conducted of a POSS-Epoxide reinforced conformal coating applied on electronic controls as a means of protection from streaming moisture environments. The POSS reinforcement of coatings and encapsulants has been proven by these tests to provide a substantial increase in protection of electronic equipment subjected to hostile temperature and moisture environments.

Francis E. Isaman, President
TechnoMerix
celind@gte.net

*(**Editor's Note:** Francis, thanks for your follow-up comments on this technology, which was developed for NASA's Jet Propulsion Laboratory. More information is available at **www.nasatech.com/tsp** under the Materials category.)*

*(**Editor's Note:** Dennis Tito's recent voyage to the International Space Station, courtesy of the Russian Space Agency, has generated both admiration and ire from our readers, including these comments from Gregory N. Shuey.)*

I was the Air Force Director of Security Engineering at NASA's Johnson Space Center during the *Challenger* shuttle disaster. The sentiment among the Air Force at the time was that NASA's penchant for grandstanding by sending non-astronauts up was a dangerous risk that was not merely a publicity stunt to generate more funding support. The net result was that Christa McAuliffe — the "tourist" — seemed to get all the public sympathy when there were other just as important people who died that day.

There is a time and place for everything. Putting a tourist on-board when the Space Station is built and valuable manpower is not as necessary would be a more prudent approach. The Russians have an amazingly juvenile mentality when it comes to dealing with the rest of the world. I worked with them following the collapse of the Soviet Union and, at the same time, tried to get America to fund projects, buy into Russian projects and business interests, and buy its engineers and its technology. Few people would listen to me. Now we're seeing the results of America's failure to become inserted into the Russian system.

Gregory N. Shuey
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gshuey@worldnet.att.net

Technologies of the Month

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For more information on these and other new, licensable inventions, visit www.nasatech.com/techsearch

New Ceramic Coating Improves Gas Turbine Performance

Robert Sherman, EPRI

When attempting to boost gas turbine efficiency, operators have traditionally increased firing temperatures. However, the resulting component wear ultimately leads to a gas turbine's failure. In an effort to prevent this, EPRI has developed a multi-layered, laminated, nanostructured ceramic coating designed to create a protective barrier against heat, oxidation, and corrosion on gas turbine blades.

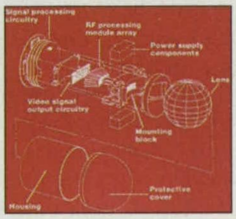
The coating is applied by an electron-beam physical vapor deposition process or by sputter coating at temperatures above 1020°C. The coating's thinness reduces stress and weight, and improves the blade's aerodynamic efficiency. The laminated ceramic coating also improves turbine performance by insulating the cooling channels cast into turbine blades and vanes, reducing the requirements for cooling air and the corresponding performance penalty.

Get the complete report on this technology at:
www.nasatech.com/techsearch/tow/epri.html

Instrument Landing System Promotes Safer Aircraft Landings in Poor Visibility

Steve Toner, TRW

Landing an aircraft in bad weather has always been challenging for pilots. Instrument landing systems (ILS) have been used to guide pilots in determining the location and size of runways. TRW has developed an ILS that uses a single, fixed, onboard multi-bean antenna system and several low-cost RF beacons on the ground to create an image of the runway as viewed from the aircraft. The antenna system is comprised of a lens, RF processing modules, signal conversion circuitry, and a power supply, all mounted securely in a cylindrical housing in the aircraft.



The ILS requires six ground emitters — four to outline the runway and two more widely spaced apart to provide a more accurate indication of range. The system does not produce a "camera-like" picture, but by using overlapping RF beams, a very accurate image is created of the runway relative to the aircraft. Because this system requires relatively little equipment, its lower cost is ideal for smaller airports. It also enables pilots to fix their position on the ground for taxiing.

Get the complete report on this technology at:
www.nasatech.com/techsearch/tow/trw.html

Bayer Develops Superabsorbent Polymers

Günter Sackmann, Bayer AG

Consumer personal care products such as baby diapers and feminine hygiene products are composed of liquid-absorbing materials called superabsorbent polymers (SAPs). Bayer's new SAPs are created through the process of hydrolysis, in which aqueous emulsions of ultra-high molecular weight polyacrylonitrile are converted into poly(acrylic acid) with sodium hydroxide. This process enables the hydrolysis to be controlled closely, producing a wider range of properties.

Through a chemical surface treatment in which they are dried, ground, and sieved to powders, SAPs can be improved even further, resulting in extremely rapid uptake of liquids while producing a "dry" feeling from the liquid-swollen particles. The new SAP powders provide a much greater surface area and have passed toxicological testing for biological side effects, including skin and eye irritation.

Get the complete report on this technology at:
www.nasatech.com/techsearch/tow/bayer.html

Polymer Blending Technique Reduces Cost and Improves Product

Bill Heise, Eastman Chemical

Dozens of natural and synthetic polymers — such as nylon, cotton, wool, rubber, plastics, and Teflon® — are a part of our daily lives. Polymers are materials consisting of many small molecules, called monomers, linked together to form long chains called macromolecules. Polymeric compounds are materials made from a blend of polymers created in a generally expensive process called impact modification.

Eastman Chemical's new polymer blending technology called Optiloy enables manufacturers to use emulsions in standard PET polymerization reactors to create blends without expensive impact modification. This technology enables a wider range of blends to be created in a polymerization reactor, including condensation-type polymers and a broader category of addition-type polymers that traditionally have been created using extruder blending. Unlike conventional impact polymerization, Optiloy enables the manufacture of a wider range of polymer blends with a simpler manufacturing process, and without large capital outlays for additional equipment, reducing overall cost.

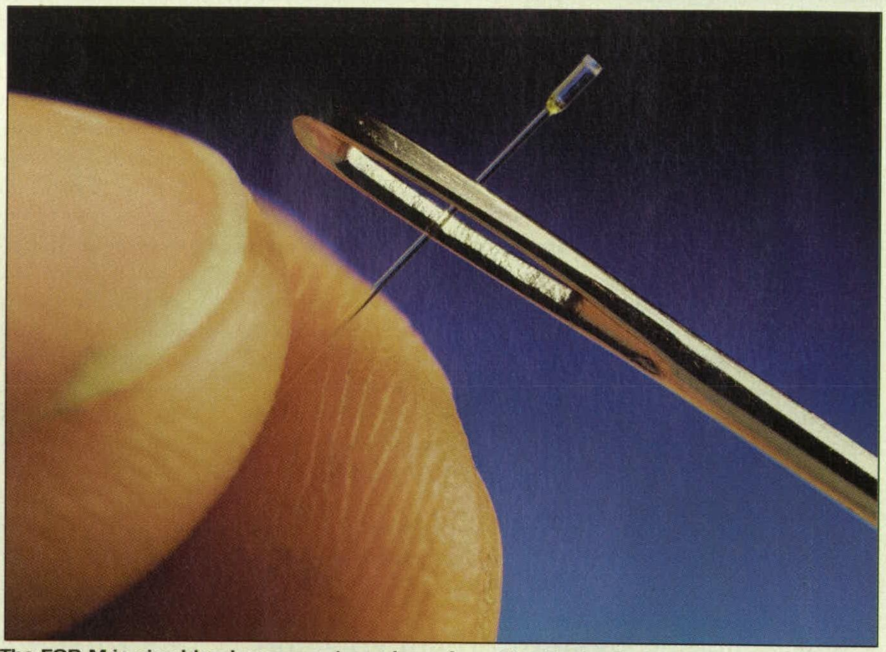
Get the complete report on this technology at:
www.nasatech.com/techsearch/tow/eastman.html

MEMS: Smaller is the Next Big Thing

The basic idea has been around since the 1960s — micron-sized devices that measure typically a few millimeters across. But it's been only in the last decade that Microelectromechanical Systems (MEMS) and nanotechnology have become important parts of most areas of science and technology.

MEMS devices are similar in most ways to conventional devices such as sensors and accelerometers, but at a much smaller size. Nanotechnology refers to devices ranging in size from a nanometer to a micron. Made using semiconductor fabrication techniques, micro injection molding, or other more specialized processes, MEMS devices are frequently combined with integrated circuits on a single chip.

The benefits of using MEMS technology are many, including the obvious benefit of size. And while you may think the smaller a device, the higher the cost, think again. Thanks to integrated circuit processing methods, thousands of MEMS can be mass-produced on a single six-inch silicon wafer, making MEMS less expensive to produce than conventional parts.



The FOP-M in-vivo blood pressure transducer from Fiso Technologies (Sainte Foy, Quebec, Canada) is a fiber-optic MEMS sensor located at the tip of a catheter, internal to the body, for high-accuracy measurements even in the presence of EM or RF fields.

MEMS also enables new functionality, according to Andrew Swiecki, vice president of sales and marketing for IntelliSense, a subsidiary of Corning that designs, develops, and manufactures MEMS devices, as well as sells MEMS-specific CAD software called IntelliSuite™. "There are many things that can be done with MEMS devices that can't be done with other devices." For example, he added, MEMS devices are very low in mass and are very reliable structures, so they can be used in all-optical switching.

New applications for these miniature wonders are popping up every day. Market research firm Frost & Sullivan estimates that the total MEMS market, now at $1.4 billion, will increase at a compound annual growth rate of 17 percent through the year 2004, when the market is expected to exceed $3 billion. Automotive applications such as airbag sensors comprise one-third of the total market, while the medical market is the second largest industry using MEMS in products like disposable blood pressure sensors.

Smart munitions that can alter their paths after firing, robotic grippers, metering nozzles for inkjet printers, drug delivery systems, accelerometers used in antilock braking systems, and automotive sensors for measuring fuel level, tire inflation, and oil pressure are just some of the many applications for MEMS. The telecommunications industry has been invaded by the MEMS wave, primarily for reliable optical switches.

According to Tom Connolly, engineering manager of silicon products for Endevco Corp. — a supplier of sensors, accelerometers, and transducers — the medical and automotive fields hold the greatest promise for commercial success of MEMS. "We're getting into the health field in pacemakers," he said. "Basically, we're using an accelerometer to determine the activity level of the person with the pacemaker. The accelerometer can tell the computer inside the pacemaker whether to increase the heart rate or decrease it, depending on how much movement is involved."

Endevco's other big focus is on the military. "During Desert Storm, the military dropped bombs onto bunkers in Iraq, sometimes exploding on the wrong floor of the bunker. We're designing an accelerometer that can penetrate and count

the number of stories it goes through in these bunkers, and explode it on a particular floor. It's able to distinguish timber, concrete, and open spaces, and even the angle of impact. It's very exciting stuff."

Exciting stuff, indeed. But for all the gee-whiz attraction of these devices, the MEMS industry has been slow to mature. According to a report from Roger Grace Associates, it's the R&D and university activities that continue to be well-funded and robust, rather than the commercial arena.

Swiecki agrees that MEMS is definitely not a mature market — yet. "It's continuing to grow very rapidly. IntelliSense has been working in the MEMS area for 10 years, which makes it one of the more experienced companies. We've been able to see the industry change over the years in all areas," Swiecki said. "Ten years ago, MEMS was used extensively in the sensing industries. Today, the big areas for MEMS are in optics and telecommunications, as well as in life sciences."

The MEMS market is rather fragmented, said Connolly. "There are a number of big players, like Analog Devices, who go after the automotive market, where they have the big volume. On the other hand, Endevco is a smaller player. We go for niche markets and applications like inertial measurement units for guided missiles. The volumes aren't very high, but we're able to work with specific application requirements," he added.

Connolly sees the MEMS market on the verge of an explosion. "They're talking about it becoming a $2 billion market. From our little world, we're seeing increased demand as applications open up." As the market expands, explained Connolly, applications are growing in the health and entertainment fields. "As acceptance increases and the costs keep coming down, it really is becoming quite a flood."

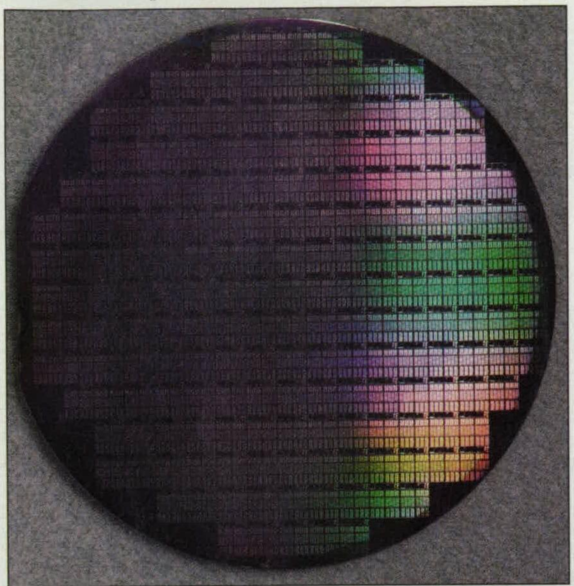
Design Challenges

So when these flood gates open and more MEMS devices pour out into commercial industries, who will make them, and how small will they get? MEMS-based designs can produce systems on a chip, in which a transceiver, batteries, sensors, and microprocessor are all on a single component not much larger than a postage stamp. The trick is designing each miniature piece of the system, and making sure they are manufacturable and durable enough to operate.

MEMS devices are surprisingly rugged and can operate for long periods of time on little power. They must be able to endure damaging internal heat build-up, and withstand excessive structural loads, ambient temperature swings, and severe shock and vibration.

"MEMS is a unique technology, so there will always be unique design challenges," said Swiecki. "For every commercial MEMS device that's developed, both the device itself and the process to make it need to be developed." Another challenge, explained Swiecki, is that MEMS requires a lot of engineering disciplines. In order to create a new MEMS device, he said, a company needs "chemical engineers, process engineers, mechanical engineers, electrical engineers, potentially fluidic engineers — a great deal of diverse expertise."

That expertise includes the ability to simulate and analyze how these devices will perform. Software vendors have even begun to specifically address MEMS development as a capability of their products. ALGOR, a supplier of Finite Element Analysis (FEA)-based simulation software, has incorporated tools for simulating MEMS. The company's solution links electrostatic analysis to structural analysis with a graphical user interface that works within many CAD systems, and includes a FEA model-building tool. "ALGOR's MEMS solution will enable engineers to design the devices that promise to make the next generation of electronic products smarter and cheaper," said Michael Bussler, ALGOR's president and CEO.



This wafer contains bulk-micromachined microfluidic components made for laboratory analytic equipment. The wafer is shown post-processing, but prior to dicing and packaging. (Photo courtesy of IntelliSense)

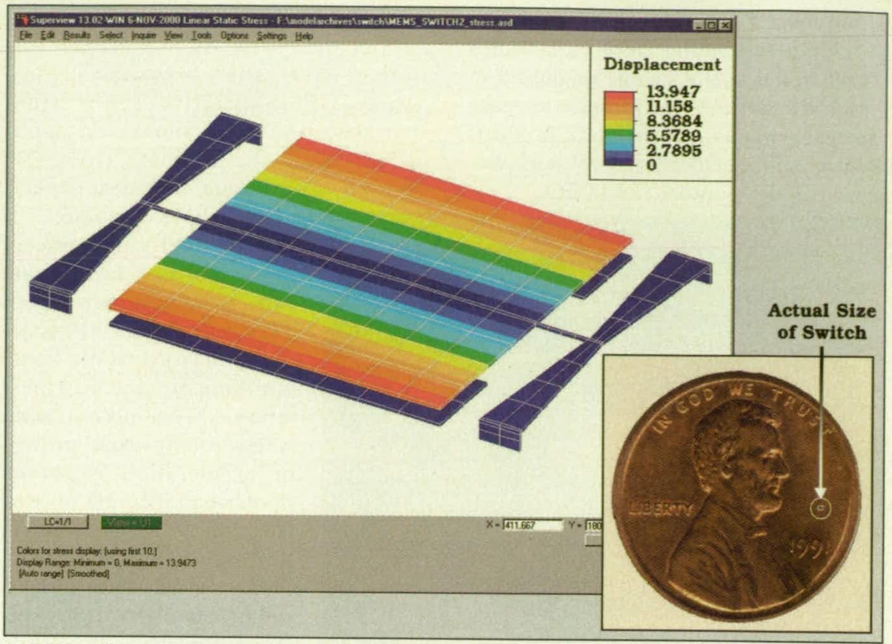
Another simulation software vendor, ANSYS, offers the ANSYS MEMS Initiative Web site (www.ansys.com/action/MEMSinitiative/index.htm) that features MEMS simulation applications using the company's ANSYS/Multiphysics package, technical papers, and a MEMS database.

With all of this engineering expertise, how small can MEMS devices get? Theoretically, said Connolly, there isn't a size limit, but there are practical limitations. "The inertial mass is essentially what gravity or acceleration is acting upon when it comes in contact with an accelerometer. If you're concerned about size, you can always make them smaller. But the larger the mass, the more sensitive the device. On the other hand, we're being pushed to make these things smaller."

Physics is ultimately what will define the smallest size possible, and the capabilities of the materials used, according to Swiecki. "On a more practical level, the applications will define how small devices need to be for each application."

Where MEMS is Going

Perhaps the most innovative and exciting applications for MEMS technology are coming not from commercial industry, but from university, government, and independent research labs. NASA has been a leader in the development of MEMS technology for missions requiring lower cost, smaller size, lower weight, and less power consumption. Nanotechnology development has been underway at a number of NASA centers, including The Center for Space Microelectronics Technology's Microdevices Laboratory at NASA's Jet Propulsion Lab in Pasadena, CA. The Center focuses on sensors, microelectronics, environmental and biomedical technologies, and high-performance computing devices that use micro- and nano-sized devices. NASA's Goddard Space Flight Center in Hampton, VA, and Glenn Research Center in Cleveland, OH, also have begun initiatives to develop and com-



ALGOR software was used to calculate the displacement of this MEMS telecom switch due to electrostatic forces. The inset shows the size of the switch compared to a penny.

mercialize microsystems. High-temperature pressure sensors, chemical sensors, bio-MEMS, and silicon-carbide microdevices are under development.

Nanotechnology also is opening doors to new materials such as carbon nanotubes, a new form of carbon that measures a few nanometers in diameter and several microns long. Carbon nanotubes have exceptional mechanical properties. Researchers at NASA's Marshall Space Flight Center in Huntsville, AL, are working on carbon nanotube material that is 100 times stronger than steel. Researchers at IBM in Yorktown Heights, NY, already have fabricated arrays of transistors from carbon nanotubes, paving the way for electronic circuitry smaller and faster than anything silicon could support.

IBM's work is just one example of commercial companies taking advantage of MEMS and nanotechnology. Said Swiecki, "The larger companies with more developed manufacturing systems and a more flexible infrastructure are beginning to take a lead role in applying MEMS technology to commercial products." The future of MEMS, he added, is in the applications. "If you asked me ten years ago where the market would be today, I would have been wrong. We'll see more commercial applications, and we'll see the technology maturing. There is a lot of potential for MEMS technology. We don't always know what will come out of that potential, but we do believe it's one of those enabling technologies that will continue to grow."

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IBM .... www.ibm.com

IntelliSense .... www.intellisense.com

NASA JPL's Microdevices Laboratory ...... http://csmt.jpl.nasa.gov/csmtpages/index.html

Roger Grace Associates .... www.rgrace.com

Recommended Reading

Handbook of Nanostructured Materials and Nanotechnology
A comprehensive five-volume guide to nanotechnology today.

Available in the *NASA Tech Briefs* on-line bookstore:

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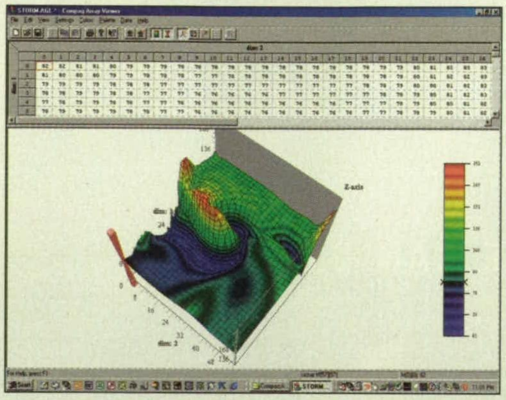
IF YOU CAN THINK IT, WE CAN DO IT.

Compaq Visual Fortran 6.5

Steven S. Ross

My first computer languages were the IBM 1620 assembly language, followed by Fortran II, then Fortran IV running on an IBM System 360. As late as 1988, I was still writing short programs in Fortran more or less from scratch. But I wasn't liking it. The real break with the tribe came when I had to rebuild a Fortran sparse matrix solver for a 40-million-cell



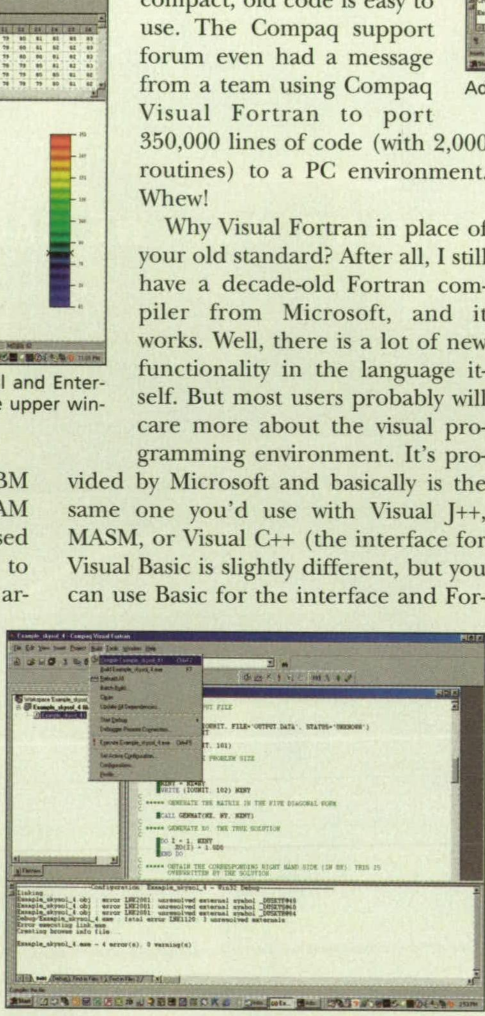
Array visualizer, available in the Professional and Enterprise versions. The graph (of the data in the upper window) can be rotated and repositioned.

data set, to run on a 16-MHz 80386 IBM PS2 Model 80 with a cushy 9 MB of RAM and a Microway co-processor. I had used too many bad programming tricks to port the code easily — not checking array bounds, for instance, so that a lot of stuff got reset to zero without any extra code. I ended up modifying a sparse matrix program written by someone else, in Microsoft Assembler (MASM).

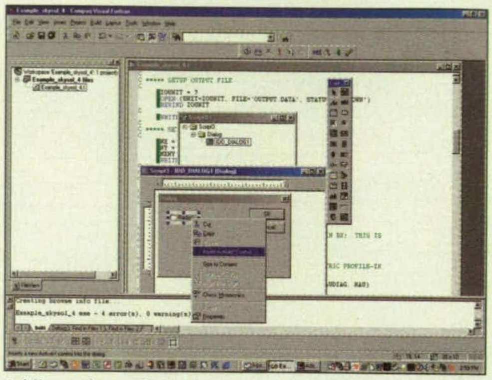
If I had had Compaq Computer Corp.'s Visual Fortran 6.5 (www.compaq.com/fortran) back then, I might have stuck with my original plan. It handled the little things well — easily checking (with a run-time module) and then compiling and building a bunch of routines from my old Mathlib disks, complete with snazzy new Windows interfaces. And the Professional Edition comes with an array visualizer, so if I had transformed my matrix into something digestibly smaller, I could have viewed the data graphically.

Why would you use Fortran today? You probably wouldn't, unless you had old code to port. It's not that Fortran is obsolete. It's just that organizations find it easier to settle on one or two languages for development. It is not as modular as the newer object-oriented languages. For another, C is continually being upgraded — C+, C++, and now C#. Nevertheless, because Fortran 90 and 95 build on earlier versions and only rarely let any functionality go, and because most Fortran code is pretty compact, old code is easy to use. The Compaq support forum even had a message from a team using Compaq Visual Fortran to port 350,000 lines of code (with 2,000 routines) to a PC environment. Whew!

Why Visual Fortran in place of your old standard? After all, I still have a decade-old Fortran compiler from Microsoft, and it works. Well, there is a lot of new functionality in the language itself. But most users probably will care more about the visual programming environment. It's provided by Microsoft and basically is the same one you'd use with Visual J++, MASM, or Visual C++ (the interface for Visual Basic is slightly different, but you can use Basic for the interface and Fortran for the back end of an application). With Visual Fortran, you also can link code written in C++ or other languages to your Fortran routines, and vice versa. You will have to get used to the idea that the Windows interface typically is much bigger than the back-end code that does the calculations.



Getting ready to run the debugger. The code has some variables that are undefined.



Adding a fancy dialog box with lots of interface options.

In the Visual Fortran environment, you specify the type of project you want to start, mainly by defining the interface. For instance, if you specify a project as a full-blown "Windows application," you can build a program that takes full advantage of the full Windows interface, with multiple windows and full graphics. But you'll probably need to know a lot of details about the Win32 API. At the other end of complexity, you can tell the system your project will be a simple command-line "console" application. In between, you can choose to create a "standard graphics" application with one window, or "QuickWin" application (multiple windows, but with basic menus, charts, and icons).

After you write or import the code, you can debug, link, and compile from the same interface. It recognizes and accepts code originally written in Fortran 90 and 77, even when the constructs are obsolete. The Standard edition includes Compaq's math library and an array viewer. The Professional edition adds a wizard to turn programs into COM servers, a sophisticated array visualizer, and the IMSL math and stats libraries. The Enterprise edition adds a toolkit and extensions for server applications.

Steve Ross is a visiting professor at Boston University this year, co-directing a new Institute for Analytic Journalism. He's written 18 books and was president of CCM, an educational software vendor and C graphics shop, in the mid-1980s.

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Who's Who at NASA

Dr. Ayanna Howard, Task Manager, Telerobotics Research and Applications Group, Jet Propulsion Laboratory

Dr. Howard is an information systems engineer who leads the Telerobotics Research and Applications Group at NASA's Jet Propulsion Lab in Pasadena, CA. The team is developing an intelligent software tool for terrain-based analysis of Mars. She also is the principal investigator on a project to develop a real-time software package for autonomous rover navigation on hazardous terrain.

NASA Tech Briefs: What are neural networks and how are you using them in your projects?

Dr. Ayanna Howard: Neural networks are one of the methods we use to give a robot the ability to learn from an experience. It allows you to associate one type of input with another. For instance, we can program a robot to know that if it encounters a four-legged animal that barks, it's a dog. Or, if the four-legged animal meows, it's a cat. Based on the input, we can give the robot parameters on how to deal with what it encounters.

One of the nice things about artificial intelligence is that the applications may change, but you can use a lot of the same techniques. Neural networks are a type of learning tool, so anything that you can learn, you can apply a neural network to. If you have the infrastructure, you may have to tweak things here and there, but the background is so solid that you don't have to re-engineer the entire process.

NTB: You also use a lot of fuzzy logic in your projects. What is fuzzy logic?

Dr. Howard: Everything in the real world is not exact — nothing is 100 percent. We, as people, deal with this all the time. If we're walking and the ground is suddenly uneven, we don't fall — we compensate. Yet, if a robot is walking on flat terrain and suddenly there's a hill, it will fall down because it won't know how to deal with it. The example I like to use is babies. A baby will learn how to walk. But if something drastic happens, and say, it loses a toe, the baby will adapt. Humans use approximation. We don't see a cat and think about the measured physical dimensions of the cat. We say that the cat is big, or small, or fuzzy.

Fuzzy logic takes what humans use — approximation, language, and linguistic-based representation — and applies it in terms of an engineering technology.

NTB: Could any of these artificial intelligence techniques be applied for commercial use in the near future?

Dr. Howard: Manufacturing would definitely be a field where these types of programs could be used. Japan actually uses a lot of fuzzy logic in their plants, so that's definitely a possibility for further use. In fact, right now you have companies trying to do pallet operations where they want the automated forklift to go into a warehouse, find the pallet it needs, lift it up, and take it out to the truck for shipment. That's the type of thing for which you could use neural networks and fuzzy logic, because it is basically the same problem. It actually would be easier because you would know what the warehouse looks like. It would be easier to apply these techniques to known elements and manmade structures than it is to apply it to an unknown environment like the surface of Mars.

NTB: How has the response to this sort of technology changed as it has grown?

Dr. Howard: Interest has grown. People now see the validity of this technology, especially if you want to send an intelligent device into a place where you don't want humans to go. Anywhere that human life might be endangered, you can send something powered by artificial intelligence. Underwater robotics is a good example. We like to send probes down to the bottom of the sea. Due to things like severe pressure, you don't want to send people. You'd send a robot with the same characteristics. Only this time, you have a 3D world instead of a flat plane. That's where fuzzy logic comes in. In terms of the neural networks, because we don't know exactly what it looks like down there, we give the robot the ability to adapt to the situation even if our initial data was incorrect.

*A full transcript of this interview appears on-line at **www.nasatech.com/whoswho**. Dr. Howard can be reached at howard@robotech.jpl.nasa.gov.*

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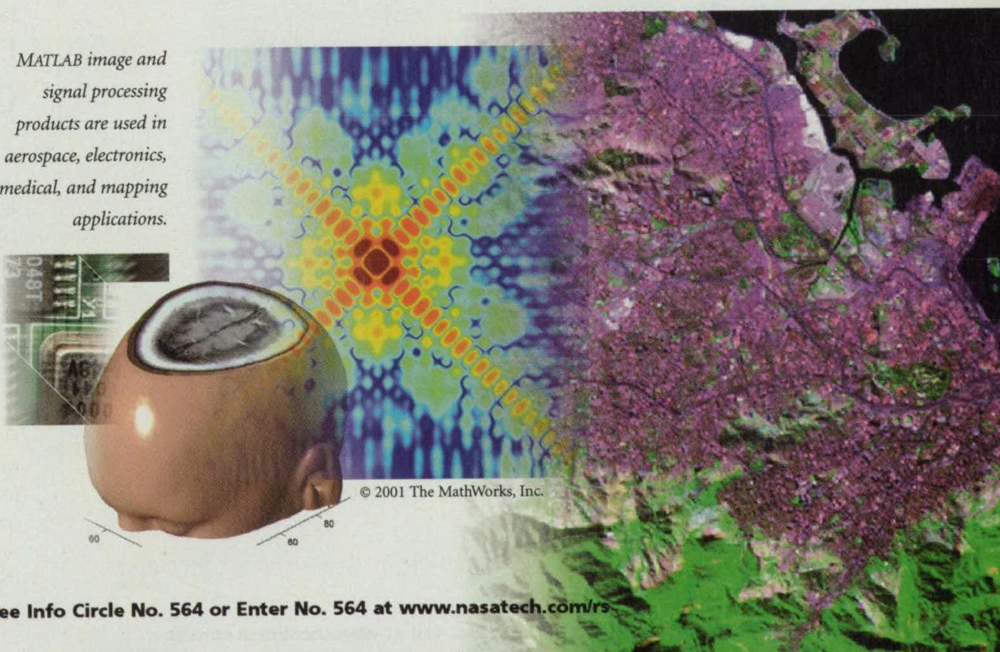

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Commercialization Opportunities

Analog VLSI Circuits for Hebbian Learning in Neural Networks

These circuits were designed and built to implement Hebbian synapses with an improved method of modifying and storing synaptic weights for use in neural-network circuits. The circuits are intended for neural networks that operate with spiking input and output signals.
(See page 28.)

Design of a Highly Reliable Controller for an I^2C Bus

The original design lacks fault-tolerant features that could protect against bit errors, shorting of output drives, or babbling nodes. The present design adds such features.
(See page 32.)

Array of Nanoklystrons for Frequency Agility or Redundancy

Multiple, individually selectable klystrons would be contained in a single, compact unit. Each nanoklystron would resemble a conventional klystron but would be many times smaller, with resonant cavities formed by micromachining in silicon.
(See page 36.)

Millimeter-Wave Dichroic Plates for High Angles of Incidence

A plate of this type is used to separate higher- and lower-frequency components of incident electromagnetic radiation linearly polarized along a specified axis. The plate is designed to reflect most of the radiation below its cutoff frequency while allowing radiation at higher frequency to pass through.
(See page 40.)

Making Ion-Accelerator Grids From Ti Instead of Mo

Titanium offers several advantages over molybdenum as material for thrusters for spacecraft. These advantages could also be expected to extend to the manufacture of grids for ion accelerators used in scientific research and fabrication of semiconductors.
(See page 45.)

Quasi-Fractal Lenticular Booms

According to the proposal, the traditional design would be replaced by an improved one to resist buckling more strongly.
(See page 46.)

Numerical Index for Quantifying Aircraft Icing Hazards

Hazard severity and meteorology are related by measuring ice accumulation rates observed on a standard airfoil under prescribed conditions. This system has greater fidelity than existing ones and is applicable to all types of air vehicles.
(See page 51.)

The NASA Spacecraft Transponding Modem

NASA's Jet Propulsion Laboratory, Pasadena, California

A report describes the NASA Spacecraft Transponding Modem (STM) — a spacecraft transponder now under development for planned use on deep-space missions scheduled for launch in the year 2003. In comparison with a traditional deep-space transponder, the STM will be smaller and less power hungry; the reductions in size and power demand will be effected by use of custom application-specific integrated circuits. The STM will perform all of the traditional deep-space-transponder functions, plus some coding, decoding, and time-tagging functions: The STM will track an X-band uplink signal and transmit both X- and Ka-band downlinks. A command detector, a code-block processor, and hardware command decoder will be integral parts of the STM. Coding functions will include Reed-Solomon coding, convolutional coding, and turbo coding for downlink telemetry. Downlink symbol rates could be ramped linearly to match the expected gain/noise temperature of a receiving station. Data could be transmitted by any of three different phase-modulation schemes at rates from 5 b/s to 24 Mb/s. Other functions will include standard turnaround ranging, regenerative pseudonoise ranging, and differential one-way ranging.

This work was done by Brian Cook, Charles Kyriacou, Constantine Andricos, Gary Burke, James Kowalski, James Layland, Jeff Berner, Jonathan Perret, Narayan Mysoor, Selahattin Kayalar, Amy Holst, Bryan Bell, Vatche Vorperian, and William Whitaker of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "The NASA Spacecraft Transponding Modem," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *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

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Refer to NPO-21004, volume and number of this NASA Tech Briefs *issue, and the page number.*

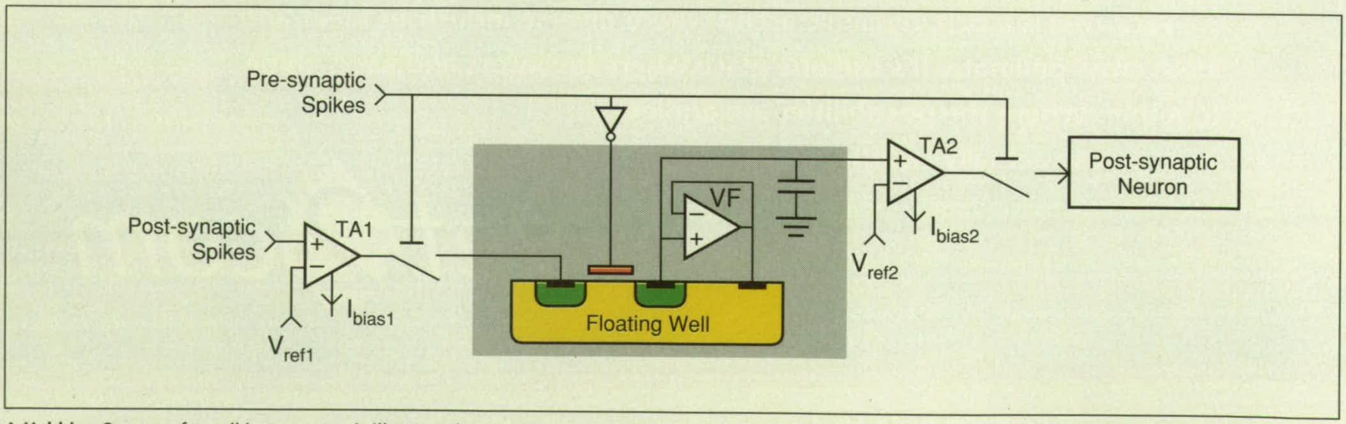
Analog VLSI Circuits for Hebbian Learning in Neural Networks

An unconventional design extends synaptic-weight-storage time and enforces Hebbian learning.

NASA's Jet Propulsion Laboratory, Pasadena, California

An analog very-large-scale integrated (VLSI) circuit was designed and built to implement Hebbian synapses with an improved method of modifying and storing the synaptic weights, for use in neural-network circuits. (In Hebbian synapses, the synaptic weights are modified through Hebbian learning, which is a local unsupervised adjustment of the weight depending on the correlation of activity between pre- and post-synaptic neurons.) These circuits are intended, more specifically, for use with neural networks of the type that operate with spiking (as distinguished from steady) input and output signals.

The development of these circuits was prompted by a need to store and adjust on-chip synaptic weights using local Hebbian learning rules. The synaptic weights must be stored in the form of analog voltages (charges on capacitive nodes). Such storage is problematic because the charges tend to decay by leakage through reverse-biased active/well/substrate junctions. The designs of the present circuits reduce the leakage currents to about one-sixth of those conventional synaptic-weight-storage circuits, thereby making it possible to store the synaptic weights for correspondingly longer times.



A **Hebbian Synapse** for spiking neurons is illustrated.

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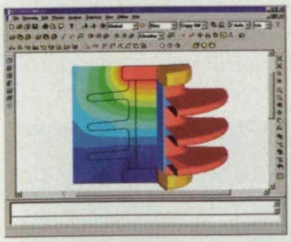

A clean, intuitive, user interface means the software is easier to use and learn than most other electromagnetic CAE tools.

Advanced Technology

We use Integrated's software to model precision magnetic circuits for the reprographics industry as well as other electromagnetic applications. The software enables us to create extremely accurate virtual results. This has allowed us to greatly reduce our prototype-to-production phase."

Group Arnold
Magnetic Technologies Corp,
Rochester, NY.

Advanced features like our intuitive user interface, extensive materials library, powerful solvers, exportable data and graphics, flexible post processing options and powerful parametric optimization routines give you the most sophisticated programs available anywhere. In addition, our coupled electromagnetic/mechanical suite gives you complete solutions.

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Mike Potter
Assistant Engineering Manager,
Industrial Coils,
Baraboo, WI.

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A circuit of the present type includes an analog-weight-storage subcircuit (as depicted within the gray box in the figure) in which the transistor that passes charge on to the capacitive charge-storage node resides in a floating well. The floating well is driven by a voltage follower (VF in the figure) from the storage node, thereby shielding the storage node by reducing the leakage current to the well and enabling the node to hold the charge longer than an ordinary switched capacitor could. The voltage across the active/well junction is held to within the offset of the follower; this typically results in a substantial decrease in leakage current from a normal well that is held at the supply voltage of the well transistor.

The charge-storage subcircuit is incorporated within a larger circuit that acts as a Hebbian synapse; that is, it takes pre- and post-synaptic spike signals as inputs, and increases the synaptic weight if the spikes occur simultaneously. The Hebbian-synapse circuit (see figure) contains two additional transconductance amplifiers (TAs): TA1 controls the learning rate by adjusting the current injected into the storage node, and TA2 converts the stored analog voltage value to a current value. The output of amplifier TA2 is gated by the pre-synaptic input spikes, and hence the final output consists of current pulses that are proportional to the stored voltage and injected into a post-synaptic neuron whenever the pre-synaptic neuron fires a spike. These output current pulses can be summed and integrated with the currents from other synapses in parallel and used to drive the spiking of the post-synaptic neuron. Hebbian learning is achieved by gating charge onto or off the storage node when the pre- and post-synaptic spikes are simultaneous or nonsimultaneous, respectively.

This work was done by Christopher Assad and David Kewley of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*
NPO-20965

Compact, Rugged Enclosure for PC-Based Electronic Circuits

The enclosure helps to protect PC boards against vibrations.

Lyndon B. Johnson Space Center, Houston, Texas

Figure 1 depicts a compact enclosure enabling the operation of personal-computer (PC)-based electronic circuits in harsh environments. The electronic circuits in question are commercial off-the-shelf Industry Standard Architecture (ISA) and Extended Industry Standard Architecture (EISA) printed-circuit boards. The enclosure provides electrical connections and mechanical shielding of the boards. The enclosure serves as a shield against radiated electromagnetic interference (EMI) between the enclosed boards and any exterior equipment. The enclosure also provides mechanical restraint (with some compression) to enable the boards to withstand shock and vibration.

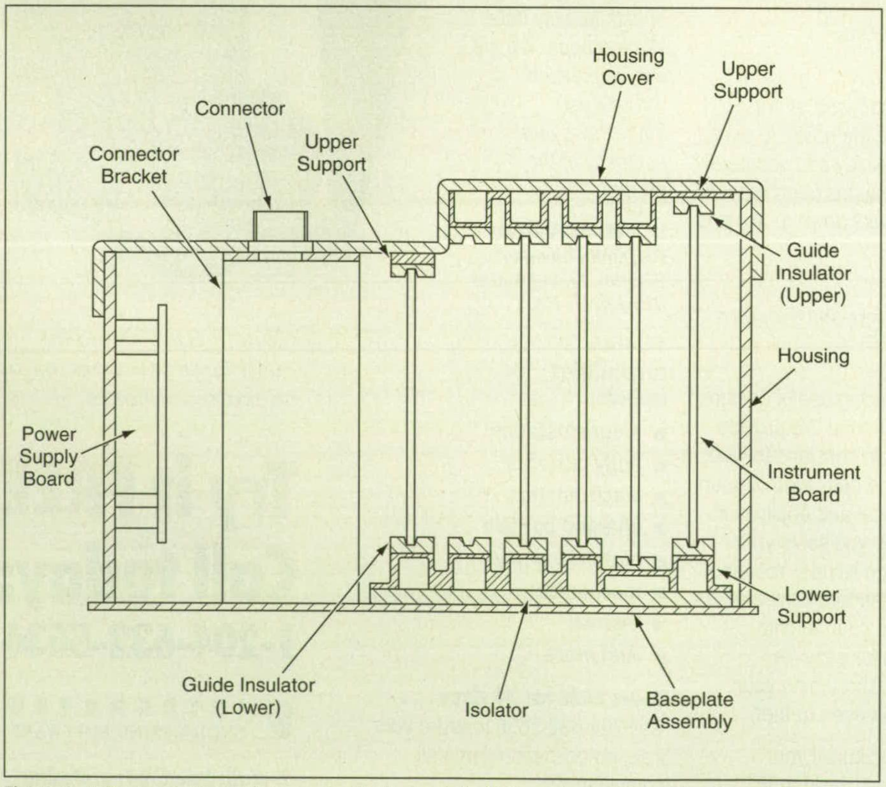

Figure 1. A **Compact, Rugged Computer Enclosure** is built to protect a PC in a harsh environment.

The enclosure consists of two main parts: the housing and the housing cover. The housing includes a baseplate isolator, lower support, lower guide insulator, power supply with EMI filter, passive back plane for the circuit cards (not shown), and connector bracket. The housing cover includes an upper support and an upper guide insulator.

The PC boards are installed in the back plane. The lower guide insulator lower support, and isolator provide support to those parts of the cards that extend beyond bus connectors. The isolator serves as a standoff as

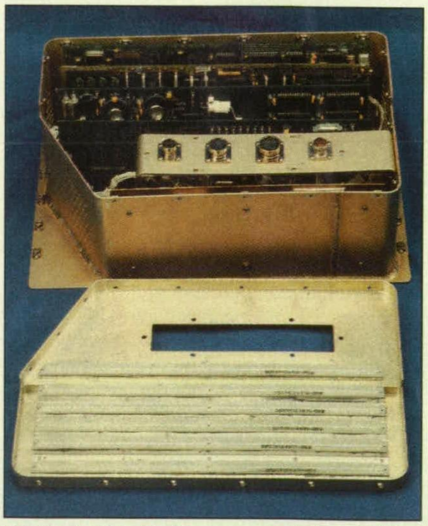

Figure 2. This **Enclosure** was designed for a voice-command-system experiment on the space shuttle. The design is readily adaptable to other (e.g., industrial) applications.

well as a vibration damper. The upper guide insulator and support acts in conjunction with the lower support, lower guide insulator, and back plane to slightly compress the cards. The lower and upper supports are designed and fabricated to match the heights of the cards: This approach enables the enclosure to accommodate cards of different sizes; it also minimizes the size of the enclosure by making it only large enough to house the tallest card.

The connectors provide electrical connectivity among the enclosed boards, the power supply, and external equipment. DC power, microphone signals, and computer communications and other discrete signals flow through the connectors. Vent holes on the housing make it possible to cool the enclosed boards by use of a fan. The vent holes are small enough not to appreciably degrade shielding against electromagnetic interference.

Figure 2 shows a photograph of the prototype version of the flight unit that is part of the voice command system. The unit successfully flew on STS-78. The enclosure with boards passed environmental tests including vibration to 6.1 g(rms).

This work was done by George Salazar and Dena Haynes of **Johnson Space Center** *and Marc Sommers, Hector De Leon, and Eric Kuehnel of Lockheed-Martin. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*

MSC-22702

Design of a Highly Reliable Controller for an I^2C Bus

Fault-tolerant features have been added to the basic I^2C design.

NASA's Jet Propulsion Laboratory, Pasadena, California

The design of a highly reliable controller for a digital data bus incorporates improvements, in both hardware and software, over the basic design of a low-speed, low-power, serial bus known in the industry as "I^2C." ("I^2C" signifies "inter integrated circuit bus" — a bus developed by Philips Semiconductors in the early 1980s.) The original design of the I^2C bus lacks fault-tolerant features that could protect against bit errors, shorting of output drives, or babbling nodes (nodes that misbehave or disrupt normal communication). The present design adds such features: It augments the standard I^2C bus protocol with low-overhead error-detection features and a fail-silent messaging system, and it adds hardware features that automatically isolate babbling nodes. These fault-tolerant features can be disabled through software (for example, to aid testing), but the design makes it difficult to do this accidentally.

The principal advantages of the present design over prior I^2C-bus designs are the following:

- Cyclic redundancy checking (CRC) is used to obtain partial immunity to errors in messages on the bus.
- Devices on the bus are inhibited from monopolizing the bus, even when hardware or software faults occur.
- Special commands have been added to enable direct control of one node by another.

- Asynchronous logic in the basic design has been replaced with synchronous logic.

In addition, the bus is compatible with devices that have been designed to function on previously designed, standard versions of the I^2C bus.

The overall function of a controller according to the present design is that of an interface between a peripheral component interface (PCI) bus and an I^2C bus. The design calls for some basic I^2C bus-controller components and associated logic circuitry for a (PCI) port, plus application-specific integrated circuits (ASICs) that implement logic functions to manage the flow of messages and to exert digital input/output (DIO) control. Additional logic circuits are used as watchdog timers and to effect CRC. On each DIO ASIC, there are two I^2C bus controllers that drive separate system and subsystem busses. Within each I^2C bus controller, there are two I^2C commercial-off-the-shelf I^2C cores. A transmitting line and a clock line between the cores are ANDed together to make them share a common clock and a data-transmission driver with a separate mixed-signal ASIC.

This work was done by Ryan Fukuhara, Huy Luong, Robert Rasmussen, Savio Chau, and Leonard Day of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*

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Refer to NPO-20876, volume and number of this NASA Tech Briefs *issue, and the page number.*

Advances in Parallel Computing on Adaptive Grids

Ames Research Center, Moffett Field, California

Five papers address interrelated topics in parallel computing and the use of adaptive, unstructured computational grids. The titles of the papers and their general subject matters are the following:

- "Parallelization of a Dynamic Unstructured Application using Three Leading Paradigms" compares the parallelization of a dynamic unstructured-mesh-adaptation algorithm by use of a message-passing, a shared-memory, and a multithreading implementation on three supercomputers. It is concluded that multithreaded systems offer tremendous potential for quickly and efficiently solving some of the most challenging real-life problems on parallel computers.
- "Self-Avoiding Walks Over Two-Dimensional Adaptive Unstructured Grids" presents an approach, based on a special class of self-avoiding walks, for partitioning computational loads among parallel processors in cases of adaptive unstructured grids.
- "A Dynamic Load Balancing Framework for Unstructured Adaptive Computations on Distributed-Memory Multiprocessors" describes the JOVE computer program, which balances loads among parallel processors according to a global view each time an unstructured computational grid is adapted.
- "Efficient Load Balancing and Data Remapping for Adaptive Grid Calculations" presents an implementation and integration of all major components of a load-balancing strategy, including the interface between a parallel mesh-adaption code and a data-remapping module.
- "Dynamic Load Balancing for Adaptive Meshes using Symmetric Broadcast Networks" demonstrates that the performance of a novel load-balancing algorithm that utilizes symmetric broadcast networks is comparable to that of a previously developed global load-balancing algorithm.

This work was done by Rupak Biswas and Leonard Oliker of **Ames Research Center**, *Gerd Heber and Guang R. Gao of the University of Delaware, Andrew Sohn of New Jersey Institute of Technology, Horst D. Simon of Lawrence Berkeley National Laboratory, and Sajal K. Das and Daniel J. Harvey of the University of North Texas. To obtain copies of the papers, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Information Sciences category.*
ARC-14106

Full-Spectrum Arraying of Receiving Radio Antennas

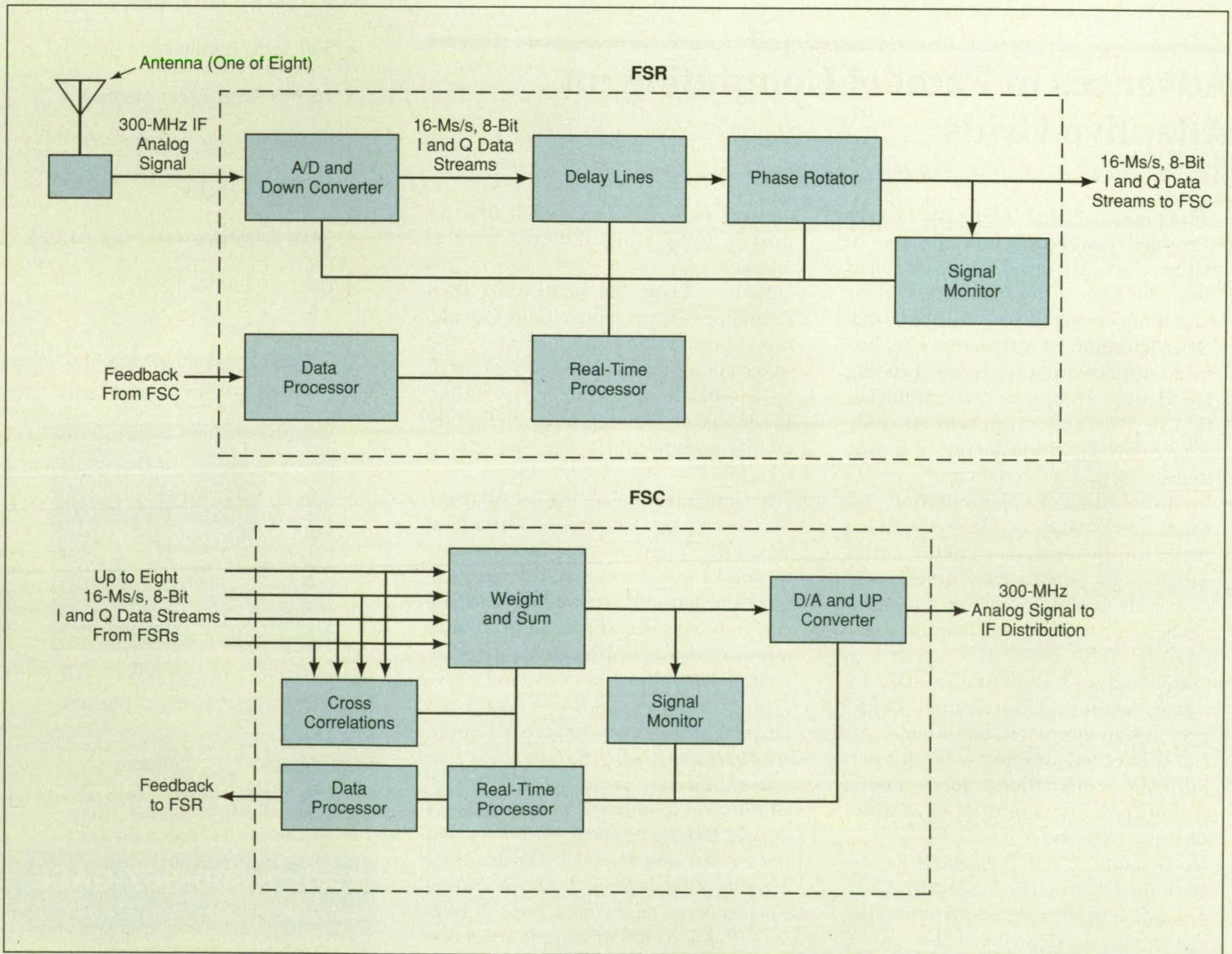
Detectability is increased and both Doppler and ranging data can be extracted.

NASA's Jet Propulsion Laboratory, Pasadena, California

A method of arraying of receiving radio antennas involves utilization of all of the signal information available across a broad spectral band that includes any signal(s) of interest. As used here, "arraying" signifies combining the signals received by multiple antennas at different locations in such a way as to improve reception, as though one had a single larger antenna. Going beyond synthesis of a larger antenna, the present method also provides for extraction of Doppler frequency shifts and differential delays of signals, thereby enabling the generation of information on the ranges and velocities of signal sources. The method was devised to enhance spacecraft-tracking and -telemetry operations in NASA's Deep Space Network (DSN); the method could also be useful in such other applications as radio astronomy, commercial satellite communications, and radio (including television) broadcasting.

In this method, the signals from the multiple antennas in an array are combined in real time by use of correlation processing, among other techniques, implemented by a combination of analog and digital electronic hardware and software. The signal received at each antenna is characterized by a delay and a Doppler shift that depend on the relative position and motion of the antenna and the spacecraft or other signal source. In order to achieve full-spectrum arraying, it is necessary to alter the signal received by each antenna to make its delay and Doppler shift equal to the delays and Doppler shifts of the similarly altered signals received by the other antennas. The altered signals are then combined coherently to obtain an improved detection of telemetry and navigation data.

In the original DSN application (see figure), the signals received by as many



In **This Implementation of Full-Spectrum Combining**, as many as eight signals in a 16-MHz-wide IF band centered at 300 MHz are processed by digital and analog means to generate an enhanced IF signal, allowing for improvement of telemetry and navigation data.

as eight geographically diverse antennas are processed by full-spectrum receivers (FSRs) followed by a full-spectrum combiner (FSC). The analog signal from each antenna is first down-converted to an intermediate-frequency (IF) band centered at 300 MHz. Then in an FSR, the IF signal is subjected to a combination of analog-to-digital (A/D) conversion and frequency down-conversion that yields an in-phase (I) and a quadrature-phase (Q) data stream, each consisting of 8-bit samples at a rate of 16 megasamples per second. The delay and phase of the I and Q streams from each antenna are altered by use of a delay line and a phase rotator. Adjustment is made first by using delay prediction, followed by a feedback measurement of residual delay and phase by the FSC.

In the FSC, cross-correlations of upper and lower sidebands from different antennas (e.g., of the upper sideband received by antenna 1 with the upper sideband received by antenna 2) are computed. The correlations contain information on frequency-dependent and frequency-independent phase offsets related in known ways to differential delays and Doppler shifts. The correlations are processed to generate phase and a delay offset for feedback to each FSR. The I and Q data streams from the FSRs are weighted and summed; the sum signal is then subjected to digital-to-analog (D/A) conversion and frequency up-conversion to obtain the desired enhanced IF signal.

This work was done by Andre Jongeling, Timothy Pham, and David Rogstad of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*

NPO-20874

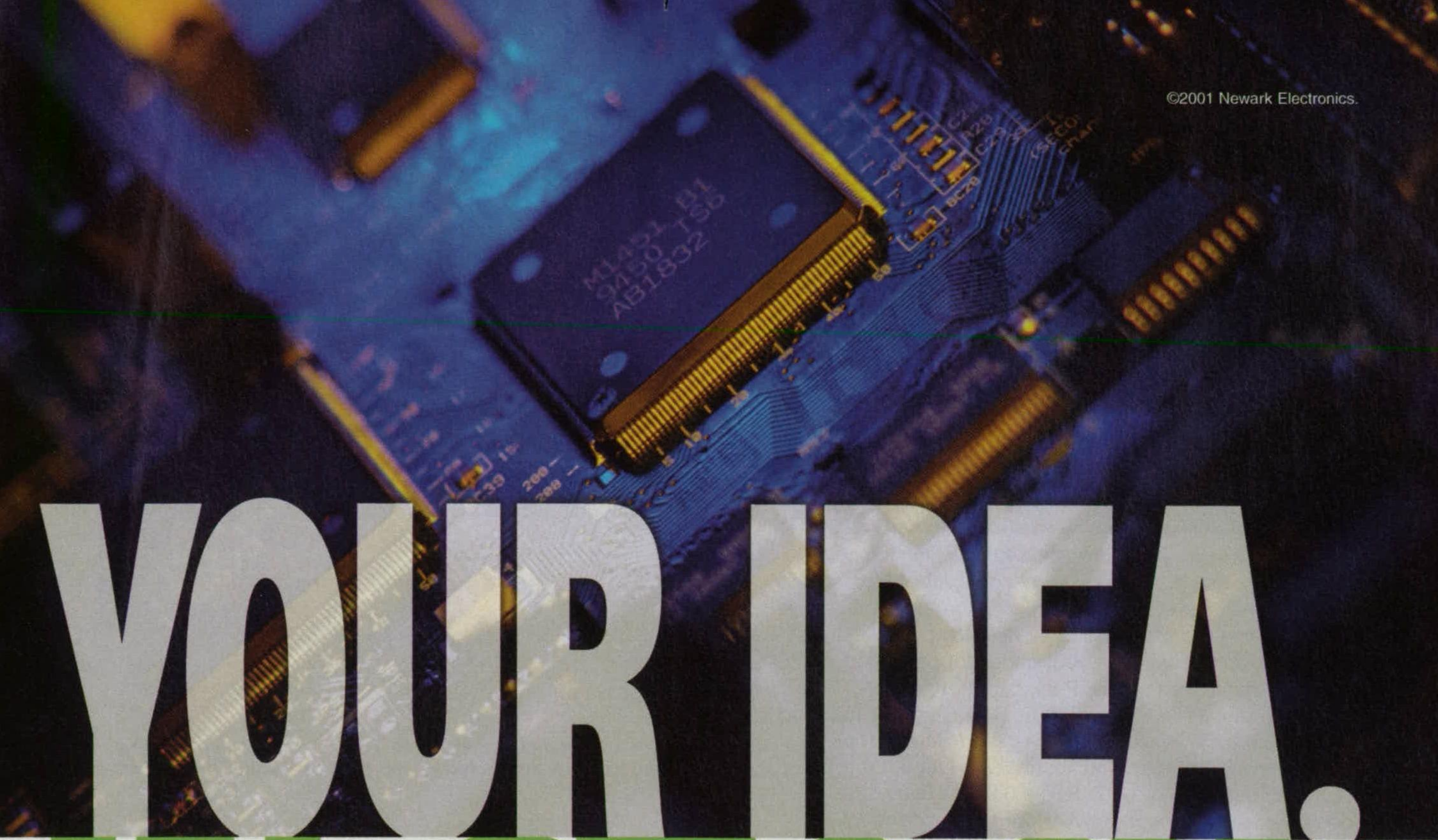
Array of Nanoklystrons for Frequency Agility or Redundancy

Multiple, individually selectable klystrons would be contained in a single, compact unit.

NASA's Jet Propulsion Laboratory, Pasadena, California

An array of monolithically fabricated nanoklystrons has been proposed as a frequency-agile and/or redundant source of electromagnetic radiation at frequencies ranging from about 0.3 to about 3 THz. Each nanoklystron would, as its name suggests, be a very small klystron. Like other klystrons, a nanoklystron would operate at a frequency determined primarily by the dimensions of its resonant cavity and the spacing of its electron-bunching grids, with some dependence on applied voltages. An individual nanoklystron could be fabricated in top and bottom halves from silicon wafers and would contain an integral output waveguide and feed horn (see Figure 1). In typical operation, a nanoklystron without a mechanical tuner would generate power only at a fixed frequency. Thus, frequency agility and/or redundancy could be obtained by incorporating into the array multiple nanoklystrons that are pretuned to generate signals at all required frequencies.

The array of nanoklystrons would be fabricated in substantially the same manner as that of a single nanoklystron, except that the nanoklystrons would be spaced at angular intervals near the periphery of the wafer. The output port of



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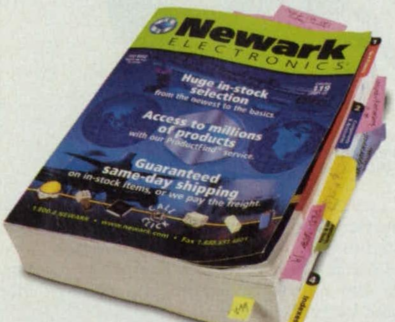

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For Free Info Circle No. 590 or Enter No. 590 at www.nasatech.com/rs each nanoklystron would then be oriented along the edge of the wafer (see Figure 2). Each nanoklystron would be fabricated to oscillate at a different predetermined frequency within the desired output band. A particular frequency would be selected by indexing the wafer.

The dimensions of silicon wafers [the present industry standard diameter is 8 in. (≈20 cm)] and the horn dimensions required for operation in the intended submillimeter wavelength range are compatible with making thousands of nanoklystrons on a single wafer in a single production run. Contact pads for supplying power to individual klystrons could be formed on the top and bottom of the disk, and registration notches could be

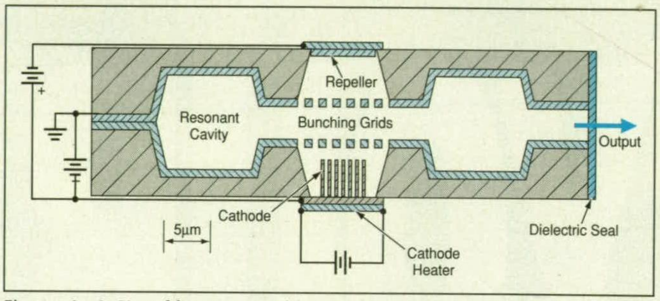

Figure 1. A **Nanoklystron** would resemble a conventional klystron but would be many times smaller, with resonant cavities formed by micromachining in silicon.

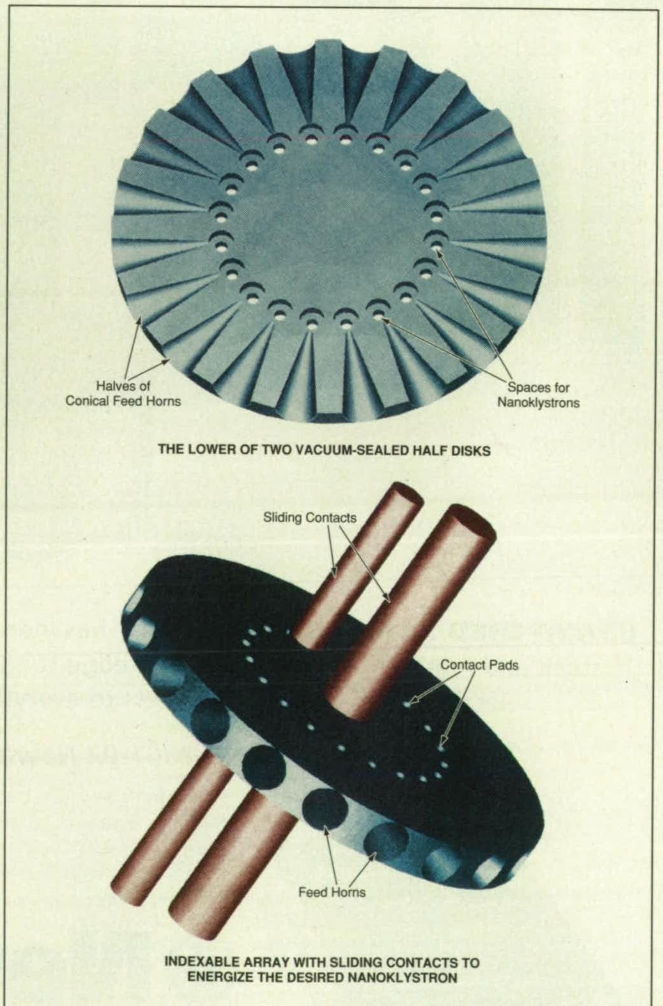

Figure 2. An **Array of Nanoklystrons** with integral output waveguides and feed horns would be fabricated in top and bottom halves of a disk made from silicon wafers. A desired nanoklystron would be selected by rotating the disk to register the top and bottom power contact pads of that nanoklystron with fixed top and bottom contacts.

formed at corresponding angular locations on the top or bottom of the disk; this would make it possible to simply rotate the disk to a detent at a designated angular position in order to obtain radiation at the frequency of the nanoklystron at that position. The contacts and detents would be arranged so that the feed horn of the selected nanoklystron would be in the proper position for output coupling.

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*** *under the Electronic Components and Systems category.*

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Refer to NPO-21033, volume and number of this NASA Tech Briefs *issue, and the page number.*

Log-Ratio Circuit With Enhanced Temperature Stability

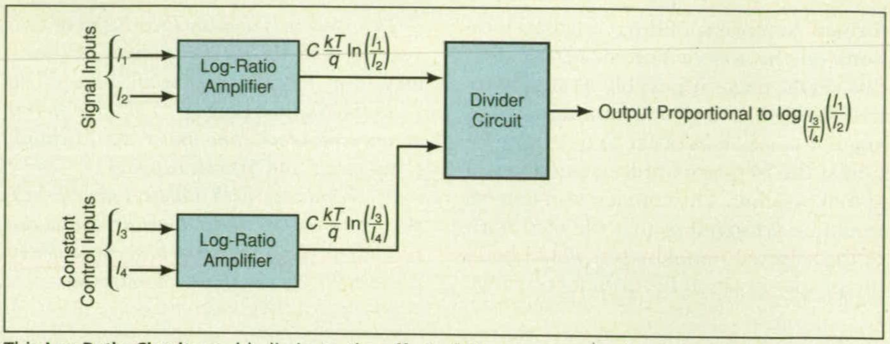
Effects of changes in temperature would be canceled at the output.

Lyndon B. Johnson Space Center, Houston, Texas

The figure illustrates a proposed analog amplifier circuit that would put out a voltage proportional to the logarithm of the ratio between two input signal currents, I_1 and I_2. In comparison with prior log-ratio amplifiers, this one would be relatively insensitive to variations of temperature over a wide range. An additional advantage of the proposed circuit is that the base of the logarithms could be varied.

In this circuit, as in other log-ratio amplifier circuits, the log function would be provided by transistors, the inputs and outputs of which are related in a highly temperature-dependent manner. In designing prior log-ratio amplifiers, attempts have been made to suppress the effects of temperature dependence by use of (a) thermostatically controlled heaters to maintain the transistors at constant temperatures or (b) adjusting the outputs by use of feedback from thermistors in close contact with the transistors. These attempts at temperature stabilization are subject to several limitations, one being that they are ineffective outside the temperature range of about 0 to 70 °C.

Unlike in prior log-ratio amplifier circuits, no attempt would be made to control temperature or compensate for changes in temperature in the proposed circuit. The proposed circuit would include two matched conventional log-ratio amplifiers, both mounted on the same die so that they could be assured of



This **Log-Ratio Circuit** would eliminate the effect of the temperature dependence in the outputs of the log-ratio amplifiers. It would also provide a convenient way to adjust the base of the logarithms.

being at the same temperature. The input signal currents would be fed to one of the log-ratio amplifiers, which would respond by putting out a voltage $(CkT/q)\ln(I_1/I_2)$, where C is a constant that depends on the design, k is Boltzmann's constant, T is the absolute temperature, and q is the fundamental unit of electric charge.

Known control currents I_3 and I_4 would be fed as inputs to the other log-ratio amplifier, which would respond by putting out a voltage $(CkT/q)\ln(I_3/I_4)$. The outputs of the log-ratio amplifiers would be fed to a divider circuit: the temperature and the other equal terms in the numerator and denominator would cancel each other in the division, so that the output of the divider circuit would be proportional to $\ln(I_1/I_2)/\ln(I_3/I_4)$, which is the same as $\log(I_1/I_2)$ to the base I_3/I_4. Thus the base of the logarithms could be selected by setting the control currents to obtain the desired value of I_3/I_4.

This work was done by Richard Steinke of Honeywell, Inc., for **Johnson Space Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*
MSC-22413

Millimeter-Wave Dichroic Plates for High Angles of Incidence

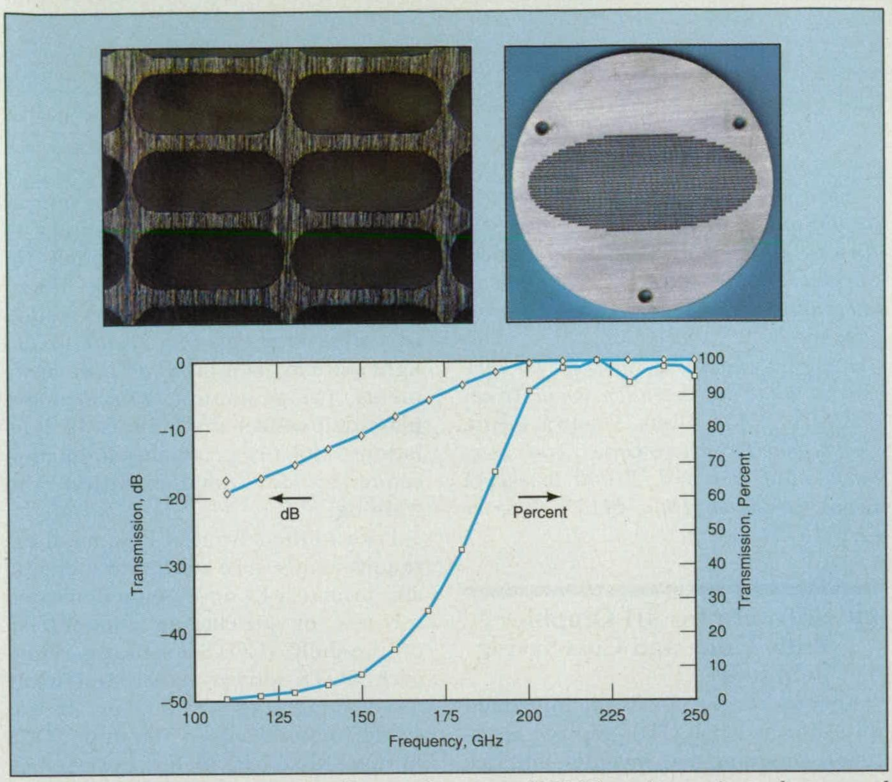
These plates can be fabricated by numerically controlled milling.

NASA's Jet Propulsion Laboratory, Pasadena, California

Dichroic plates for cutoff wavelengths down to about a millimeter and high angles of incidence can be fabricated by numerically controlled milling of rectangular arrays of waveguide slots in half-wavelength-thick metal plates. A plate of this type is used to separate higher- and lower-frequency components of incident electromagnetic radiation linearly polarized along a specified axis; the plate is designed to reflect most of the incident electromagnetic radiation at frequencies below its cutoff frequency while allowing most of the radiation at higher frequencies to pass through.

Thick metal plates containing regular arrays of holes have been used before as dichroic reflectors. In the case of a plate containing circular holes in a rectangular or a triangular array, performance deteriorates substantially (sharpness of cutoff decreases and insertion loss increases) as the angle of incidence increases beyond 20°. Experience at submillimeter wavelengths has shown that the loss of performance at increasing angle of incidence can be mitigated by use of rectangular holes or slots instead of circular holes.

It is not practical to make arrays of precisely rectangular slots at the plate thicknesses needed for wavelengths in the millimeter range because (1) the preferred fabrication technique in this thickness range is numerically controlled milling and (2) the diameters of the end mills that must be used in this size range are such that the corner or end radii of the slots cannot be much less than the thicknesses of the plates. However, slots with rounded ends or corners can be used, as long as the effects of rounding are taken into account in design computations and acceptable frequency responses can still



This **Dichroic Plate** was designed to reflect at a frequency of 118 GHz and transmit at a frequency of 240 GHz at an angle of incidence of 40°. The slots, each 0.036 in. (0.91 mm) long and 0.0145 in. (0.37 mm) wide, were end-milled in a 0.030-in. (0.76-mm)-thick plate at length-axis intervals of 0.038 in. (0.97 mm) and width-axis intervals of 0.185 in. (4.7 mm). The area containing the slots is an ellipse with axes of 2.78 and 1.18 in. (70.6 and 30.0 mm).

be obtained; this is the basis of the present development.

The frequency response of a dichroic plate containing a rectangular array of slots depends on the thickness of the plate and the shape and spacing of the slots. Typically, for a half-wavelength-thick dichroic plate, the half-power transmission frequency is close to the nominal cutoff frequency of the dominant waveguide mode. For a rectangular slot with sharp corners regarded as a waveguide, the cutoff frequency for the dominant mode is well known and is simply the frequency for which the width of the slot is a half wavelength. For a slot with semicircular ends and an aspect ratio (length ÷ width) of 2.5, the cutoff frequency is about 8.5 percent higher. The figure depicts a dichroic plate containing slots of this shape, along with its frequency response.

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

NPO-20826

Computing Diffusion in High-Temperature Coating Layer

COSIM is a computer program that numerically simulates oxidation and diffusion in a metallic coating layer on substrates made of nickel-base alloys. COSIM is primarily useful for analyzing the gradual deterioration and predicting the lifetimes of the protective coating on turbine blades and vanes. At typical high operating temperatures, such deterioration involves oxidation and interdiffusion characterized by times of the order of tens to thousands of hours.

COSIM implements a finite-difference mathematical model to simulate (1) the diffusion of chemical species within the coating including the solute needed to support the growth of a protective oxide scale, (2) diffusion between the coating and the substrate, and (3) oxidation. The program predicts concentration profiles for up to three elements in the coating and substrate after various oxidation exposures. Ternary cross terms and concentration-dependent diffusion coefficients are taken into account. Recession of the surface because of loss of solute is also predicted.

The program incorporates a previously developed mathematical model of growth and spalling of oxide, for use in simulation of either isothermal or cyclic oxidation exposures. The oxide-spalling submodel accounts for consumption of solute at higher rates in cases of cyclic oxidation accompanied by total or partial loss of the oxide scale. The program can predict the life of the coating layer(s) on the basis of a concentration-dependent or other failure criterion (e.g., the concentration of the solute at the surface falls to 2 percent). Hence, the program facilitates parametric studies for evaluation of tradeoffs among coating and substrate parameters (e.g., coating thickness, solute concentration) to obtain the same coating life or for identifying parameters that exert the greatest effect on coating life.

Written in an extension of FORTRAN 77, COSIM contains numerous subroutines that render it easily modifiable for application to different coating-oxidation problems.

This program was written by James A. Nesbitt of **Glenn Research Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *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-16754.

Software for 3D Graphics With Time- and Cost-Saving Features

Enigma version 4.4 is an integrated three-dimensional (3D)-graphics application program that includes multiple cost- and time-saving features. Enigma provides capabilities for building geometric models, key-frame animation, and video recording, and provides graphical front ends for use by simulation application programs. Enigma can add textual and graphical overlays and can incorporate such visual effects as fades and dissolves — features unavailable in many other 3D-animation software packages. What is most remarkable about Enigma is that additional expensive editing hardware is not necessary for taking advantage of all of these features.

Cost and time savings have already accrued at Johnson Space Center, where major simulation application programs are being ported to Enigma, and at other NASA centers, at the facilities of U.S. government contractors, and at the Canadian Space Agency. There is no doubt that Enigma can prove useful to other government agencies and to private industries. Within months of its introduction in April 1995, Enigma was already in use at approximately 100 sites. Although several commercial products could offer competition to Enigma, none offers the full capabilities inherent in Enigma — especially in terms of rendering speeds and flexibility.

Enigma was originally developed for the U.S. space program. It was needed because several Space Shuttle and Space Station engineering and mission operations activities have related but divergent 3D-visualization requirements. The space program has unique software requirements pertaining to (1) generating 3D solid models for various uses, (2) defining the hierarchical relationships between models and other elements (e.g., cameras and light sources) common to 3D environments, (3) generating graphical displays that reflect the outputs of simulations, and (4) producing animation sequences for documentation and training.

Prior to the advent of Enigma, these requirements were addressed individually, primarily by developing dedicated software or purchasing commercial-off-the-shelf (COTS) software. However, COTS software offered as many disadvantages as advantages. It was costly to purchase or develop COTS software that had to be converted in order to render it useful for multiple products. It was also costly to lose time waiting for procurement, development, and execution of products. Moreover, cooperative efforts were hindered by data-conversion requirements and by the unfamiliarity of engineering personnel with software tools procured or developed by other groups. Enigma overcame these disadvantages.

Enigma version 4.4 affords capabilities to build 3D solid models, define hierarchical relationships between models and other elements in the 3D environment, define and record animation on a video or computer disk, and generate graphical displays for simulation software. The program also features an on-line hypermedia documentation system. Enigma can be used as a stand-alone model-building, animation, and non-dynamic simulation software tool, and as a display driver to provide graphical support for other simulation software tools. The only support Enigma cannot supply is audio support.

This program was written by Sharon Goza and Michael Goza of **Johnson Space Center** *and Thomas Field, Mark Manning, Kurt McMullen, David Shores, Mike Gaboury, Sheila Haun, Sephanie Grizzle, and Cheyenne McKeegan of Muniz Engineering, Inc. For further information contact the Johnson Space Center Commercial Technology Office at (281) 483-0474.*
MSC-22680

Obtaining Consistent, Reliable Results in Elastomer Seal Testing

Compression stress relaxation results help predict long-term sealing performance.

Dyneon, Oakdale, Minnesota

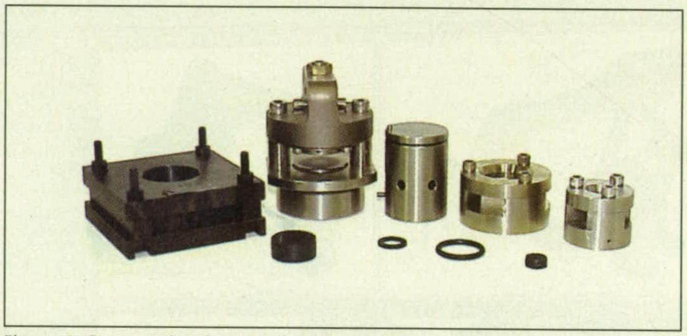


Figure 1: **Compression Stress Relaxation** samples and test jigs.

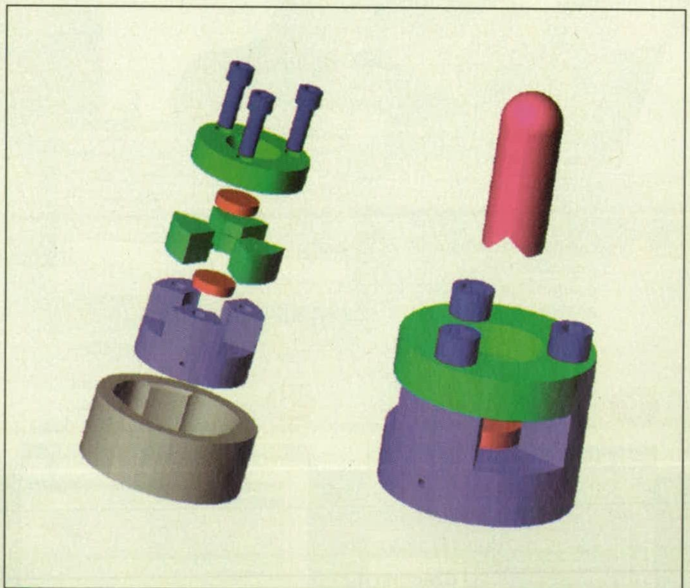


Figure 2: **Loading Jig and Pin Indentor:** Dyneon test configurations.

Compression Stress Relaxation (CSR) is an important factor in evaluating elastomer materials and seal configurations for their ability to provide sealing force retention under a variety of conditions. Increasing emphasis on the performance and longevity of elastomer seals, used most often in aerospace and automotive applications, is strengthening the need for more accurate CSR testing procedures.

CSR data is only valuable if different samples and test jigs provide consistent results. Obtaining reproducible, scaleable CSR results is now the primary emphasis for predicting long-term sealing performance.

In the past, compression set resistance was relied upon to judge the performance of different materials, as a means of quality control, and for specification purposes. CSR and compression set resistance can be used to estimate sealing capability; however, problems arise when different materials can be shown to have the same compression set resistance but different percentage of retained sealing force as measured with CSR. When using CSR methods, the sealing force will provide a direct correlation to sealing capability.

CSR testing equipment and methods can have advantages, as well as limitations, that can include cost, ease of use, jig size, test capability, and reproducibility. Since variables in each test method and differences in equipment can determine how accurate CSR test results are, it is important to differentiate among equipment, procedures, and responses seen with each test configuration.

Equipment used to help collect sealing force retention data can provide benefits and challenges, depending on how each piece functions. A modified tensometer can provide the most information about sealing force, but only when a precise test configuration is used. Similarly, the success with a Shawbury Wallace tester that uses a contact break point method is also dependent upon a specific test configuration because certain fluids or environmental conditions affect the electrical contact conductivity during testing and can introduce erroneous test results.

A third method of testing utilizing the Elastocon Relaxation tester is most useful for measuring sealing force at elevated temperatures, but does not reflect where the sealing force is lost first, which is at lower temperatures.

Test results indicate the most effective way to collect data is with smaller samples and jigs. Smaller samples generally are more representative of gasketing profiles or cross sections. Smaller test jigs also allow more samples to be evaluated in a smaller volume of liquid, making them easier to handle, drain fluid from, and cool.

Dyneon LLC, a 3M company, has designed a small CSR test jig that offers easier handling for CSR testing. Dyneon also has developed a centering jig and pin indentor to help limit the rocking effects of shims. This equipment yields better-defined load deflection curves for the determination of sealing force.

Test results show how frictional effects on jigs and samples can affect the variability of initial sealing force measurements. The use of lubricants and polished test surfaces will provide the best results. The advantage of the Dyneon jigs and others that use removable shims is that uniform frictional properties can be obtained by either repolishing or replacing the shims for a minimal cost.

Shape factor effects also are important to control during testing. Samples with high shape factors show more variability due to the large change in sealing force with small changes in deflection. Also, their high compressive modulus makes it difficult to define the sealing force from changes in the slope of the load deflection curve. Using samples with lower shape factors appears to provide more consistent data. Samples with higher shape factors also appear to experience increased sealing force loss.

Sealing force is affected, in part, by changes in temperature — decreasing at lower temperatures and increasing at higher ones. Because of this, it is important to measure and control both the sample and jig temperatures when measuring sealing force. Dyneon's test jig provides a thermocouple well to allow for this measurement.

It is important to differentiate the sealing force responses that occur during testing. Initial stress decay takes place when the compressed sample reaches an equilibrium-relaxed value at room temperature. Relaxation occurs when the sample is heated to a temperature above that at which it was compressed. This response is a result of thermal expansion, increased stress, and higher molecular motion that forces the polymer to relieve stress through molecular rearrangement. Aging effects, which are time-dependent, result from molecular bonds being formed or broken. This response is of most concern for predicting long-term durability or service life.

For more information, contact Doug Chirhart at Dyneon, a 3M Company; Tel: 651-736-9241; or visit the Web site at: www.dyneon.com.

Making Ion-Accelerator Grids From Ti Instead of Mo

Titanium grids last longer, cost less, and have greater strength/weight ratios.

John H. Glenn Research Center, Cleveland, Ohio

Titanium has been found to offer several advantages over molybdenum as the material used to construct electrostatic-accelerator and -screen grids for ion thrusters for spacecraft. These advantages could also be expected to extend to the manufacture of grids for ion accelerators used in scientific research and the fabrication of semiconductors.

Titanium was chosen as the result of a search for a grid material that is less vulnerable to sputter erosion and from which grids could be fabricated at acceptably low cost. At a given current density, the volumetric rate of sputter erosion of titanium is about half that of molybdenum. Hence, in comparison with a thruster containing molybdenum grids operating at a given beam current density, a thruster of the same size containing titanium grids can last about twice as long; alternatively, the thruster containing titanium grids can last about the same amount of time when operated at twice the beam current density. Similarly, accelerators containing titanium grids could be operated at higher voltages.

The strength-to-weight ratio of titanium exceeds that of molybdenum, making it possible to reduce the weights of ion accelerators. The substitution of titanium for molybdenum does not entail any increase in the complexity of ion-accelerator design.

Titanium grids can be fabricated by use of photochemical-etching and hydroform processes heretofore used to make molybdenum grids for Glenn Research Center. Previously, attempts at photochemical etching of titanium were thwarted by the corrosion-resistant nature of titanium, but recent advances in photochemical etching have overcome this obstacle.

Finally, titanium offers the advantage of lower cost: at the time of reporting the information for this article, the cost per unit weight of titanium was 43 percent less than that of molybdenum.

This work was done by Vincent K. Rawlin of **Glenn Research Center** *and George C. Soulas of Dynacs Engineering Co. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials 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-16893.

Mechanics

Quasi-Fractal Lenticular Booms

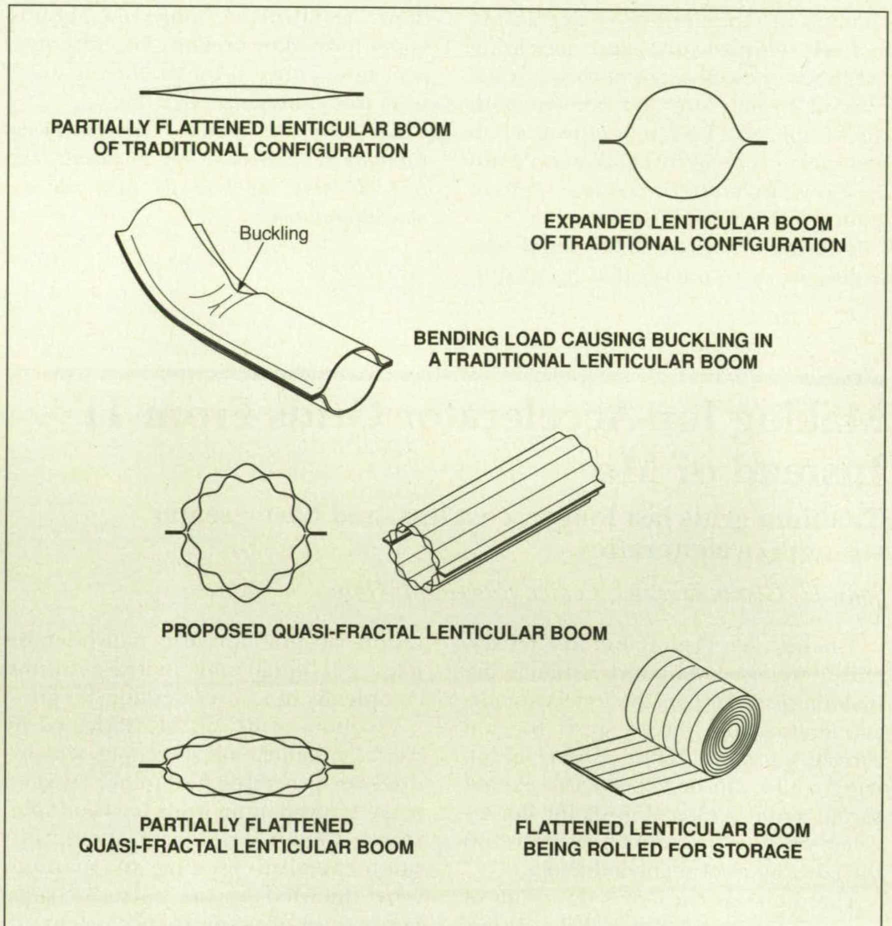
Resistance to buckling would be increased.

NASA's Jet Propulsion Laboratory, Pasadena, California

An improved configuration for large, thin-walled lenticular booms has been proposed to reduce their susceptibility to buckling. Lenticular booms have been used on spacecraft because they can be flattened and rolled onto drums for compact storage during transport, then deployed by unrolling them from the drums. Lenticular booms could also be useful on Earth in special applications in which there are requirements for lightweight, deployable structures that can withstand small mechanical loads.

Even when large lenticular booms have very thin walls, they can be made fairly resistant to bending, but because the walls are very thin and only slightly curved, they are not highly resistant to buckling. The figure depicts some lenticular booms in traditional and proposed configurations. According to the proposal, the thin, slightly curved wall of a traditional large lenticule would be replaced by a wall comprising multiple smaller lenticules that would have greater curvatures and would therefore resist buckling more strongly.

This work was done by Donald Bickler of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Mechanics category.*
NPO-20815



Larger Lenticules Would Be Subdivided into smaller ones with larger curvatures to strengthen structures against buckling.

Vacuum Pumping Station

John F. Kennedy Space Center, Florida

A proposed valve unit called a "vacuum pumping station" would be incorporated into a plumbing system that supplies a vacuum for vacuum insulated cryogenic equipment. The vacuum pumping station is intended to perform functions now performed by, and to be a simpler and more reliable alternative to, an assembly of components that include a vacuum-pump-out valve and a separate vacuum-isolation valve (with a separate actuator) used to monitor vacuum levels. The present assembly includes a leak-prone threaded connection between the pump-out and isolation valve, and leaks can also occur at other locations. The vacuum pumping station would include a vacuum-pump-out port, a thermocouple port, a thermocouple-isolation valve, a pressure-relief valve, a pressure-relief port, and a single mechanism for actuating the pump-out, isolation, and pressure-relief functions of the valve. The number of joints where leaks could develop would be only half that of the present assembly.

This work was done by Robert L. Smithson of United Space Alliance for **Kennedy Space Center.** *For further information, contact the Kennedy Space Center Commercial Technology Office at (321) 867-6224.*
KSC-12038

Nonintrusive Pressure Gauges

Fluid pressure can be measured without interfering with measurement of mass flow.

Lyndon B. Johnson Space Center, Houston, Texas

The state of the art of pressure gauging has been advanced by the development of a new technique, and of a nonintrusive gauge based on the technique, for measuring the pressure of a fluid in the same segment of pipe in which the mass-flow rate of the fluid is also measured. NASA anticipates the first use of the technique in support of the High Flow Test Facility at White Sands Test Facility, and Kennedy Space Center has expressed interest in applying the technique on the X-33 aerospace launch vehicle. Nonintrusive pressure and flow gauges based on the present technique could also supplant older pressure and flow gauges in a variety of commercial processes and pressure systems in which the intrusion of gauges is known to affect local fluid dynamics.

Prior flowmeters and pressure gauges are subject to some limitations:

- Frequently, pressure gauges of prior design are attached to the outside walls of straight pipe segments, but intrusive wall taps are needed to couple fluid pressure to the transducers in the gauges. A wall tap can disturb the local flow profile and introduce fluid-entrapment zones and fluid-containment volumes.
- Straight-tube mass-flow meters of prior design do not measure pressures along with mass-flow rates.

Gauges for simultaneous measurement of pressure and flow rate would be useful on NASA's space shuttle. An important consideration in the design of such gauges as retrofit items is that they are not allowed to intrude into the plumbing carrying the fluid to be gauged. Therefore, the present technique for measurement by an externally mounted, nonintrusive gauge was conceived. The technique offers the advantage of eliminating not only flow-disturbing intrusions into the plumbing but also the complications associated with implementation of pressure taps.

The present technique involves the use of a piezoelectric transmitting transducer, mounted on the outside of a fluid-filled pipe, to excite vibrations in the pipe. The transducer is driven by a voltage-tunable electronic power oscillator. A receiving transducer, also attached to the exterior surface of the pipe, is used to measure the frequency and phase of the vibrations. An external phase-locked-loop control circuit ensures that the frequency of the power oscillator automatically tracks the resonance frequency of the selected vibrational mode of the pipe. The frequency output of the gauge can be coupled to external readout equipment by use of an optical fiber. The pressure of the fluid is then computed by use of the correlation between the fluid pressure and the resonance frequency (the pressure varies approximately linearly with the frequency).

Because the only part of the gauge that comes in contact with the fluid is the pipe segment, which is already part of the plumbing, the nonintrusive pressure gauge can coexist with a mass-flow gauge that utilizes or is mounted in or on the same pipe segment. Although the sensitivity of the present nonintrusive pressure gauge is lower than that of a typical intrusive gauge, the very fact of its nonintrusiveness enhances its potential utility. Once the issue of sensitivity is addressed, the gauges based on the present technique could be expected to become tools of choice in commercial as well as aerospace applications.

This work was done by W. C. Smith of Honeywell for **Johnson Space Center.**

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center, (281) 483-0837. Refer to MSC-22738.

PVP-MP Method for Wrinkling Analysis of Space Membrane Structures

Distributions of stress can be predicted for taut, slack, and wrinkled areas.

NASA's Jet Propulsion Laboratory, Pasadena, California

Parameter-Variation-Principle (PVP) based Mathematical Programming (MP) is the basis of a computational method of analyzing wrinkles in membranes. Devised for original application to lightweight membrane structures in outer space, the method can also be applied on Earth to similar structures, to diverse industrial products that include paper and textiles, and to structures made from these products.

PVP is a variational principle, for which some of membrane strain components, unlike in a traditional variational principle, do not participate in functional variation. PVP is suitable for analyzing wrinkled membranes because it is valid for all three general membrane conditions — taut, slack, and wrinkled. With PVP, the traditional problem of membrane wrinkling is transformed to a mathematical programming problem, which can be efficiently solved by numerical methods. As a result, the present PVP-MP method guarantees numerical convergence for all three conditions. In this method, one uses an optimization technique instead of traditional iteration to search for the minimum of this principle. This search guarantees convergent numerical solutions with finite steps in computation.

A membrane by itself usually has very little resistance to in-plane compression and very little stiffness against out-of-plane bending. Out-of-plane stiffness is usually imparted to a membrane through pretensioning. Therefore, out-of-plane stiffness is a function of the distribution of in-plane stress. Wrinkles appear when some areas of a membrane are subjected to in-plane compression to a certain level; indeed, the formation of wrinkles is a membrane local-buckling phenomenon.

Ordinary stress analysis procedures are limited in predicting wrinkles. Numerical iteration methods for wrinkling analysis used heretofore to analyze wrinkles apply different values of membrane material properties, depending on whether it is taut, slack, or wrinkled. These methods often present difficulties that prevent or impede convergence or that lead to incorrect solutions.

The present PVP-MP method guarantees accurate results with much less (relative to prior methods) computational effort. The method involves two main steps. In the first step, one develops a PVP principle, including a controlling parameter vector. With the help of the controlling parameter vector, taut, slack, and wrinkled states of the membrane can be represented by one variational principle. In the second step, one searches for the minimum of the variational principle by use of the applicable optimization technique. Because the search can reach the minimum of the variational principle at the exact solution, this method can predict the distribution of stress throughout the membrane, including any taut, slack, and/or wrinkled areas.

This work was done by Houfei Fang, Michael Lou, and Bingen Yang of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Mechanics category.*

NPO-21133

Manufacturing/Fabrication

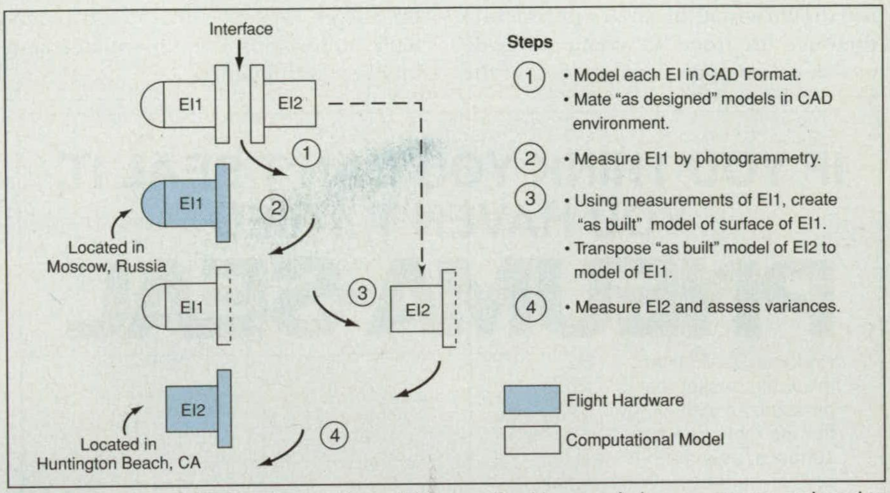
Digital Preassembly Process

Assembly of major elements of large structures is simulated in a CAD environment.

Lyndon B. Johnson Space Center, Houston, Texas

Because the International Space Station is being assembled in orbit, there was a need to verify in advance that it could, indeed, be assembled there and that the various assembled parts would function as intended. A digital preassembly process was devised to satisfy this need for verification, without having to perform assembly on Earth. The process enables designers to simulate the assembly of major elements of large structures by use of a computer-aided design (CAD) system. The process could also be applied in any type of manufacturing and in many types of construction.

The verification problem arises because Space Station components are being produced by subcontractors scat-



Computational Models of mating end items (EIs) are refined by use of photogrammetry and used to simulate mating, in order to detect potential obstacles to final assembly.

tered across the United States and by international partners. Costs and schedule restrictions prohibit either building a full scale, high-fidelity mockup or shipping Station components to different locations for design verification. Components being built in Russia, Japan, Europe, and Canada will not be available for pre-launch interface tests with those components built in the United States.

In the digital preassembly process, two-dimensional hardware-production drawings are used to create three-dimensional computational models of the structural elements or other end items (EIs) that mate at a given interface (see figure). The process includes modeling of the mating surfaces and hardware as well as all external components installed near a stay-out zone (a region in the vicinity of the interface that must be kept clear of any potential obstruction). The process includes identification of any off-nominal variances of mating surfaces, alignment and latching components, externally mounted components, fluid lines, or cables that could potentially encroach on the stay-out zone and interfere with mating.

Once the EIs on both sides of the interface have been modeled as designed, mating is simulated in the CAD environment. Portable digital photogrammetric equipment is then used to measure the real EIs. These measurements are mapped back into the computational model, creating an as-built computational model of the mating EIs. The revised computational model of the first-measured EI (say, EI1) is loaded into the computer of the portable digital photogrammetric equipment, which is moved to the location of the other EI (EI2) when that EI becomes available. The revised computational model is then used to perform a digital mating, which helps to identify variances between mating elements and potential interferences that could create problems during mating. Thus, the digital preassembly process provides early indications of potential problems in mating and assembly. The data gathered in the digital preassembly process could also be mapped into flight-element parametric models (when available) to extend the assessment to more dynamic thermal and pressure conditions.

This work was done by Vincent E. Heyworth and William F. McGilton of Boeing for **Johnson Space Center**. *For further information, contact the Johnson Space Center Commercial Technology Office at (281) 483-0474. MSC-22756*

Physical Sciences

Numerical Index for Quantifying Aircraft Icing Hazards

This index would offer several advantages over the present four-level index.

NASA's Jet Propulsion Laboratory, Pasadena, California

A new method for assessing and communicating aviation in-flight icing hazards has been proposed. This methodology creates a simple numerical index for quantifying hazard severity. The index is traceable to flight-level meteorology and aircraft-specific, icing-induced reductions in aircraft performance. It also provides a connection to a statistical data base of icing meteorology. This system will clarify the terminology used to describe the degree of danger posed by specific meteorological conditions. The relationship between hazard severity and meteorology is related by measured ice accumulation rates observed on a standard airfoil under prescribed conditions. This system has greater fidelity than the existing system and is applicable to all types of air vehicles.

The proposed numerical index is based on a multidimensional matrix representation of meteorological parameters that pertain to icing. For example (see Figure 1), suppose that ice-accretion rates for a given aircraft could be determined from three parameters; the outside air temperature, the fraction of cloud water droplets with diameters >100 µm, and the liquid density (the volume of water per unit volume of air). The three-dimensional space for these three parameters would be segmented into cells, each representing a unique meteorological state. Each cell could be assigned a probability of occurrence estimated from meteorological data bases. Aircraft manufacturers would then be able to specify surfaces in the three-dimensional parameter space that bounds safe operating conditions for each of their aircraft for various ranges of exposure times. Thus, the meteorological matrix concept would provide traceability among meteorological conditions, aircraft performance, and cumulative probabilities of occurrence of icing.

To reference each level of the proposed index to the degree of hazard, the index would be related to measured rates of ice accumulation on a standard wing cross section. The rates would be measured over a wide range of meteorological conditions for a standard set of flight conditions (such as airspeed and angle of attack). Aerodynamic modeling software could then be used to translate the observed icing phenomena to commercial airfoil shapes with some confidence.

The proposed index would feature some number of levels — possibly 12 —

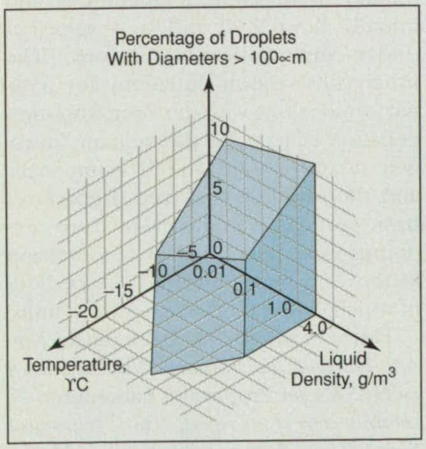


Figure 1. A **Meteorological Matrix** would be used to characterize the range of meteorological conditions that pose in-flight icing hazards. The shaded region is a fictitious example of a boundary defining the region for safe operation of a specific aircraft.

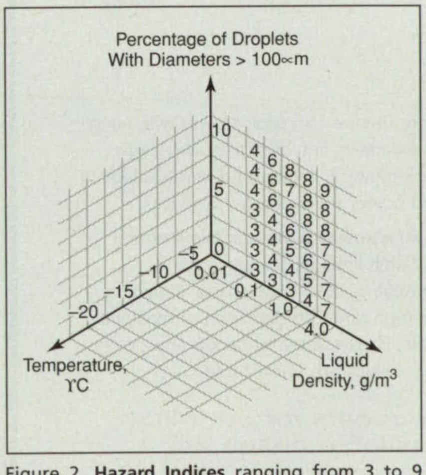


Figure 2. **Hazard Indices** ranging from 3 to 9 have been placed in the cells in one plane of a meteorological matrix. The hazard indices shown here constitute a fictitious example.

chosen to increase the fidelity of reporting beyond that of the current four-level system, without making the levels so narrow that the differences between them could not be reasonably measured. The levels would be assigned to cells in meteorological matrices (see Figure 2). The twelve-level scale would be related to the present four-level system in the following way: Zero would represent meteorological conditions that do not induce icing; three through six would correspond to the "light" level; seven through nine would correspond to the present "moderate" level; and 10 to 12 would correspond to the present "severe" level. The correlations between measured icing rates, the present four levels, and the proposed index would be established in a consensus process that would involve airlines, pilot organizations, government, and aircraft manufacturers.

This work was done by Steven J. Walter of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category. NPO-20465*

DNS of Mixing of Supercritical Heptane and Nitrogen

NASA's Jet Propulsion Laboratory, Pasadena, California

A report discusses direct numerical simulations (DNS) of a developing mixing layer between nitrogen and heptane initially at different temperatures and initially flowing at different velocities under supercritical conditions. The usual conservation equations for a binary fluid, along with the Peng-Robinson equation of state for the heptane/nitrogen mixture, were solved numerically and the solutions analyzed. Departures from perfect-gas and ideal-mixture conditions were quantified by compression factors and mass-diffusion factors, both of which exhibited decreases from unity.

This work was done by Josette Bellan, Kenneth Harstad, and Richard Miller of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Direct Numerical Simulations of Supercritical Fluid Mixing Layers Applied to Heptane - Nitrogen," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category. NPO-20790*

Books & Reports

Gas Generator for Inflating Structures in Outer Space

A report proposes a system that would supply gas for inflating one or more inflatable structure(s) in outer space. The system would include a small tank of helium for initial inflation, plus a catalytic hydrazine gas generator that would supply makeup gas over the long term. After initial inflation, when makeup gas was needed, liquid hydrazine from a tank would be made to pass through a catalytic bed, where it would become decomposed into a mixture of N_2, H_2, and a small amount of NH_3. This gaseous mixture would constitute the makeup gas and would be stored in the tank that previously contained the helium. The makeup gas would be released from the tank to the structure(s) as needed. In comparison with an inflation system based only on compressed gas stored in tanks, the proposed inflation system would offer the advantage of lower mass: About 25 percent of the masses of representative previously contemplated large inflatable outer-space structures would have been contained in their inflation systems. In contrast, the mass of the proposed inflation system has been estimated to be only about 13 percent of the total mass of a representative structure.

This work was done by Larry Roe of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "System For Initial Inflation and Replacement Gas For Inflatable Space Structures," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Machinery / Automation category.*

NPO-20539

Thermal Insulation Would Use CO_2 in the Martian Environment

A report describes the development of a lightweight thermal insulation system for Martian surface applications. The ambient Martian atmosphere, which is predominantly carbon dioxide at a pressure of 10 torr, is used as the insulation medium with a modest multiple radiation shield enclosure. The carbon dioxide has a thermal conductivity that is very close to traditional insulation, and the carbon dioxide is naturally available on the Martian surface. Preformed Mylar spacers that are affixed to the hardware create the necessary standoff distance from the enclosure.

This work was done by Gajanana Birur, Glenn Tsuyuki, and James Stultz of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Novel light weight Thermal Insulation for Martian Environment using Carbon Dioxide gas," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category.*

NPO-20978

Martian Landing Balls

A report describes Martian landing balls, which are under development for use in delivering scientific payloads to Mars. Martian landing balls are related to other soft-landing devices that resemble beach balls and that have been described in several previous *NASA Tech Briefs* articles. They are also related to the Zorb (or equivalent) — a commercial recreational device that looks like a large, transparent beach-ball/tire hybrid with a central volume that is open to the atmosphere and that accommodates a human rider. In a Martian landing ball, the central volume contains a rigid cylinder that carries the payload. The cylinder is surrounded (except for small openings) by an approximately spherical airbag. In the intended use, Martian landing balls would be dropped from slowly descending solar-heated balloons. It has been estimated that a Martian landing ball with a mass of 2 kg could deliver a 10-kg payload with a landing acceleration of less than 50× normal Earth gravitation (less than about 490 m/s^2). Once on the Martian surface, the airbag could be deflated; alternatively, the airbag could be kept inflated to take advantage of the wind to blow the payload to a desired location.

This work was done by Jack Jones, Andre Yavrouian, and Tim Connors of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Martian Landing Ball," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Mechanics category.*

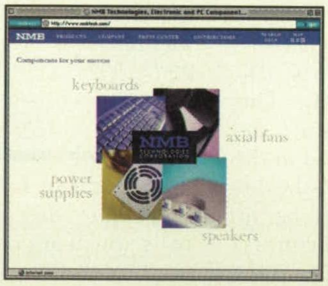
NPO-20977

New on the WEB

Hydraulic Flanges

Main Manufacturing, Grand Blanc, MI, has instituted a new Web site with information on hydraulic flanges. The interactive site allows the user to build a flange, obtain the specifications and model code, and submit an RFQ. Technical support and printed literature also are offered. **www.mainmfg.com**

Fans and Blowers



A redesigned site by NMB Technologies Corp., Chatsworth, CA, provides information on axial fans, blowers, power supplies, speakers, and keyboards. Included are datasheets, on-line model locators, and real-time inventory checking of fan products, which allows customers to locate and purchase fans from participating distributors. **www.nmbtech.com**

Seal Materials

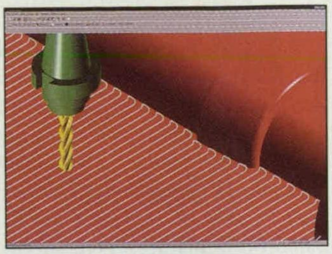
ExpresSeal™, Lancaster, NY, has launched a new Web site on the computerized manufacturing technology used to produce seals such as U-cups, wipers, piston rings, bushings, bearings, packings, O-rings, prototypes, and customs seals and shapes. Available seal materials also are described. **www.expresseal.com**

Heating and Control

Chromalox, Pittsburgh, PA, offers installation guides, instruction sheets, free downloadable software, and a Design Wizard for users seeking information on electric heat and control products such as heaters, cables, and sensors. The KnowledgeBase feature includes archived material, commercial issues, research data, and product information. **www.mychromalox.com**

New on DISK

CAD/CAM



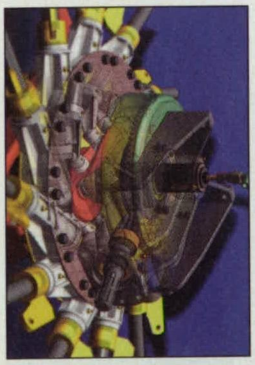
SURFCAM 2001 CAD/CAM software from Surfware, Westlake Village, CA, features high-speed machining for machine motion and plunge roughing, an updated NC editor with back-plotting, right-click menu, and live update technology. Parameter associativity allows toolpath parameters such as tool numbers, offset registers, and feed rates to change without repeating the steps required to create the toolpath. The software also features enhanced design and solid modeling features. **For Free Info Circle No. 717 or Enter No. 717 at www.nasatech.com/rs**

Drawing and Diagramming

Microsoft Corp., Redmond, WA, has released Microsoft® Visio® 2002 drawing and diagramming software that features Web integration and publishing capabilities for collaboration via the Internet. It also includes Extensible Markup Language (XML) capabilities, support for Component Object Model (COM) add-ins, and adoption of industry standards. The two primary products are Visio Standard for creating flowcharts, organizational charts, and timelines; and Visio Professional for IT professionals and software developers. **For Free Info Circle No. 718 or Enter No. 718 at www.nasatech.com/rs**

Mechanical CAD

UGS, Cypress, CA, has announced Solid Edge Version 10 mechanical CAD software that focuses on large-assembly design and drafting.



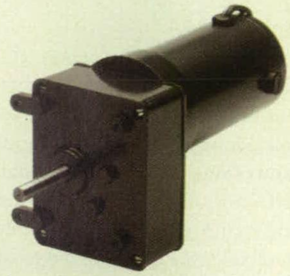
Enhancements include tools that streamline modeling of families of assemblies and alternate position assemblies, a drawing view tracker, part/feature/assembly color options, translator enhancements, curve and surface modeling, pipe threading, and a new collaboration Web portal service called Edge eXchange. Users can create subassemblies, disperse subassembly components, and change the order of parts while maintaining all positioning relationships. The software provides a built-in Parasolid to ACIS bi-directional translator for interoperability with CAD tools based on the ACIS solid modeling kernel. A healing technology automatically finds and corrects faults in imported 3D CAD data. **For Free Info Circle No. 719 or Enter No. 719 at www.nasatech.com/rs**

Numerical/Visual Analysis

JWAVE 3.5 from Visual Numerics, Boulder, CO, is a client/server solution that utilizes Java components to develop and deploy applications across an enterprise via the Internet or an intranet. JWAVE lets users who are developing applications using Java or HTML to perform numerical analysis and visual interpretation of complex datasets. Users can zoom in or out of a chart, profile a row or column across an image, select a point on a chart, and interactively rotate a 3D chart. **For Free Info Circle No. 721 or Enter No. 721 at www.nasatech.com/rs**

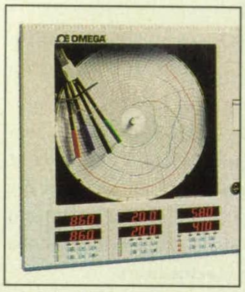
New on the MARKET

Shaft Gearmotor



RAE Corp., McHenry, IL, offers the G209 series permanent magnet, brush-type, DC parallel shaft gearmotor for pumps, conveyors, medical equipment, and small vehicles. The gearmotor features long gear life, reduced noise, balanced armature, high-energy ceramic magnets, externally replaceable brushes, and class "F" insulation. Other features include gear ratios from 10:1 to 2328:1, ratings up to 50 inch-pounds, 12 to 90 V (DC), and speeds of up to 350 rpm. **For Free Info Circle No. 725 or Enter No. 725 at www.nasatech.com/rs**

Circular Chart Recorder



OMEGA Engineering, Stamford, CT, has released the CT1901 programmable circular chart recorder for up to four process signals. Pen ranges are individually set for each signal. Users can see the status of a process at a glance. Six-digit displays provide an indication of up to four process values simultaneously, as well as active alarm flashing LEDs. Features include thermocouple, RTD, voltage, current inputs, and a user's choice of one to four pens. User-configurable math functions, mass flow calculations, and RH tables are supported. **For Free Info Circle No. 726 or Enter No. 726 at www.nasatech.com/rs**

Pressure Sensor

The P4000 pressure sensor from Kavlico, Moorpark, CA, incorporates MEMS technology into an all-welded, stainless steel package. The transducer is suited for HVAC-R, off-highway vehicles, pressurized tools, adaptive suspension systems, material testing, hydraulic press monitoring, and other hydraulic applications. The sensors are available in pressure ranges of 0-100 through 0-8000 PSI absolute or sealed gage. The sensor has a total error band of ±1% over the operating temperature range of -20°C to 100°C. **For Free Info Circle No. 728 or Enter No. 728 at www.nasatech.com/rs**

Coated Wire

California Fine Wire, Grover Beach, CA, offers custom wire fabrication with PTFE (polytetrafluoroethylene) coatings that can be enameled to 1,000 metals and alloys. The PTFE-coated wire is put inside tubing and is drawn to a small diameter, creating a coaxial cable. Liquefied PTFE is applied to fine wires in continuous lengths of up to 10,000 feet. PTFE-coated wire is appropriate in environments where wire-related products, including microprocessor-controlled equipment, is exposed to corrosive chemicals. **For Free Info Circle No. 730 or Enter No. 730 at www.nasatech.com/rs**

New
LITERATURE

Metals and Coatings

General Magnaplate Corp., Linden, NJ, offers a friction data guide on CD that aids engineers in selecting combinations of metals and coatings that improve the service life of mating components. The guide shows comparisons of the coefficients of friction between combinations of treated and untreated surfaces. **For Free Info Circle No. 710 or Enter No. 710 at www.nasatech.com/rs**

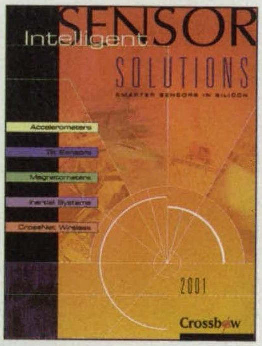
Rail Assembly Guide

WAGO, Germantown, WI, has released ProServe Software Version 2.5 for custom rail assembly that allows customers to design, mark, document, and test their own rail-mounted terminal block assemblies. The CD includes a product locator, allowing users to search a database of over 9,000 parts according to product groups, part numbers, key words, and technical data. **For Free Info Circle No. 712 or Enter No. 712 at www.nasatech.com/rs**

Thermoelectric Coolers

A four-page brochure from Melcor, Trenton, NJ, describes thermoelectric coolers for telecom applications. The coolers feature operating temperatures from 93°C to 232°C, and Pb-free construction solders up to 271°C. Other features include custom sizes, power densities, and ceramic patterns; and wire bondable posts, metallized pads, and wires. **For Free Info Circle No. 711 or Enter No. 711 at www.nasatech.com/rs**

Sensors/Accelerometers



Crossbow Technology, San Jose, CA, has released a 95-page catalog highlighting accelerometers, sensors, magnetometers, inertial systems, and wireless products. The catalog features various products utilizing the Bluetooth wireless technology, and analysis and evaluation software. **For Free Info Circle No. 715 or Enter No. 715 at www.nasatech.com/rs**

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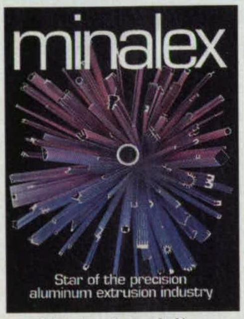

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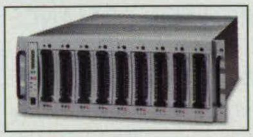

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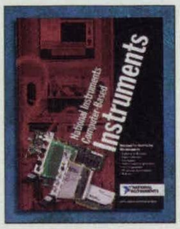

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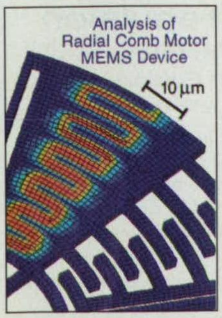

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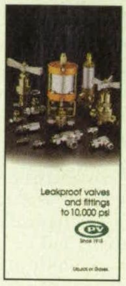

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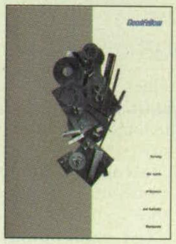

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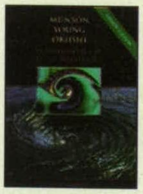

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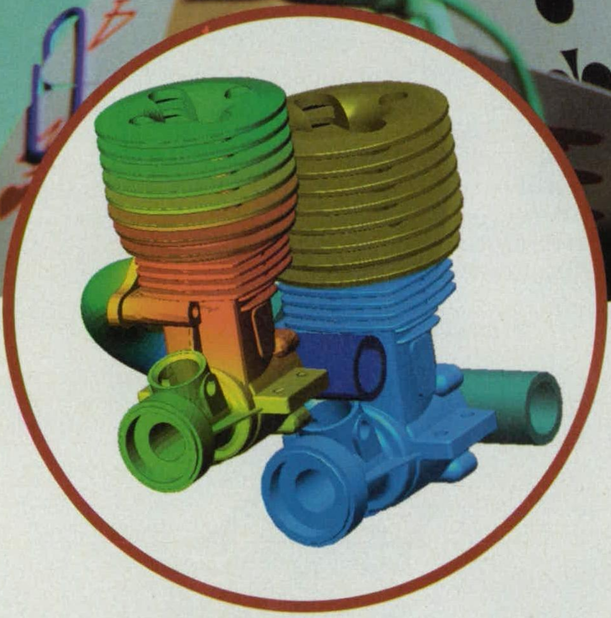
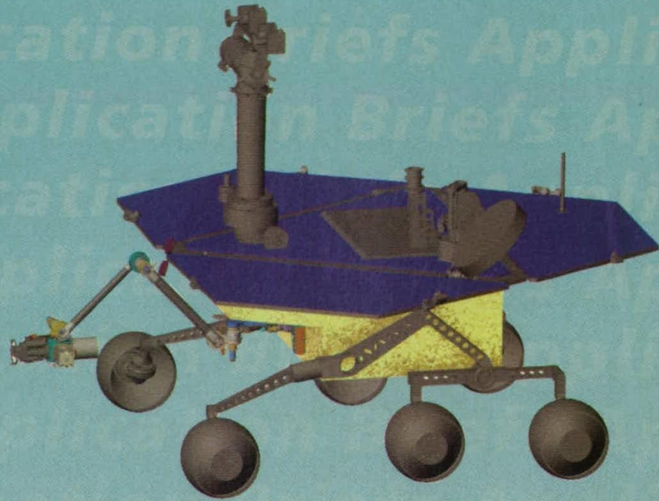


Robotic Arm Designed with FEA & CAD Software

COSMOS/Works finite element analysis software
Structural Research & Analysis Corp. (SRAC)
Los Angeles, CA
310-207-2800
www.cosmosm.com



Under contract to NASA's Jet Propulsion Lab, Alliance Spacesystems Inc. (ASI) of Pasadena, CA (www.asi-space.com) is designing the robotic arm for the Mars Exploration Rover (MER) project, which will send twin rovers to Mars in 2003. The five-degrees-of-freedom arm is one meter long with scientific instruments at the end. It has five actuators, moving joints, and conductor wires, and must meet requirements for stiffness and mass. ASI used COSMOS/Works software for stress analysis and mass minimization during the design process.

Jim Staats, ASI's chief engineer, noted that mass is the crucial component of any space mission. "You just can't get there from here if you can't get the mass within the envelope," he said. Because its protective aeroshell can hold only so much mass, the MER lander must be within limits. Other crucial factors are the extreme temperatures on Mars, ranging from -184°F to +176°F, and the 50 to 60 mph impact of landing.

Each of the two rovers will drive to its likely location, extend its mechanical arm, and hold its instruments near a rock. The arm will rotate so each instrument can scan a specific spot in turn. The ASI team thought the integration of CAD and FEA would save them time and effort. The team used SolidWorks for design (CAD) and COSMOS/Works for FEA. With the integration of the two, ASI engineers did not have to manipulate CAD data to get it into a form suitable for FEA. Data transfer is automatic and does not require a file export and import. The result is iterations that take hours rather than days.

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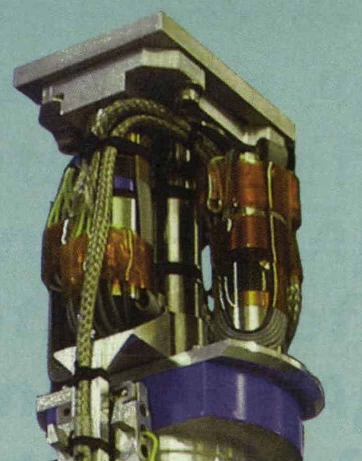
Grinding Tool to Reveal Martian Rock

Rock Abrasion Tool (RAT)
Honeybee Robotics, Ltd.
New York, NY
212-966-0661
www.Hbrobotics.com



Honeybee Robotics is designing and building a robotic precision grinding tool for the twin rovers slated for launch as part of the Mars Exploration Rover (MER) project in 2003. The instrument is being created to bore into hard rock surfaces on the Martian landscape. By boring into the rock, the RAT will reveal fresh rock that will be analyzed by instruments on the rover. This assists scientists studying Mars by allowing them to go beyond the weathered surface of the planet and examine the contents of Martian rocks.

The RAT will be mounted on the rover's robotic arm, which will position the RAT against a rock to let it operate. The RAT will use low force and high speed to comply with the limited power supply available during the mission. The tool will be equipped with two diamond matrix wheels that it will use to scrape the rock surfaces.

In order to comply with NASA's regulations, the RAT will weigh less than 750 grams (roughly 1.7 pounds), be 7 cm (2.7 inches) in diameter, and only 10 cm long (less than 4 inches). By using three small motors, the RAT will only use 30 watts of electricity. NASA's Jet Propulsion Lab (JPL) in Pasadena, CA is managing the twin rover mission.

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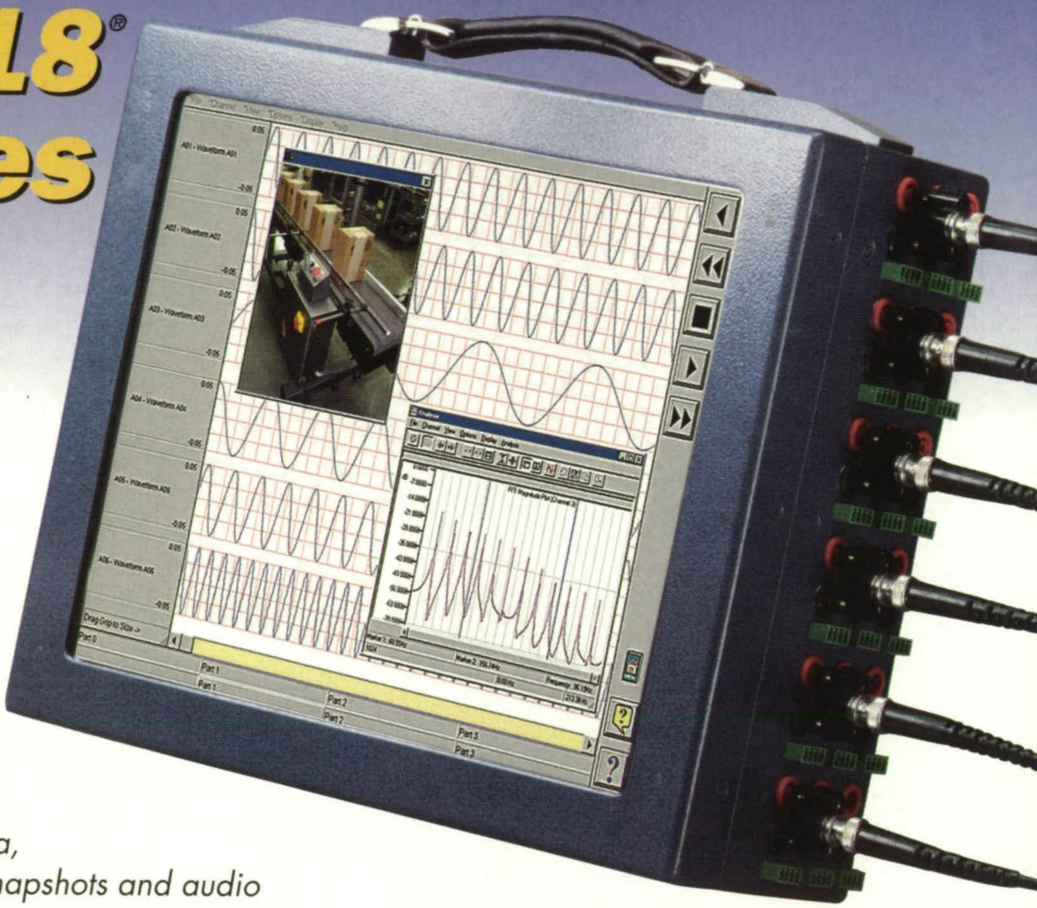

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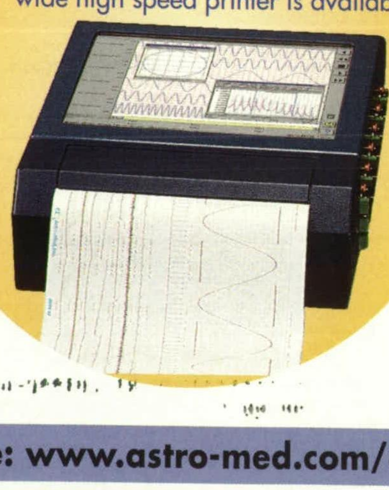

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