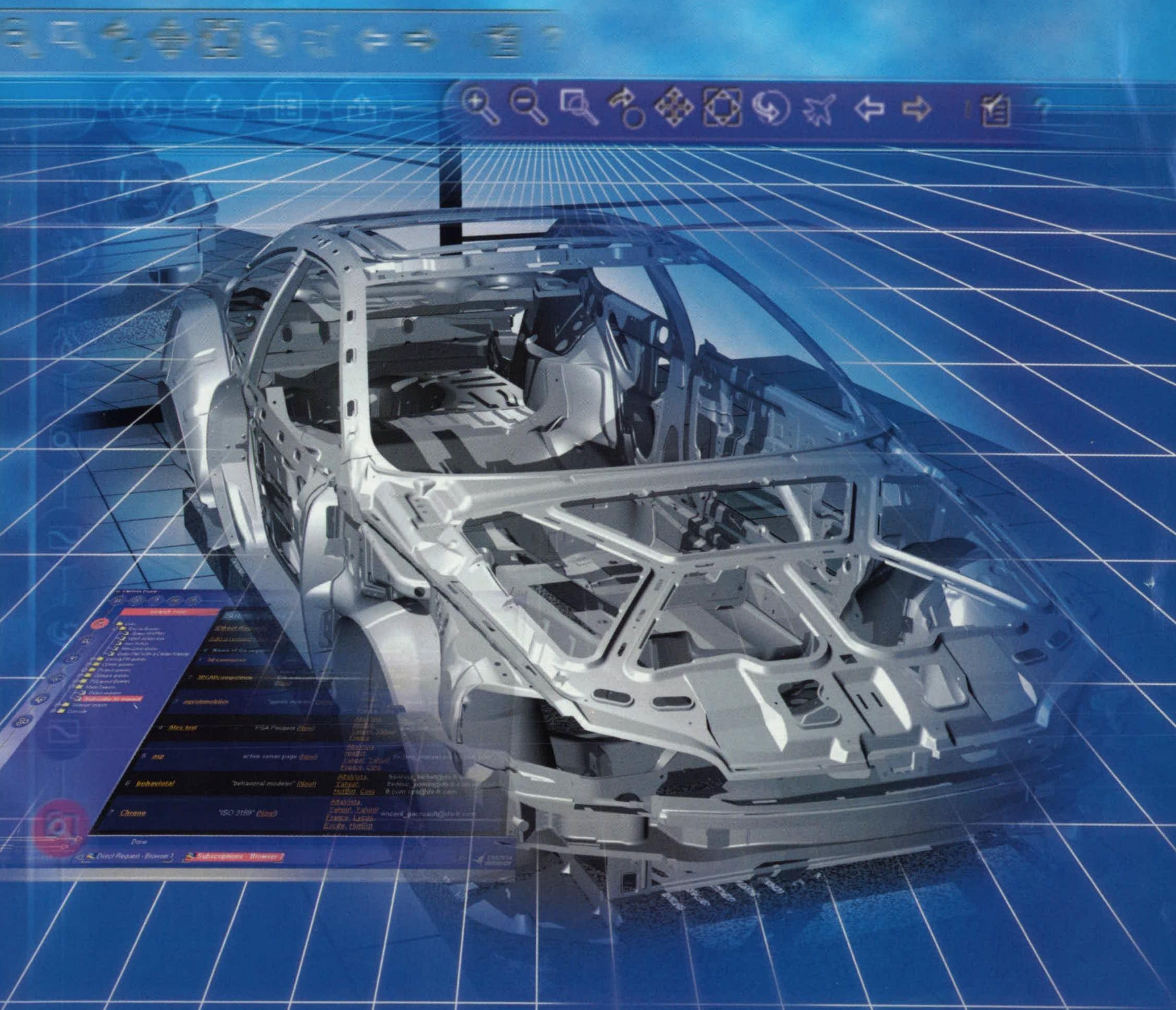
March 2001

Vol. 25 No. 3

TECH BRIEFS

ENGINEERING SOLUTIONS FOR DESIGN & MANUFACTURING



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NASA TECH BRIEFS
ENGINEERING SOLUTIONS FOR DESIGN & MANUFACTURING
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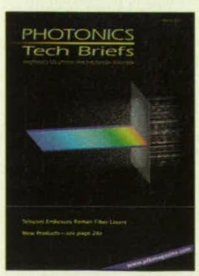

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The Meterman line of test and measurement instruments from Wavetek Meterman Test Tools, Everett, WA, includes multimeters, ammeters, testers, and bench instruments.

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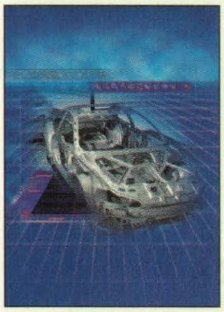

The design of this Peugeot 406 coupe was created using CATIA CAD/CAE software with CATIA's Visualization Studio from Dassault Systemes/IBM (Dallas, TX). CATIA is just one of many CAD packages that has held its own in the fast-changing design and analysis software market. New, easy-to-use, inexpensive solid modelers and Web-based analysis offerings have altered the pace of innovation in CAD and CAE. Find out what leaders in the software market think about the future of the industry in our feature article on page 20.

(Image courtesy of PSA/Peugeot-Citroen)

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NASA Commercial Technology Team

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

NASA's Technology Sources

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

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

Dryden Flight Research Center
Selected technological strengths: Aerodynamics; Aeronautics Flight Testing; Aeropropulsion; Flight Systems; Thermal Testing; Integrated Systems Test and Validation.
Jenny Baer-Riedhart
(661) 276-3689
jenny.baer-riedhart@dfrc.nasa.gov

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

Jet Propulsion Laboratory
Selected technological strengths: Near/Deep-Space Mission Engineering; Microspacecraft; Space Communications; Information Systems; Remote Sensing; Robotics.
Merle McKenzie
(818) 354-2577
merle.mckenzie@jpl.nasa.gov

Johnson Space Center
Selected technological strengths: Artificial Intelligence and Human Computer Interface; Life Sciences; Human Space Flight Operations; Avionics; Sensors; Communications.
Charlene E. Gilbert
(281) 483-0474
charlene.e.gilbert1@jsc.nasa.gov

Kennedy Space Center
Selected technological strengths: Fluids and Fluid Systems; Materials Evaluation; Process Engineering; Command, Control and Monitor Systems; Range Systems; Environmental Engineering and Management.
Jim Aliberti
(321) 867-6224
Jim.Aliberti-1@ksc.nasa.gov

Langley Research Center
Selected technological strengths: Aerodynamics; Flight Systems; Materials; Structures; Sensors; Measurements; Information Sciences.
Sam Morello
(757) 864-6005
s.a.morello@larc.nasa.gov

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

Marshall Space Flight Center
Selected technological strengths: Materials; Manufacturing; Nondestructive Evaluation; Biotechnology; Space Propulsion; Controls and Dynamics; Structures; Microgravity Processing.
Sally Little
(256) 544-4266
sally.little@msfc.nasa.gov

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

NASA Program Offices

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

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

Dr. Robert Norwood
Office of Commercial Technology (Code RW)
(202) 358-2320
rnorwood@mail.hq.nasa.gov

John Mankins
Office of Space Flight (Code MP)
(202) 358-4659
jmankins@mail.hq.nasa.gov

Terry Hertz
Office of Aero-Space Technology (Code RS)
(202) 358-4636
thertz@mail.hq.nasa.gov

Glen Mucklow
Office of Space Sciences (Code SM)
(202) 358-2235
gmucklow@mail.hq.nasa.gov

Roger Crouch
Office of Microgravity Science Applications (Code U)
(202) 358-0689
rcrouch@hq.nasa.gov

Granville Paules
Office of Mission to Planet Earth (Code Y)
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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.

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

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

Dr. William Gasko
Center for Technology Commercialization
Massachusetts Technology Park
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J. Ronald Thornton
Southern Technology Applications Center
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Gary Sera
Mid-Continent Technology Transfer Center
Texas A&M University
(409) 845-8762

Lani S. Hummel
Mid-Atlantic Technology Applications Center
University of Pittsburgh
(412) 383-2500

Chris Coburn
Great Lakes Industrial Technology Transfer Center
Battelle Memorial Institute
(440) 734-0094

NASA's Business Facilitators

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

Wayne P. Zeman
Lewis Incubator for Technology
Cleveland, OH
(216) 586-3888

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

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

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

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

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

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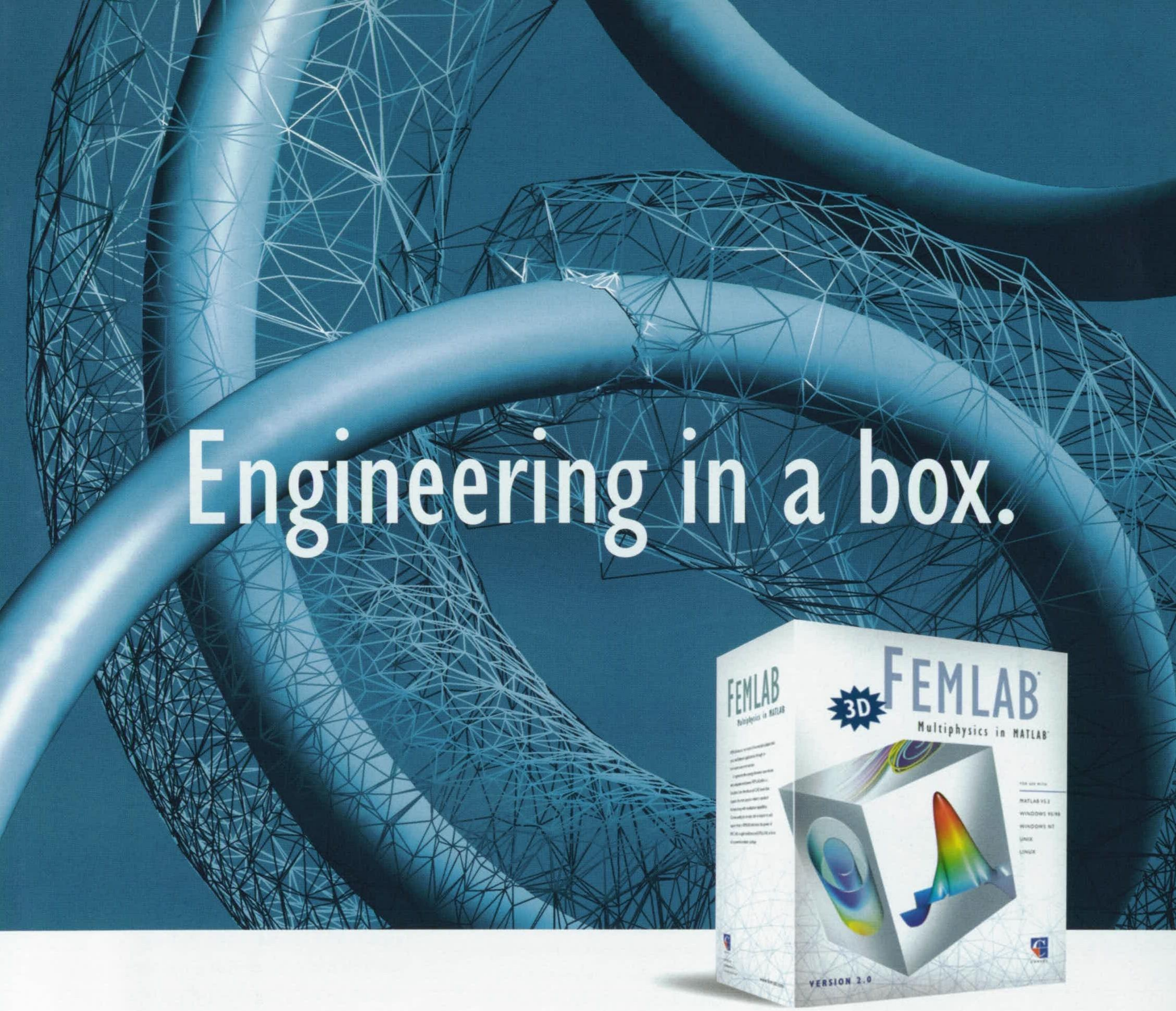
(256) 704-6000

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

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

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.

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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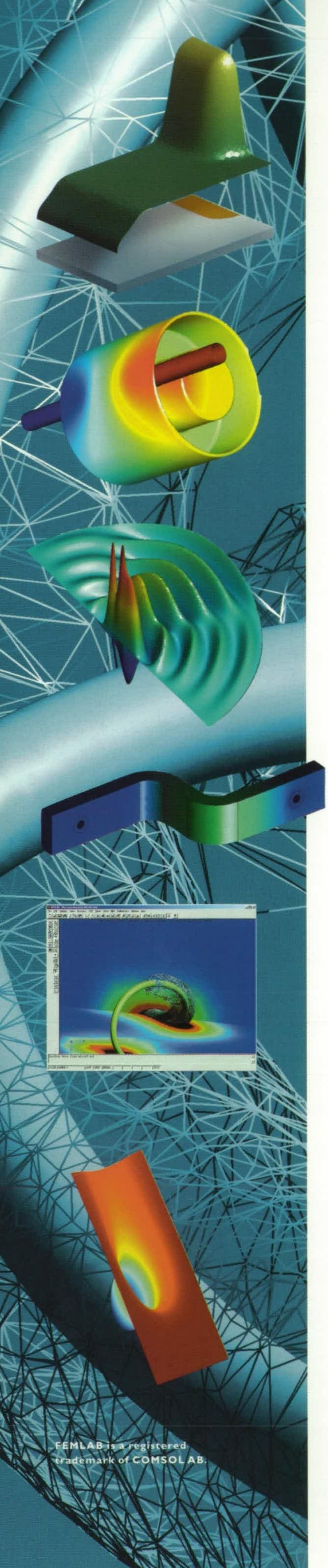

The semiconductor formulation can be derived from Maxwell's equations and Boltzmann transport theory. The problem can be formulated for three independent variables and strong nonlinear dependencies are present. Similar problems arise in the modeling of photonic devices. FEMLAB´S advanced design, which allows for arbitrary couplings, provides engineers the flexibility they need to model such phenomena.

The design of equipment that is expected to perform at high voltage requires careful evaluation. This model studies the electrical properties of the insulation between the electrodes in an HV connector.

The propagation of alternating fields is studied by using the j-ω method, which is readily available to you through FEMLAB´S graphical user interface. FEMLAB includes a number of other ready-to-use applications for computational electromagnetics.

FEMLAB is able to arbitrarily couple different physical phenomena. In this case, the heat generation in a current collector is studied as a function of current density. The current and heat balances are fully coupled through the dependence of the conductivities of temperature and through the heat exerted by the current passing through the collector.

Electrostatic precipitators are often employed to remove particles from effluent gases. The electrodes in these units are often helical shaped. The figure shows the electrical field in the vicinity of the helix during operation of the filter.

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- Ready-to-use application modes for different engineering fields
- Equation based modeling for arbitrary system of PDES

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FEMLAB employs sophisticated numerical techniques developed by our staff of leading scientists in collaboration with industry experts from around the world. These scientists had a goal of making modeling available to every engineer and scientist. FEMLAB is the result of our commitment to putting engineering mathematics in a box.

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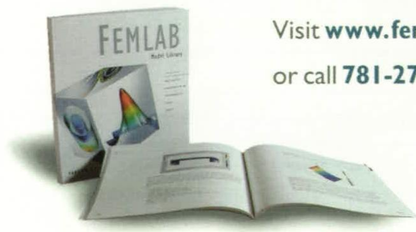

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NASA Tech Briefs previously published a tech brief by three researchers at NASA's Jet Propulsion Laboratory called "Miniature Ring Orbitron Getter Ion Vacuum Pumps." I am interested in learning more about the electric field distribution to understand the spiraling paths of the electrons around the anode ring. Thank you.

Pramod Naik
dr.naik@vsnl.com

*(**Editor's Note:** The tech brief you're referring to was published in the September 1999 issue. To get more information on the subject, visit **www.nasatech.com**, click on the Tech Briefs heading, and look under the Physical Sciences category. You'll find a listing for the briefs published in September 1999, and from there, you can access the Technical Support Package available on this brief.)*

I'm trying to make a humidity sensor using the microbending phenomenon by the swelling of hydrogel. The problem I'm facing is that the hydrogel gets very hard after a few dips, and it does not return back to its original form even after left to dry for hours. It may be that the ratio or type of hydrophobic and hydrophilic chemicals we're using is not right. Does anyone know of a source for information on the correct ratio for the two types of chemicals, and what kind of polymer would be best for this purpose? Any suggestions would be appreciated.

Rajeev Jindal
raj_jindal@hotmail.com

I am trying to locate a source for shaker tables that are capable of vibrating a full-sized van. I also need to find information on how to design a facility to vibrate van-sized vehicles under computer control. Thanks for any assistance.

Carl Bertrand
cbertran@dot.state.tx.us

My company is looking for a material that will resist temperatures of 400 to 900°F for one hour. We need the material to protect an EEPROM chip, so thermal transfer must not take place, as is the case with ceramics. The material cannot contain a metal composition. The chip will be packaged to be about the size of a deck of cards. We'd appreciate information on any substance that may work in this application.

James Heurich
james@rfidinc.com

NASA Patents

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

Real-Time Visualization of Tissue Ischemia

(U.S. Patent No. 6,083,158)

Gregory H. Bearman, Thomas D. Chrien, and Michael L. Eastwood, Jet Propulsion Laboratory

There are many clinical settings in which the oxygen content of tissue is needed to help in identifying, and/or monitoring and treatment of, areas of healthy, diseased, or dead tissue. During surgery on an organ, areas of its tissue can become ischemic, and they could be treated instantly if they could be localized. The JPL team offers a means for easily localizing and imaging specific organs, providing feedback during surgery and treatment. A real-time display of tissue ischemia comprises three charge-coupled device (CCD) video cameras, each with a narrow bandwidth filter at the correct wavelength. The cameras simultaneously view, through beamsplitters, tissue suspected of having ischemic areas. The output from each camera is adjusted to give the correct signal intensity for combining with the others into an image for display. Measurement at three wavelengths, combined in a real-time red-green-blue video display with a real-time DSP board to implement image algorithms, provides direct visualization of ischemic areas.

Blading System and Method for Controlling Structural Vibrations

(U.S. Patent No. 6,102,664)

Inventor: Nhan Nguyen, Ames Research Center

The reliability of an axial-flow turbomachine in general depends on the durability of its component parts. In the event of vibration fatigue, the blading system of the turbomachine can dangerously jeopardize such durability. The present invention provides a unique damper and method for controlling the structural vibrations in axial-flow compressors, turbines, or fans, as in aircraft engines and like turbomachines that have a stator disc and a rotor disc, without affecting their aerodynamic performance. The rotor disc defines several radial hubs that retain the rotor blading systems. Each of them includes a blade formed of an airfoil, and a root attachment which is dimensioned to fit within, and to engage a corresponding hub. Viscoelastic dampers are selectively applied to the outer surfaces of the root attachment on which compressive or shear forces are likely to develop, intermediate the root attachment and the hub upon rotation of the rotor disc, in order to dampen structural vibration.

Emergency Multiengine Aircraft System for Lateral Control Using Differential Thrust Control of Wing Engines

(U.S. Patent No. 6,102,330)

Inventors: John J. Burken, Frank W. Burcham Jr., and John Bull, Dryden Flight Research Center

The object of this invention is to create a sufficient degree of lateral control through differential thrust modulation of laterally displaced engines, that is, engines equally spaced on both wings or both sides of the aircraft fuselage, to provide directional control of the aircraft independent of longitudinal (flightpath angle) control and, in the case of making a landing approach, to make a safe landing when only engine thrust is available. Lateral control is provided in response to a heading angle command produced by a pilot through a thumbwheel or by an instrument landing system. That command is compared to a sensed heading to produce an error signal that corrects the heading sensed after compensation by feedback signals from selected aircraft dynamic sensors to improve dutch-roll damping and closed-loop performance. Bank angle rate is included as a feedback for the dutch-roll damping. Yaw rate, bank angle and true velocity are included as feedback signals for efficient turn coordination and smooth change in heading.

For more information on the inventions described here, contact the appropriate NASA Field Center's Commercial Technology Office. *See page 12 for a list of office contacts.*

PRODUCT OF THE MONTH

The Meterman line of more than 60 test and measurement products from Wavetek Meterman Test Tools, Everett, WA, includes digital multimeters, basic and specialty testers, clamp-on ammeters, and test tools. The products are for use in the evaluation, design, installation, production, and service of electronic and electrical equipment and systems. The tools feature large displays, extra fusing, safety test leads, Digi-Glo™ backlighting, live voltage safety testers, warning beepers, and a line of accessories. Products include the HD and XT Series digital multimeters for electronics troubleshooting, logic probes for detecting pulses and logic in electronics, bench instruments such as function/sweep generators, amp-clamp meters, and accessories such as test lead kits, cases, current transformers and transducers, and temperature probes.

For More Information Circle No. 756

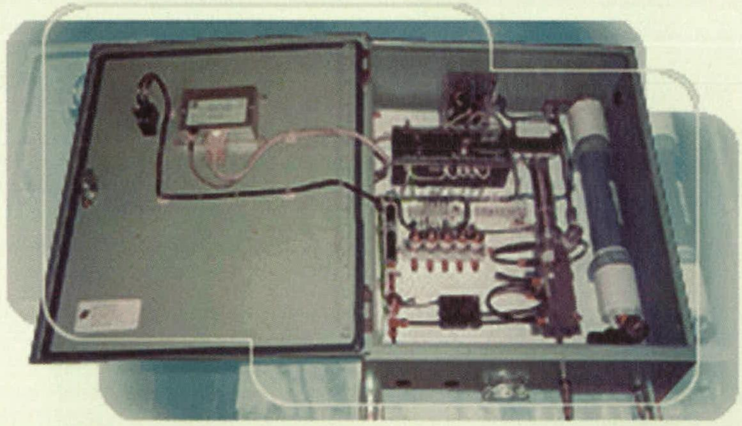
What is IT?

IT's been in the news, on the Internet, and just about everywhere else. But what is IT? Inventor Dean Kamen isn't talking about his invention (thought to be some type of machine) that has technology experts predicting it will be more significant and revolutionary than the World Wide Web.

Engineers and inventors around the world are guessing that IT is an acronym for individual transport — a Jetson-style hovercraft or jet-pack. The theories continue to abound. What do you think IT is? Send me an e-mail at linda@abptuf.org with your educated guess.

NASA Spinoff Proves Fruitful

Geo-Centers of Newton, MA, is now marketing a patented ethylene monitoring and control system that was developed under a Small Business Innovation Research (SBIR) contract with NASA's Kennedy Space Center (KSC) in Florida. The system originally was planned for use in KSC's biomedical office's Bioregenerative Life Support System (BLSS). The purpose of that project was to monitor the environments in closed plant growth chambers. As plants grow, they produce byproducts of ethylene and ammonia, both of which are harmful to plant development. A monitoring system is required to control the concentrations and optimize plant growth.



The monitor that Geo-Centers developed also has applications in the citrus processing market. It provides an automated, rapid means of monitoring and controlling ethylene concentrations in citrus degreening, ripening, and storage applications. Ethylene is used to ripen fruit, but finding the proper balance in ethylene concentration is necessary to reduce fruit loss.

The system continuously monitors at multiple points within a fruit storage area, eliminating the need for manual sampling. It is the only commercially available system that monitors and controls ethylene concentrations 24 hours a day. The economic impact to a packing house from fruit loss due to excess ethylene exposure may run from $15,000 to $100,000 annually.

Units have been sold to degreening facilities in the US and Spain. Systems are being manufactured and sold through Geo-Centers' distributor, Beshaco, of Vero Beach, FL.

For more information, contact Bruce Nelson at Geo-Centers; Tel: 617-964-7070; www.geo-centers.com; or contact Tom Gould at NASA's Kennedy Space Center at 407-867-6238.

Who's Who at NASA

Robert P. Hill, Manager, NASA Acquisition Pollution Prevention Program, Kennedy Space Center

Robert P. Hill is the Manager of the NASA Acquisition Pollution Prevention (AP2) Program based at Kennedy Space Center in Florida. The NASA AP2 Office was established to identify and achieve a mutually beneficial pollution prevention project, seeking common goals for NASA centers and Department of Defense partners.

NASA Tech Briefs: How did the NASA Acquisition Pollution (AP2) Program get its start?

Robert P. Hill: There was a need identified by the Department of Defense (DoD) and the CEOs of about 60 of this country's industrial base defense companies — the Boeings, the Lockheed-Martins and so on — for assistance dealing with multiple customers sharing the same processing lines. In other words, they'd have ten different weapons systems from across the Army, Navy, and Air Force being plated or painted down the same processing line. Of course, each weapons system component and sub-component was being driven by different contracts. So to change the process, you had to change many of the contracts, and to change the contracts, you had to prove individually to each one of those [companies] that an alternative was viable.

In order to make changes to single processes, they had to go back and try to change the manufacturing processes. You don't want to get something plated with a hazardous chemical and then come in and change to a clean technology process. You have the hazardous waste when you strip down the old part, so you want to try and change manufacturing and maintenance at the same time.

The Joint Logistics Commanders (JLC) — the lead logistics body of the DoD — authorized the creation of the Joint Group on Acquisition Pollution Prevention (JG-APP), which received informal status in 1994. As the JG-APP began to examine processes for the DoD, we identified that many of NASA's components and parts were sharing the same types of manufacturing processes. We invited NASA to participate in the group. In late 1997, a proposal was made to set up an office at NASA to mirror the program we were running at DoD. With my experience at the DoD organization, I was asked to leave the Air Force and run the NASA program.

NTB: What is the main goal of the AP2 program?

Hill: We've been set up to integrate activity for the agency in identifying common pollution prevention needs. Subsequently, we turn those shared needs into single-level-of-effort projects where they affect multiple NASA sites, or, if there is a NASA activity that is common to an Air Force or Navy activity, we link the two together and start a common project.

NTB: What major successes have you achieved at AP2 since its inception?

Hill: We've established a single point of integration for targeting all the needs within the program offices, the enterprises, and the institutional centers. In the past, there was no mechanism to determine, for example, that Marshall Space Flight Center has a chrome plating process, and so does Kennedy. What we're finding is that we may have four or five NASA centers that have the same need, and one of them already has solved the problem.

NTB: Has any of your research and information been applied to commercial manufacturing?

Hill: No Joint Group on Pollution Prevention (JG-PP) project can be proprietary in nature. We're working in an open environment and industry has responded well to us. We tested for Boeing a non-chrome primer a couple of years ago on the F-15 and several weapons systems. We took the results to Boeing and they painted a couple of doors on some Delta AirLines aircraft. There are several Delta airliners flying today with this non-chrome primer on their entrance doors as part of the flight-testing to determine if the primer can be used as part of the construction and maintenance process for future aircraft.

*A full transcript of this interview appears online at **www.nasatech.com**. Mr. Hill can be reached at Robert.Hill-3@ksc.nasa.gov.*

Want to make the jump to Fibre . . .

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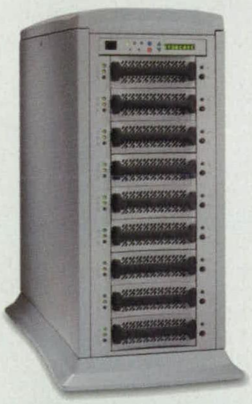

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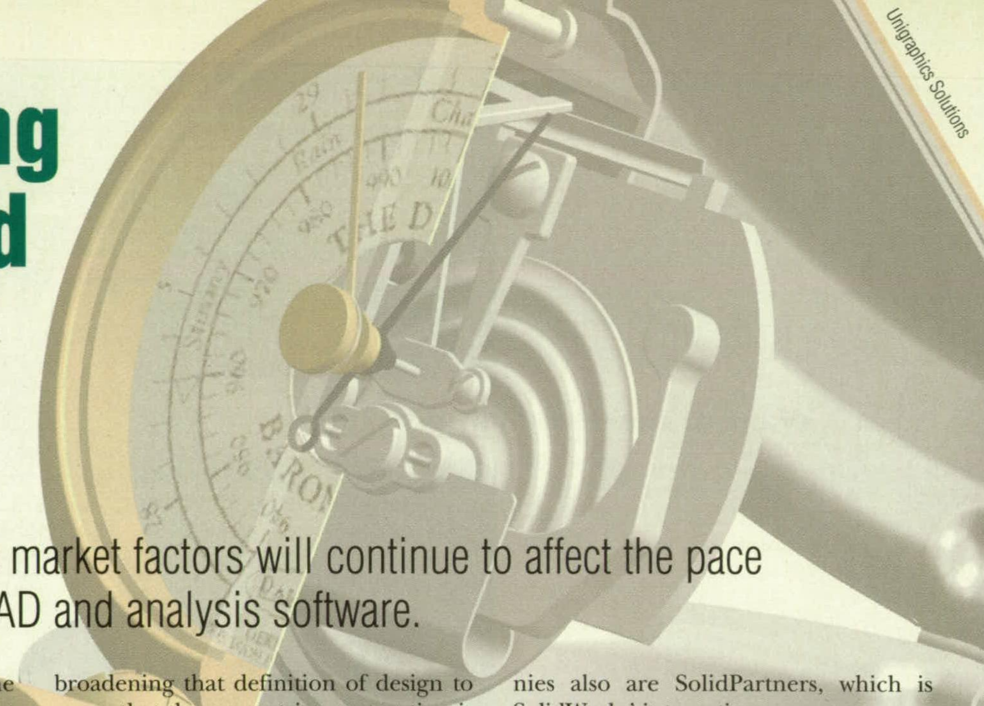
Reinventing Design and Analysis Software



The Internet and various market factors will continue to affect the pace of new innovations in CAD and analysis software.

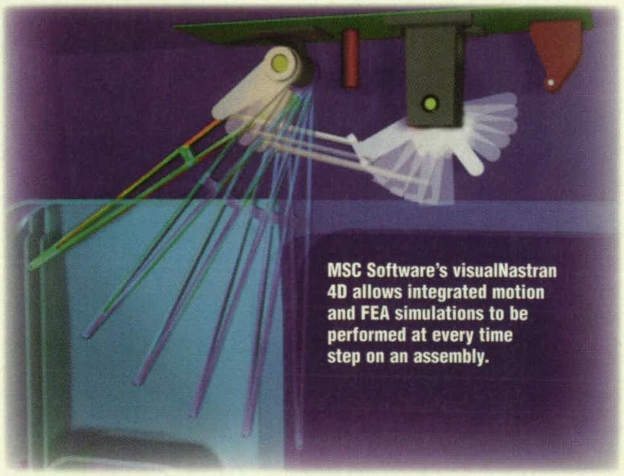
Design and analysis software — the words often are used together, but the truth is, they are two very different types of software for two very different users. And if you ask software vendors — which we did — they have very different ideas of where the CAD (computer-aided design) and analysis software markets are heading, thanks to the Internet, market consolidation, and other factors.

CAD software builds the geometry, or what the product should look like. Analysis software answers the question of whether or not the product will work. The best-case scenario is to have the products so tightly integrated that engineers can move seamlessly between the two. But in the real world, what good is finite element analysis (FEA) to a designer if he or she isn't capable of using it? It's not much good at all, according to Michael Bussler, president and CEO of Algor, Inc., which develops FEA, motion, and stress analysis software.

"A company spends a lot of money training a CAD operator, but it's probably not going to spend that money cross-training an engineer to become a CAD operator," explained Bussler. "CAD has to do with geometry and making parts, and engineering has to do with deciding how the design should be — if it's okay from a stress standpoint. These things really don't integrate."

So CAD software is for designers and analysis software is for engineers, and never the two shall meet. Not so, said Marc Dulude, President and CEO of Moldflow, a vendor of plastic simulation analysis software. "In the past, the term 'design software' has been taken fairly narrowly to mean geometric construction. So a CAD system would be the only thing that would fall within the design category. I think increasingly, people are broadening that definition of design to mean that the geometric construction is only one part of the design process."

As a result, CAD vendors are integrating more analysis features into their software, and analysis software vendors are making their programs easier to use for both designers and engineers. For example, Algor offers the InCAD*Plus* line of plug-ins that add into the menus of many solid modeling programs to capture the exact CAD model memory within Algor without translation to a CAD standard neutral file. The model then can be used for FEA, stress, fluid flow, heat transfer, or any other analysis function within Algor. Ansys has developed its DesignSpace analysis tools for designers and engineers with minimal to no experience in traditional FEA. Using engineering process wizards, DesignSpace takes users through a step-by-step process to find stress, thermal results, and other information.



MSC Software's visualNastran 4D allows integrated motion and FEA simulations to be performed at every time step on an assembly.

Most major CAD vendors now provide FEA, stress, motion, and other tools through partnerships with analysis software companies. Unigraphics Solutions' Solid Edge Voyager Program consists of companies that integrate their hardware and software seamlessly with the Solid Edge modeling program. Algor, Ansys, Moldflow, MSC Software, and Structural Research and Analysis (COSMOS analysis products) are some of the leading analysis software vendors participating in the program. Many of the same companies also are SolidPartners, which is SolidWorks' integration program.

MSC takes its CAD integration a step further. The simulation and analysis software provider offers visualNastran 4D, which, according to Ryan Withop, product manager of MSC's e-visualNastran line, lets users run a finite element analysis on a single part within a CAD system. "We have a product that works inside [Autodesk's] Mechanical Desktop, one that works in SolidWorks, and another that runs in Solid Edge." Said Withop, the next step will be to "run a finite element analysis over the Web through our SimulationCenter through your CAD system. It would take the CAD geometry and transfer it to the Web, where you can run your analysis online."

What's On the Web

Offering analysis software online means different things to different companies. MSC, for example, offers their simulation and analysis tools online on a project-by-project basis. Their customers, according to Robert Swette, di-

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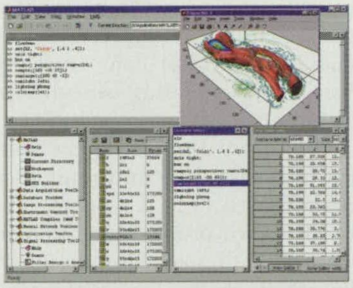

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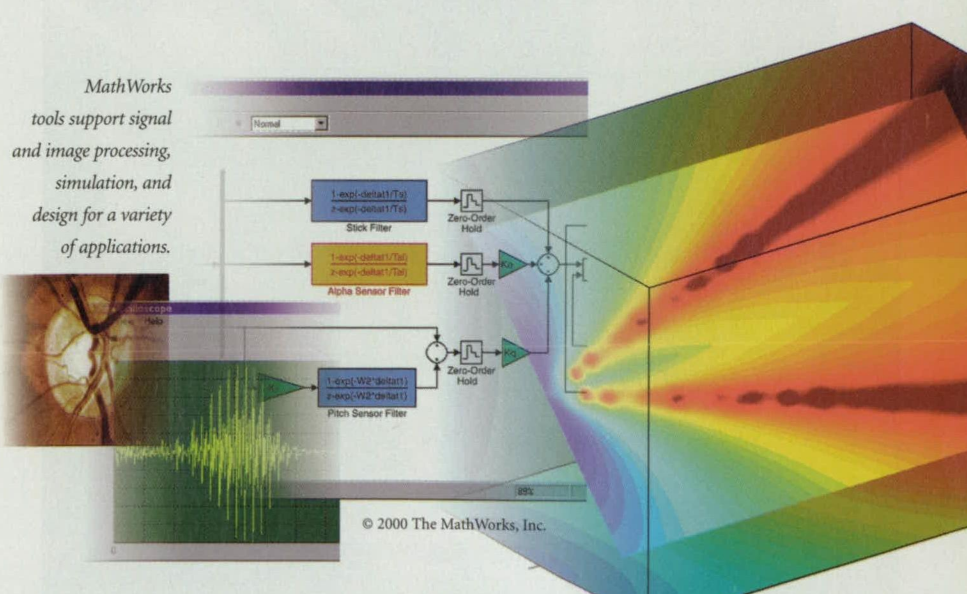

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rector of Strategic Marketing, may only need analysis software for the duration of a project, whether it's a month or six months, and do not want to invest in purchasing the shrink-wrapped software. "Another group," said Swette, "is those that have never used FEA before. This is a way for them to try it." Customers like to have the software resident on their computer for security reasons. For them, MSC offers an on-demand license. "They come to our engineering-e.com site, and buy the license for a week or a month," he explained. "We send them an authorization and they're up and running."

Bill McClure, director of the Solid Edge Line of Business for Unigraphics Solutions, agrees that the success of such pay-as-you-play software depends upon the market and the type of software. "Markets like AEC [architectural, engineering, construction] are project-oriented businesses, so they are more likely to pay as they go. It also depends on the type of tool and how often you use it," explained McClure. "Manufacturers will want to own their own core design tool. They may want to lease or rent an analysis product as they need it."

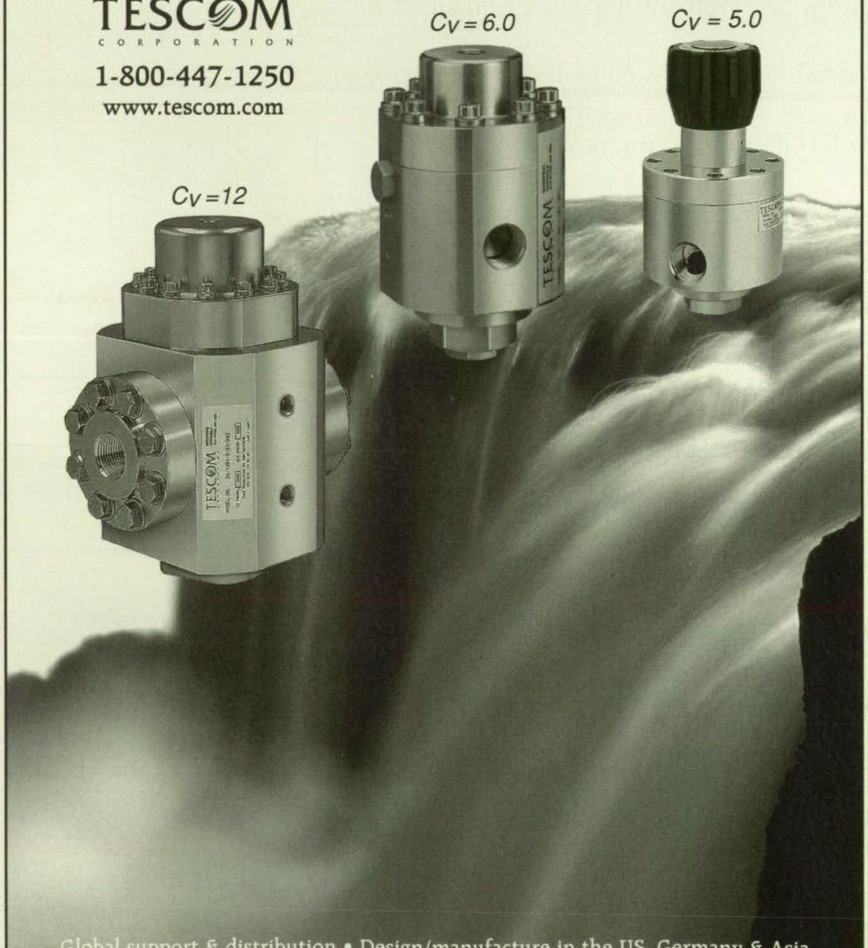
Algor's Bussler believes that it's not so much how you deliver it, but what you deliver. Algor software "will continue to be delivered in the least expensive way possible," he said. If his customers want to get their software via the Internet, "we'll give it to them that way. They can do that today with us if they want."

While most CAD vendors use the Web to sell their software, they have varying ideas on when and under what conditions customers actually will be downloading software directly from a web site, marking the end of the shrink-wrapped product. Robert Bean, president and CEO of CADKEY Corp., sees an important distinction between downloading and using software on the Web. "I've seen some predictions that say in three years, people will be downloading most software over the Web instead of installing a CD. But running over the Web is a different story. I don't see that happening anytime soon. I don't see user demand for it. Most companies are very wary about operating over the Internet with proprietary information."

Moldflow's Dulude agrees that security is a major issue in running software over the Web. "Very few people are going to allow their proprietary data models to leave their firewall. They do not want to put their models on somebody else's server." He also feels that even with high-speed Internet connections, downloading large CAD models can be problematic. "If you take a large data file that needs to be moved across the Internet, few people are prepared for the kind of slowdown they'll see."

Performing relatively simple design and working on 10,000-part assemblies are very different tasks, especially as far as the Web is concerned. And while companies like Autodesk see the inevitability of Internet downloading of CAD, there are logistical concerns. "I do think that what is on the desktop today will ship to Internet. That is what we perceive as our next environment," said Robert Kross, vice president of Autodesk's Manufacturing Division. However, it won't be an overnight process. "We'll go through some internally hosted services and then we'll go to the general Net."

While it may be some time yet before Web downloading of CAD is commonplace, software vendors are taking advantage of the Internet in a myriad of other ways. Algor, for example, not only sells its products via the Internet, but also offers demonstrations and training in the form of Webcasts. A weekly, live demonstration on the Internet instructs viewers on using FEA and other analysis products. Viewers



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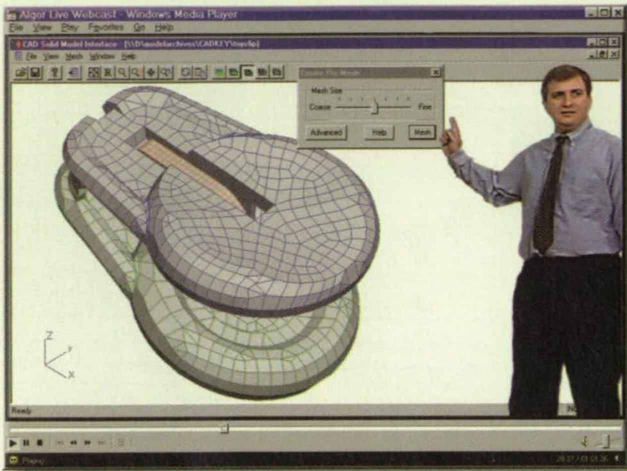


Algor's Webcasts use the Internet to fill the demand for engineering software education with full-screen, TV-quality video. Engineers can perform a variety of FEA analysis in an integrated environment within the CAD package.

can phone in or e-mail questions to be answered by Algor engineers during the Webcast. Web Courses provide instruction on a variety of topics, and use full-screen graphics and broadcast technology to place instructors "inside" the software. "The Internet gives us the opportunity to sell our products through demonstrations over the Internet, and we've found that today we're delivering more training to more people for less money with our Internet-based Web Courses," Bussler explained.

In a similar vein, MSC offers its own knowledge databases online. "Some of our customers dial in to our system to interrogate our internal databases to find the solution to a problem. We can take over a customer's terminal and work with him on a specific project, seeing what he can see," according to Richard Bush, director of marketing communications for MSC. "We provide Webinars to talk through the demonstrations."

Communicating with customers, and allowing customers to communicate with each other, are further enabled by Internet technology. "The biggest impact of the Internet, in our view, is in the areas of supporting our users and communicating 3D data to other people," said Jon Hirschtick, CEO of SolidWorks. "We have a knowledge database, online training materials, support over e-mail, web-based publishing tools to interact, web casts, and interactive phone and web use. I think it will be a huge impact on support and training."

While he does not believe in the Internet as a delivery mechanism for CAD software, Joe Costello, president and CEO of think3, makers of thinkdesign CAD software, sees huge potential in other applications of the Web. "The truth is that the Internet has a tremendous role to play in MCAD as a fundamental communication vehicle. That's the key. We use it for customer service and support, and it is a great tool to get people working together. You have to use the new Web technology and see how it's best going to fit into this environment."

Explained Dassault Systemes' marketing director, Pierre Moreau, the company's new release of CATIA, coupled with other Dassault products, offers customers "a unique collaborative tool to support digital product creation from concept design to maintenance in service." This combination of CAD software (CATIA), data management software (ENOVIA), and other products — called Product Lifecycle Management (PLM) — supports collaborative and distributed engineering via Internet technology.

A Leap of Faith

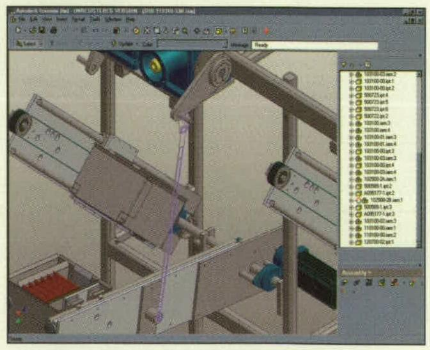
When we talk about using, distributing, and sharing CAD data, we usually think about 3D solid models. The truth is, anywhere from 60 to 85 percent — depending upon whom you ask — of design engineers still use 2D software to design their products. Even with the proliferation of affordable, easy-to-use 3D solid modeling packages, users are reluctant to change. Again, it's a matter of the type of application and the tools that are needed.

"There are cultural changes to be made going from 2D to 3D," said Hirschtick. "People tend to think that if the software's easy enough to use, that's the whole story. When someone moves to SolidWorks or any brand of 3D CAD software, they're not just changing software. It's a change in how you do things." And it's not the cost, either, according to Hirschtick. "It's being confident that they are going to be successful with it. Look at the adoption curve of PCs in homes — why didn't every home have a PC? Was it that they were too hard to use? No. It's a little naive and self-centered to think that we as software vendors — if we make the software totally easy to use and free — could make everyone switch tomorrow. It's the psychology of people."

But the 2D stalwarts aren't going away, said CADKEY's Bean. "About 50 percent of our customers just do 2D drafting with CADKEY [a 3D solid modeler]. The reason is that the design work they do is simple enough that all they need is 2D. In smaller companies that do very large projects, much of their work is done in 2D."

The switch from 2D to 3D remains a fear factor with many design engineers; with others, it's a matter of the learning curve outweighing the benefits. Kross recognizes that while Autodesk continues to sell 2D products, they want to make it easier for customers to shift to 3D. With Inventor solid modeling software, Autodesk has created a platform in which users can still perform 2D design while migrating to 3D, allowing them to keep their comfort level while they make the transition. "I think one of the big things is that the perceived risk of designing in 3D is much lower than it used to be," said Autodesk's Kross. "Not long ago, it was the 'lunatic fringe' that designed in 3D — everybody else was making 2D designs. Now it's perceived to be the safe way of doing design."

People still get scared about using CAD packages because they're so complicated, according to Costello. "Until you get to the point where people have no fear and know that they can easily transform their design, why should it be so hard for people to express themselves in mechanical design packages?" Over time, what CAD vendors want, Costello believes, is to put the incredible power of 3D design in the hands of everybody — "mass 3D" as he calls it. "Don't train the human to use the product," he said. "Let the machine do the work and let the humans focus on what they're good at — the creative side of things."



A 2D AutoCAD drawing is used as a subassembly component in an Autodesk Inventor assembly model. The capability lets users lay out assembly mechanisms and test them without having to model the entire assembly first.

(continued on page 26)

According to Costello, the 3D CAD industry has a long way to go in making 3D CAD a product for the masses. That won't happen, he said, until a user "can take something that exists and modify it, stretch it, shape it, change it, morph it, and use it for a new function in minutes — not days, not weeks, not months."

"We have to continue to make software easier to use and more intuitive," Bussler added. "The software has to handle easily a wider and wider range of things that can be simulated in a 'what-you-see-is-what-you-get' style. If someone makes widgets, he wants the software to be able to model and analyze his widgets, and show him if they'll pass or fail from a stress standpoint."

Bean agrees that there is room for improvement in the user interface. "There is always a way to make things easier. The fact is, it still takes people an awfully long time to learn a mid-range parametric CAD product. The current mode that is prevalent in designing in parametric mode is still very constraining."

Both analysis and design software companies face the problem of making an easy-to-use product at an affordable price. As with many markets, from consumer electronics to breakfast cereals, there is the ingrained belief that "you get what you pay for." To many, design and analysis software is no different. "There unfortunately is this notion that there is something of a contradiction between what is lower in cost and everyone has access to, and having less function — high function should be high cost," said Costello.

To keep customers, software vendors need to consistently give them what they want. The problem with satisfying customers, though, said McClure, is that software vendors "have a propensity to deliver more technology than our users can use."

Costello agrees that customers are getting what vendors think the customer needs and wants. Contrary to what many vendors say, Costello explained, customers "are not demanding new software capabilities, and, by God, they should be. What customers want is to have their entire team using advanced 3D. They need a real power tool in their hands."

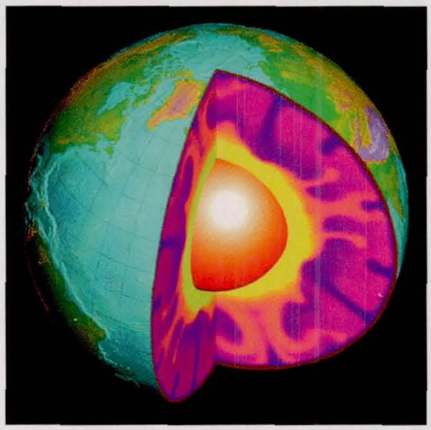
According to Richard Cooke, vice president of engineering for Research Systems, a supplier of data visualization software, empowerment is the key to keeping users happy. "Customers want higher levels of automation — a way to do the job quickly with less skilled people."

Surviving — And Thriving

Design and analysis software have both come a long way since high-end products like PTC's Pro/ENGINEER first hit the market. Mid-range products like SolidWorks and Solid Edge burst onto the scene about six years ago as a totally different type of solid modeling package, and today, programs like think3's thinkdesign are making waves as the ultimate in easy-to-use CAD.

Where does the industry go from here? A recognized consolidation in the CAD market and status quo in the analysis market don't seem to bode well for software innovation. But the next great thing could be right around the corner, according to Costello. "There is tons of room for innovation," he said. "It irritates me when I listen to leaders in the industry say that all of the high-end CAD problems are solved." The biggest innovations, he believes, will have to come from new companies. "The current CAD companies have gotten tired. There is no room for growth for them unless they change. There is room for a new crop of companies that will come along and really turn the industry upside-down."

Customers and vendors alike will know that type of innovation when they see it, said Hirschtick. "When you first saw AutoCAD versus the mainframe CAD systems, that was new and different.



IDL (Interactive Data Language) visualization software from Research Systems produces simulations such as this simulated model of the Earth's core, mantle conversion data, and surface shaded relief.

When you first saw Pro/E, that was new and different. I think when you first saw SolidWorks, that was new and different. You didn't have to spend more than 30 seconds to realize that these products were different."

The analysis software market could experience its own resurgence, said MSC's Bush. "The analysis side of the market has been shrinking for a number of years now, but there are always opportunities for new vendors to enter the field."

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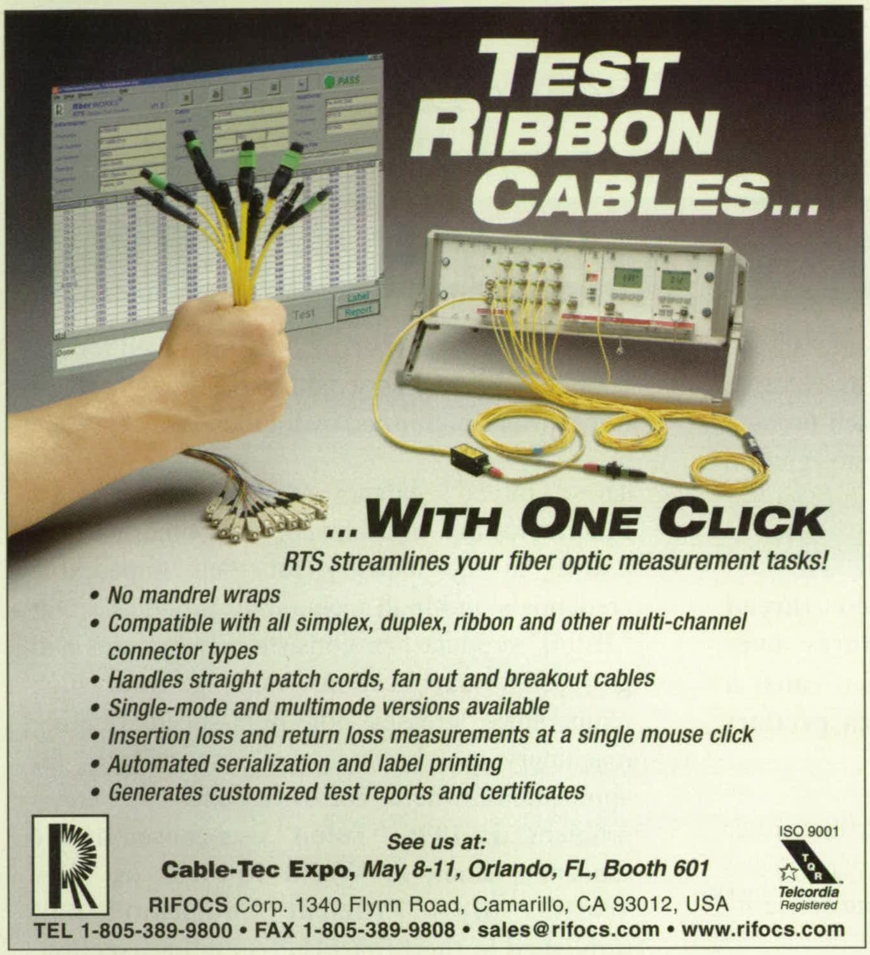

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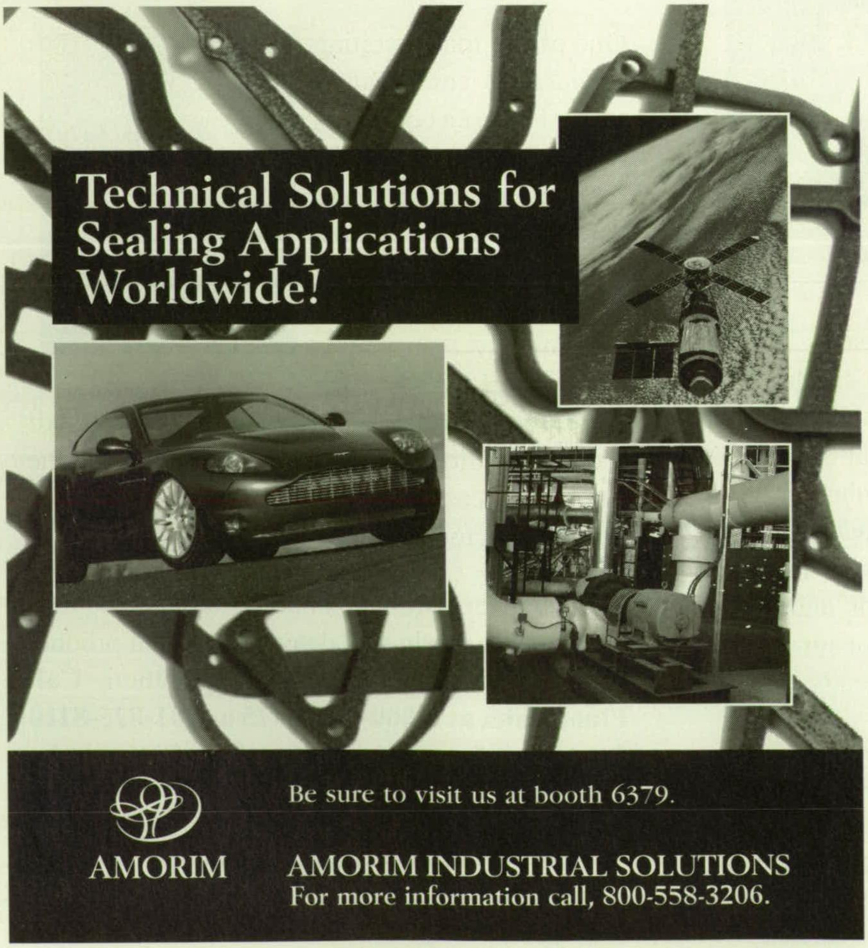

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There is a vast difference between surviving and thriving. According to Kross, "you can't just be a CAD vendor. I think it's a broadening of the playing field." For example, Autodesk, he said, is trying to become more of a manufacturer's supplier. "If you look at your customers, what's their need for design and design data? It goes much further than just the designer that you're after. It's all the people who can touch that data."

There's always room for improvement, both in the way software companies design their business model, and in the products they offer to their customers. "In this market segment, we want to always look at doing more things," said Hirschtick. "But the fact is that we don't do the core activities well enough yet."

Costello believes it's all about reinvention. "The winners re-think — they look at the marketplace and the customer problems and ask how they're going to take it to the next level. We said, 'What's it going to take to make widespread use of 3D happen?' And we built our company — every piece of it — around how you can make that real for customers." He vows that think3 will be one of the CAD companies that continues to push the envelope. "You can learn extremely complicated things with a more interesting approach than the dry, boring technical approach. There's no reason you can't have fun and do something great."

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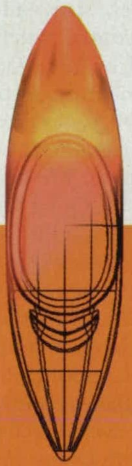

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NASA Tech Briefs Publisher Launches "Quick Quotes" to Connect Buyers and Sellers of Custom Manufacturing Services

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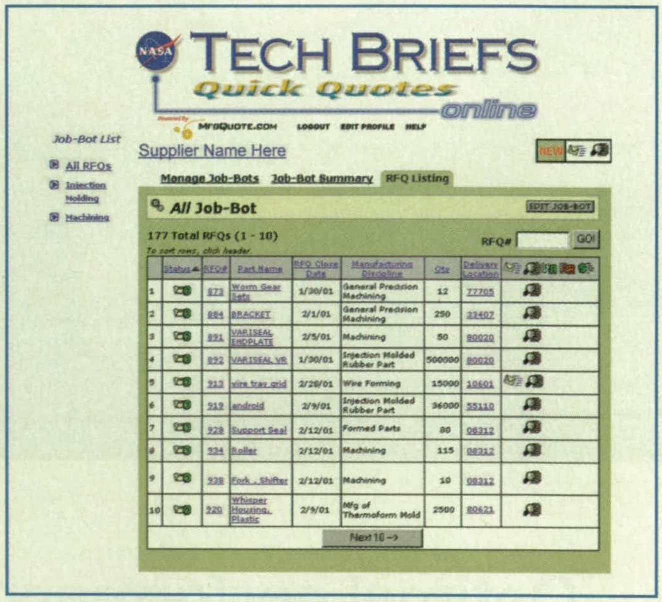
The mission of *NASA Tech Briefs* is to inform industry of opportunities, both business and technological, that can make their jobs easier, open doors to new commerce, and help solve engineering and manufacturing problems. As the world becomes smaller via the Internet, a vital eProcurement service — MfgQuote™ Marketplace — has been created to address the Request for Quote (RFQ) needs of the custom manufacturing sector. We are proud to announce an exciting new Web site called Quick Quotes (www.nasatech.com/quickquotes), which accesses the MfgQuote Marketplace developed by ManufacturingQuote, Inc. (Smyrna, GA), a leading eProcurement platform provider.

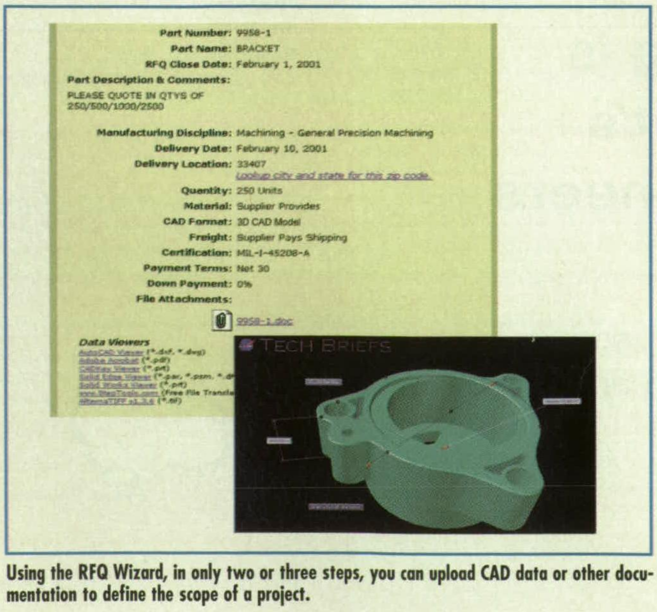
Quick Quotes links buyers and sellers of custom manufacturing services, such as CNC machining, molding, casting, or rapid prototyping. Members easily can post, receive, and manage RFQs using Quick Quotes to interact with vendors and suppliers. If buyers can't find an off-the-shelf part to fit their needs, they can use Quick Quotes to find a job shop to make a custom part.

Unlike other procurement Web sites that primarily offer, bid, or auction industrial hard goods and standard parts, Quick Quotes is a private negotiating channel for manufacturing services. In response to enormous user feedback, the MfgQuote Marketplace recently broadened its manufacturing segments to include over 100 custom manufacturing disciplines.

The MfgQuote Marketplace launched on February 14, 2000, and has attracted over 1,000 members — both buyers and suppliers — and received over $40 million in quotes for custom fabricated components. Buyer members are diverse and include Fortune 1000 companies such as Motorola, Whirlpool, BMW, Ingersoll-Rand, Parker Hannifin, Gardner Denver, Payload Systems, Dresser Industries, and Purolator. Unlike some other buyer/seller eMarketplaces, Quick Quotes does not charge a commission on jobs placed, but rather a flat membership based on level of selected services. Buyers can post RFQs absolutely free of charge.



Job-Bots™ automatically search for RFQs that meet a supplier's expertise and capacity.



Using the RFQ Wizard, in only two or three steps, you can upload CAD data or other documentation to define the scope of a project.

"Quick Quotes is the perfect venue for manufacturing companies with buying power to solicit a competitive deal with qualified job shops," stated Mitch Free, president of ManufacturingQuote, Inc. "Quick Quotes is easy to navigate with state-of-the-art security. Companies can post and search RFQs 24 hours a day. Our eMarketplace is a 'win-win' for both buyers and sellers looking to improve their bottom line and reduce the total bidding process from weeks to days."

Solution-Level Services

Quick Quotes allows buyers to conduct a confidential quoting process to procure the best value in cost and quality from participating suppliers. More than a matchmaking service, the Web site introduces sophisticated features for Collaborative Procurement Management (CPM) — online software toolsets designed to utilize the Internet to automate traditional offline procurement ac-

tivities. CPM technology was developed with the mid-sized and small manufacturers in mind.

The procurement process for custom parts relies on the accurate and timely communication of technical information. Dialogue between buyers and sellers typically involves the exchange of CAD data and technical specifications, as well as addressing business and logistical issues. Data incompatibilities and nonconformity to industry standards are common roadblocks that add time and cost to the bottom line. Collaborative Procurement Management not only matches buyers and sellers, but more importantly, it also automates interaction and facilitates shared business processes. CPM allows buyers and sellers to efficiently manage their relationships with one another.

Quick Quotes is simple to use. Companies buying manufacturing services post an RFQ by completing an online form and attaching a drawing. Suppliers who are Quick Quotes members can search for RFQs that meet their expertise and capacity at any time. To bid, they fill out an on-line quote submission form that is sent directly to the buyer. This process generates competitive quotes from manufacturers delivered via e-mail to potential customers.

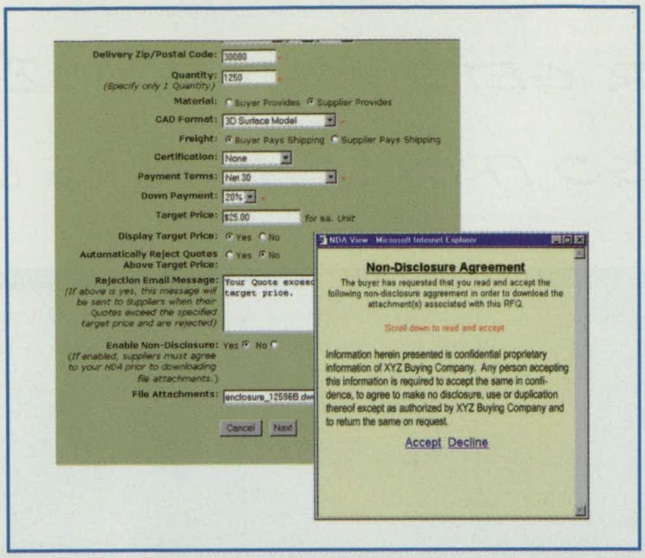
Buyers can manage RFQs as projects, make RFQs selectively available to certain vendors, specify RFQ target price, and utilize closed projects for historical analysis. Active projects contain valuable summary information in real time, including time-to-project completion, estimated project cost, variance to project budget, and RFQ-supplier activity for a particular project. By organizing RFQs in a project associated to a procurement activity, buyers and suppliers easily can sort and filter through an infinite number of RFQs by criteria such as RFQ status, activity, close date, and more.

Buyer members also can upload their company's non-disclosure agreement (NDA) as a part of their member profile, and enable the agreement when posting an RFQ. Once an NDA is enabled by the buyer, suppliers must read and accept the NDA before they can access the RFQ's file attachments. A red padlock illustrates that the file attachments are inaccessible until the NDA is accepted; once agreed to, the padlock turns green for full access.

For suppliers of manufacturing services, CPM delivers the tools to manage their business more efficiently, allowing them to manage outstanding quotations, reduce cyclical workloads, and increase profitability. Job shops or suppliers can employ Job-Bots™ to automatically search for RFQs that meet their expertise and capacity. Job-Bots are specific to machine tools, work cells, or specific processes on a supplier's shop floor, and automatically notify suppliers of RFQs meeting the Job-Bot criteria. Suppliers also can analyze "won vs. lost" quotes, obtain instant notification of accepted or rejected quotes, learn how their quote ranked against other quotes submitted, and directly communicate with potential customers worldwide.

This month, Quick Quotes will introduce new, advanced CPM features for all phases of eProcurement such as production monitoring and visual collaboration. Quick Quotes also will present a new system for dynamic rating of suppliers and buyers by combining quantitative and qualitative data.

How do engineers and manufacturers benefit from this type of service? Companies often are looking for additional manufacturers, especially when their usual contractors are booked with work. Engineers can post an RFQ with a fast turnaround as part of the criteria, and fish in a much larger pond of qualified



Buyers can post and manage RFQs using Quick Quote's Collaborative Procurement Management system. They can also upload their company's non-disclosure agreement (NDA) as part of their member profile.

suppliers. Another benefit for buyers is that they do not need to burden their company's computers with management, data, and history, since it resides on the Web site, not on the desktop.

Geography used to play a large role in the procurement of manufacturing services outside of the vendor's local area. But that factor has become obsolete, as shipping costs are nominal, and quotes have grown to be highly competitive. Buyer members in rural areas looking for CNC machining and other automated capabilities now can reach out beyond their backyard for job shops. Other buyers may be looking for global suppliers and find great shops in their locale.

Many small manufacturers are looking for new business opportunities, and new suppliers, and need help with procurement. The CPM technology gives them a totally customizable procurement management system and a way to accurately source work in less time. It also provides the purchasing department of any size manufacturer a way to streamline comparison shopping.

Suppliers performing custom manufacturing services often are dependent on a few customers and are limited by geographic boundaries. Many have cyclical workloads and are unable to focus on higher margins that could be realized from locating work that best matches their expertise, equipment, and capacity. Quick Quotes gives them "reach" and enables them to bid on jobs that are more closely aligned to their capabilities. Supplier CPM tools give them a viable solution to manage outstanding quotations.

Manufacturers are finding that the MfgQuote Marketplace fulfills an important niche. Supplier members strongly state that getting work done and keeping their machine tools in motion is far better than being on the road making sales calls. This eMarketplace gives them on-demand access to a global arena of business opportunities via the Quick Quotes Web service. We welcome you to visit www.nasatech.com/quickquotes and test-drive the service. The Web page is content-rich with information on all facets of the service. We are anxious to get feedback from our readers at quickquotes@nasatech.com.

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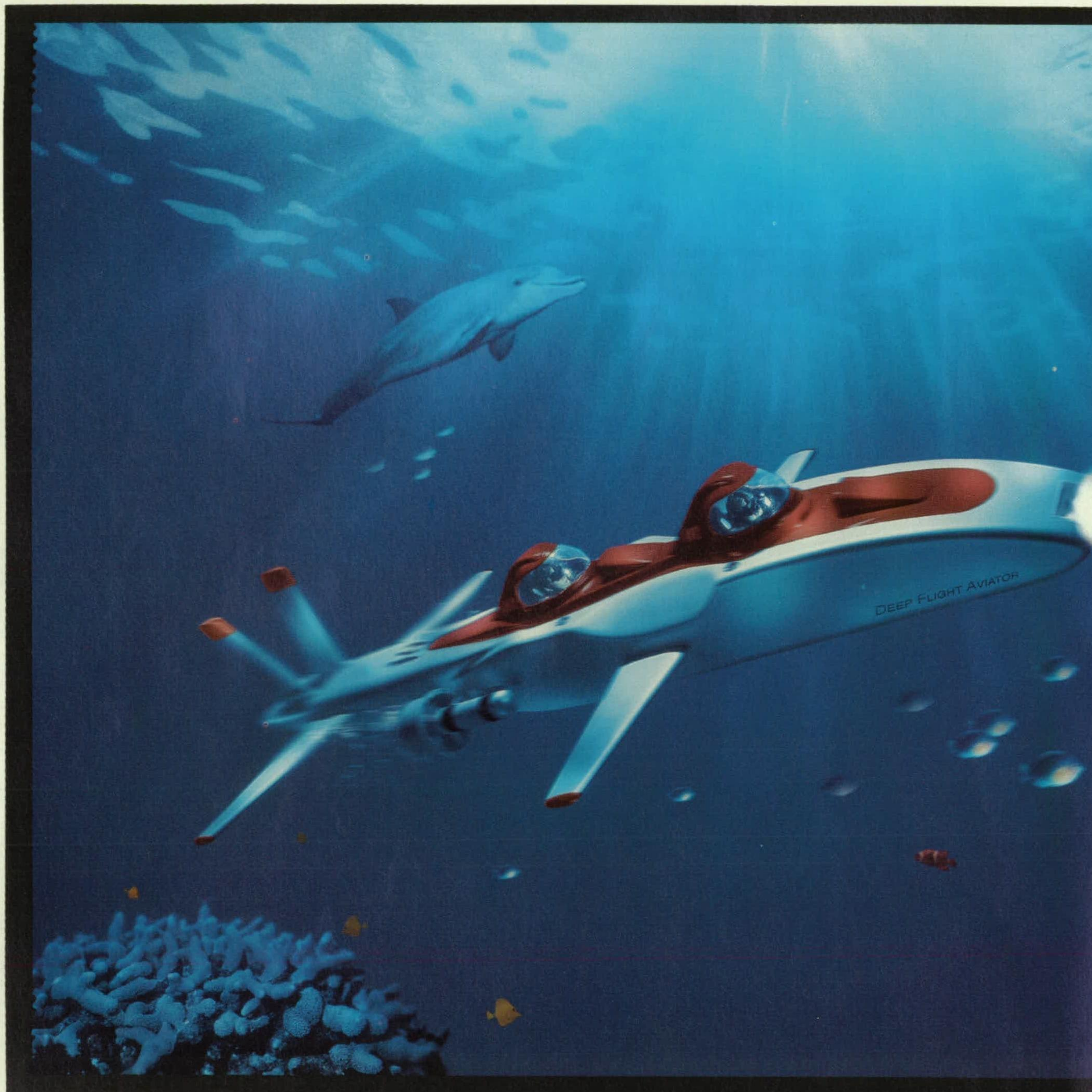


Deep Flight Aviator was invented and designed by Graham Hawkes of Hawkes Ocean Technologies using Autodesk Inventor software

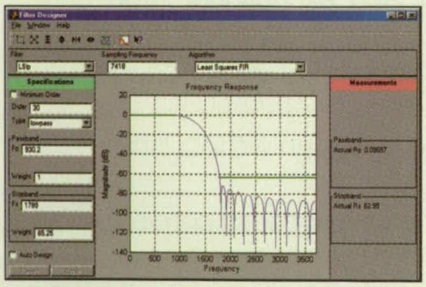
MATLAB 6: Evolutionary Improvements

Steven S. Ross

The MathWorks' new Release 12 of its numeric analysis and simulation tools offers a few new capabilities, more speed, and a spiffy new help system and interface — especially for users of Windows and certain UNIX boxes. The improvements are more evolutionary than revolutionary. But specific types of users will find a lot to make their lives easier, and everybody will find the many separate packages inside this release easier to use.

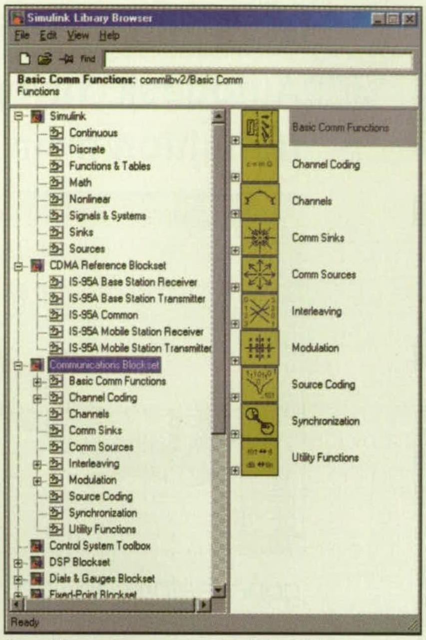
Changes in the flagship products, MATLAB 6 and Simulink 4, are (almost by definition) the most important. MATLAB — short for Matrix Laboratory — is designed to write programs that analyze data matrices, often with only a line or two of code. It comes with many functions and you can add a wide range of application-specific "toolboxes" devoted to areas such as statistics, signal processing and simulation.

Each toolbox is a collection of programs (calculators, if you will) that each handle a specific function. These programs are called M-files. You can combine them, modify them, or write your own. You can also compile them. The MATLAB compiler now has a Visual Studio add-in that allows the code to be integrated easily into Microsoft Visual C or C++ 5.x or 6.x. It works the other way as well — you can convert C and C++ code into MATLAB executables (so-called Mex files). There's a new interface for calling Java code (it comes with many Java "beans," or pre-built objects).



Interface to signal processing tool. You can play only portions of a signal. Note the toolbar to the left.

MATLAB's new versions always seem to add statistics features, and this one is no exception. There's a particularly powerful curvefitting and extrapolation routine. Succeeding versions also tend to get faster, and tend to have more intuitive commands for editing and annotating graphics. Again, this one is no exception. There's a new library for fast Fourier transforms, for instance. It promises more speed and higher accuracy. There are also more solvers for differential equations.



New library browser in Simulink. Clicking on any of the items in the list at left brings up symbols at right. Or, use the search window at the top of the screen to find what you need. The blocks get combined to form logic simulations in a finished model.

Simulink, the block-diagram modeling package for simulating and designing dynamic systems, also got a facelift and some new functionality. As with MATLAB, it is easier and faster to generate C code from within Simulink with the expanded add-on Real Time Workshop. It even has support for blocks that get data from a lookup table.

The new graphical debugger built into Simulink itself is especially nice. In fact, there are a host of other new features for supporting development of very large simulations — better code editing, toolbars, a "find" dialog box that lets you find a model's components more easily, easier handling of sub-assemblies, improved library and model browsers, and so forth. There's a separate new "model differencing tool" available in Simulink Performance Tools 1 (an add-on) that highlights the differences between two models and reports on execution of different pathways through a complex model.

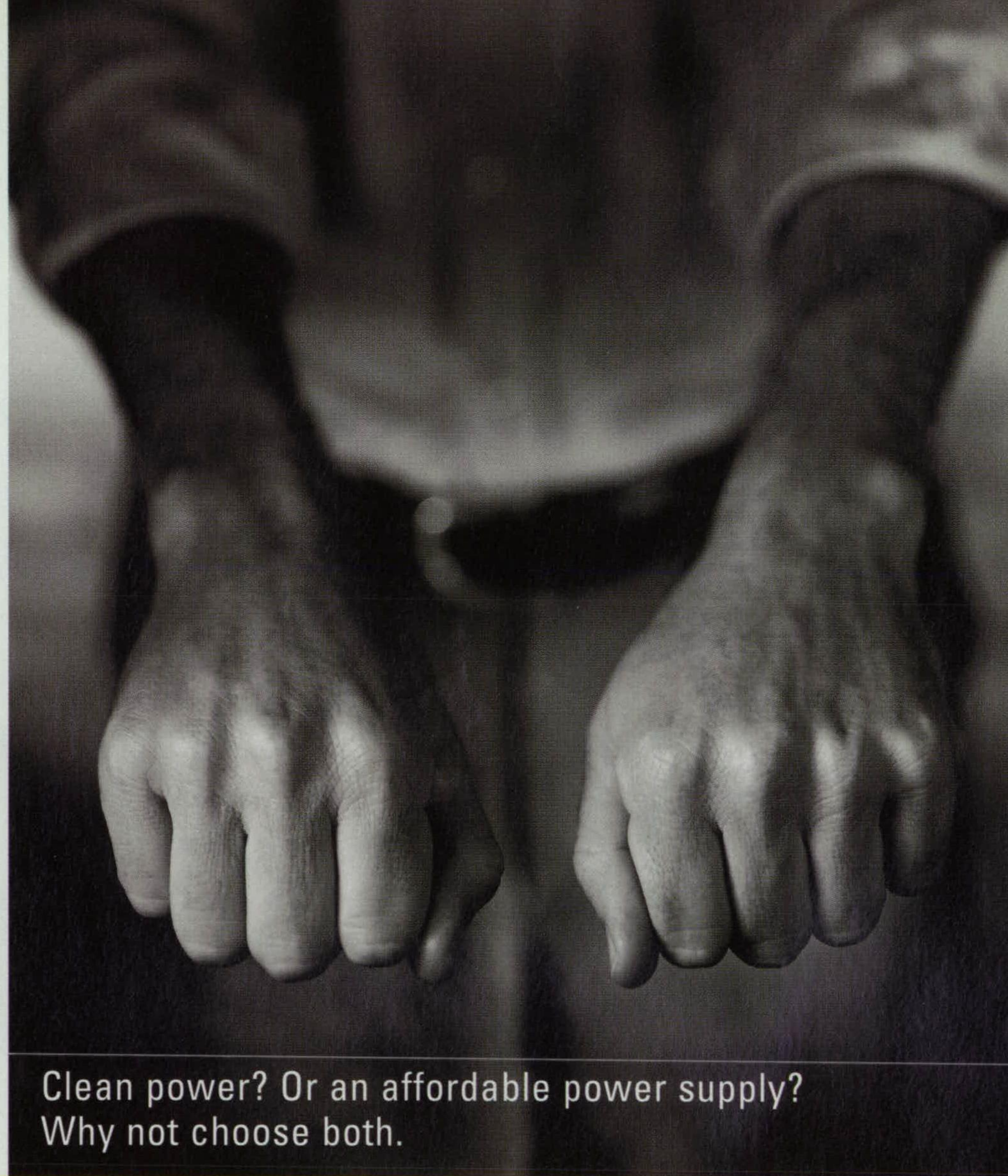
Those who need digital signal processing functionality will find much faster DSP routines. There's also a new filter design toolbox available, with much more functionality for designing digital filters.

The new, expanded Instrument Control toolbox expands interfaces between MATLAB and data acquisition devices, more in line with some of the products available from instrument makers themselves such as National Instruments. (MATLAB gained serial port control in this release, too.) Another add-on, Data Acquisition Toolbox 2, controls a wide variety of external hardware devices; it added ComputerBoards support in this release.

In Windows, a minimum of 128 MB of RAM is preferred, although we ran most modules comfortably in 64 MB. Files for any typical installation are not huge, but a complete installation of everything in Release 12, including documentation files, took 550 MB. Expect to use 50 to100 MB of disk space, typically.

US list prices for MATLAB 6 start at $1,900 for an individual PC license; Simulink starts at $2,800. Add-on products range from $200 to $7,500. The initial purchase price includes Subscription Service, which provides product updates and technical support for the first 12 months. Contact The MathWorks, Natick, MA; Tel: 508-647-7000; Fax: 508-647-7001; www.mathworks.com.

Steve Ross is an associate professor in journalism at Columbia University, where he runs the science writing program and teaches analytical journalism. His 18 books and three commercial software packages include several on statistics and quality control. His undergraduate degree is in physics.



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For More Information Circle No. 529

Application Briefs

New Millennium Craft to Verify Key Technologies

Earth Observing-1 spacecraft
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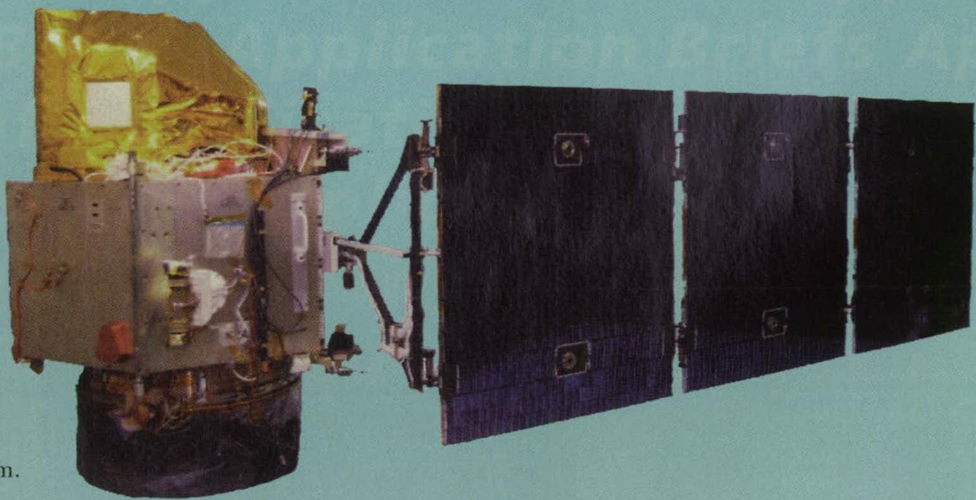
301-595-5500
www.swales.com

NASA's New Millennium Program seeks to make space exploration more affordable by developing advanced technology and testing it during spaceflight. The first Earth-observing mission of the program is the Earth Observing-1 (EO-1) spacecraft, which will demonstrate new remote sensing, spacecraft, and operations technologies. Swales Aerospace designed and fabricated the spacecraft, developed hardware, and performed instrument integration. They also fabricated or procured the structural/mechanical subsystem, propulsion system, harness, attitude control system, solar array, and data handling subsystem.



EO-1's main instrument, the Advanced Land Imager, was built by MIT's Lincoln Lab and was integrated into the spacecraft bus by Swales at NASA's Goddard Space Flight Center in Greenbelt, MD. Swales' spacecraft bus features an S-Band uplink and telemetry downlink, 50 Ah super NiCad battery, and a 1773 data bus.

Swales also manages the ground operations at the launch site and the launch vehicle interface. The company's engineers worked on-site with subcontractors in integrated teams to facilitate spacecraft component development.

For More Information Circle No. 750

Components Help Power International Space Station

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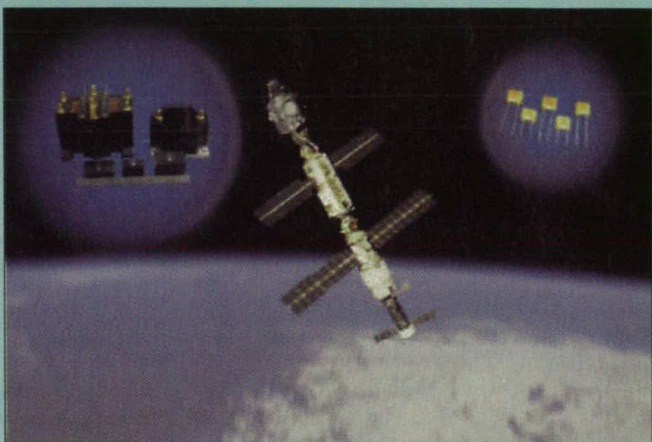
Switch mode power supply capacitors and radial leaded capacitors are playing a role in providing vital services such as power conversion and distribution, air conditioning, and air quality on the International Space Station (ISS). The capacitors are used in the main power supply conversion system that adapts power from the solar panels. When complete, the ISS solar arrays will supply 60 times more power than those on the Mir space station.

In the inhabited areas of the ISS, SMPS capacitors are used in the air conditioning and air quality equipment, and are found in the robotic arm of the Space Shuttle that will be used in the continuing construction of the ISS.



The SV capacitors feature an internal design that minimizes electrical stress and partial discharge activity within the dielectric, resulting in a reliable device for high-voltage circuits. The SMPS capacitors have been used in military and commercial satellite programs.

For More Information Circle No. 751

Commercialization Opportunities

Measuring Contact Angles of a Sessile Drop and Imaging Convection Within It

An apparatus has been developed that simultaneously and synchronously records magnified images of a sessile drop. Such a study of the spreading of drops can contribute to understanding of coating, film cooling, lubrication, boiling, and spreading of biological cells, among others.
(See page 50.)

Improved Encryption-Mode GPS Receiver

An improved GPS receiver processes an encrypted P-code signal without knowledge of the encryption code. The improved design signal-to-noise ratios are greater than in prior GPS receivers, especially when GPS satellites are at low elevation angles.
(See page 54.)

Metal-Supported Catalyst Beds for Reacting CO_2 With CH_4

In the proposed application, these catalyst beds would be used on Mars to produce hydrogen as a rocket propellant or as fuel for fuel cells. On Earth, such beds would be applicable to steam reformers and other catalytic reactors to produce fuels and other specialty chemicals.
(See page 64.)

Chemical Reactors Based on Catalyzed Wires

The basic concept of these reactors allows for adaptation to numerous variations, which could be as simple as a straight tube containing a catalyst-coated wire suspended on the cylindrical axis.
(See page 64.)

Thrust-Control System for Emergency Control of an Airplane

This system relieves the pilot of the longitudinal-control task, enabling the pilot to keep the wings level for landing. The system was flight tested on an MD-11 airplane.
(See page 68.)

Weld Repair of a Directionally Solidified Superalloy Article

This technique for repair of a directionally solidified nickel-base superalloy also forms a directionally solidified microstructure similar to that of the original material. The technique can be used on turbine blades or vanes.
(See page 72.)

Field-Reversed Magnetic Mirrors for Confinement of Plasmas

The proposed configuration is intended to increase the degree of confinement achievable by a magnetic mirror. The magnetic flux density needed would be reduced.
(See page 74.)

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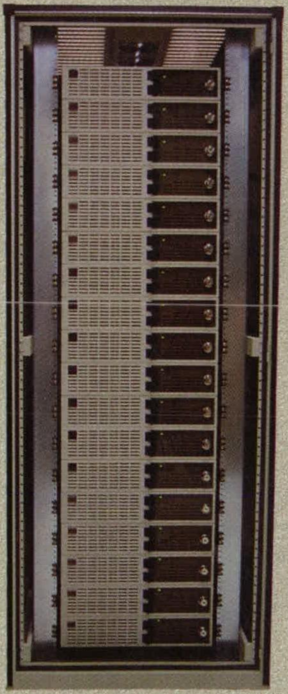

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> — Bruce Faust, founder of DigitalScape and Carrera Computers

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Data Acquisition Boards: A Guide to Time and Frequency Domain Measurements

The bewildering array of data acquisition specifications given by various manufacturers can confuse even the most experienced engineers. This article examines the most important specifications for time-domain and frequency-domain measurements. Determining which specifications are most important depends on the type of information that is being collected. If the most important information is the voltage level being acquired, or the characteristics related to the shape of a waveform, then you are interested in time-domain measurements. If the important information is the frequency content of the signal, then you are interested in frequency-domain measurements (Figure 1).

Different products are optimized for different types of measurements, and the specifications given for those products reflect this difference. Most multiplexed data acquisition boards are optimized for time-domain measurements, so their specifications typically focus on allowing the user to determine the absolute accuracy of a voltage measurement. Dynamic Signal Acquisition (DSA) boards are optimized for frequency domain measurements, and their specifications typically focus on attributes like dynamic range and total harmonic distortion. However, since data acquisition boards are general-purpose instruments, they often are used to make frequency domain measurements. For that reason, it is also important to evaluate the dynamic specifications of a data acquisition (DAQ) board.

Before discussing various specifications, we should understand the architecture of a typical data acquisition board and where various errors and uncertainties are introduced. Figure 2 is a high-level diagram of a typical multiplexed data acquisition device. The signals to be measured are connected to the multiplexer (MUX). The MUX routes the signals into the programmable gain instrumentation amplifier (PGIA), which is responsible for delivering the measured signals to the ADC. The multiplexer, PGIA, and other circuitry that condition and route the input signals to the ADC are known together as the analog front-end. The ADC digitizes these signals, and then passes the digitized value back to the computer, by way of the FIFO and bus controller.

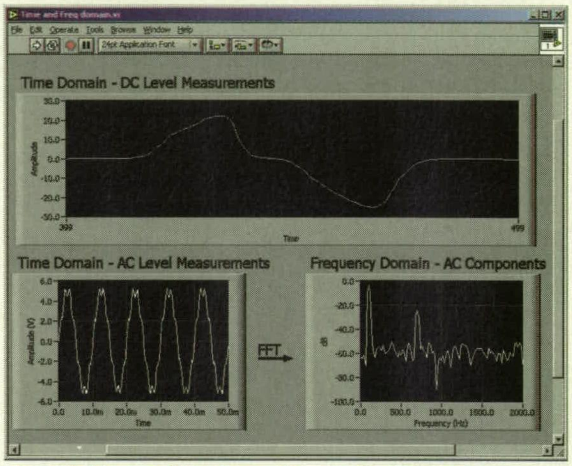


Figure 1: Time- and Frequency-Domain Measurements

Ideally, any measurement by a DAQ device would be converted immediately into digital data and transferred to the computer with no loss or modification of the signal. However, the components used in measurement devices are not ideal, and these components introduce various inaccuracies into the signal path. Typically, these errors consist of settling time errors due to the MUX and the PGIA switching between various signals, gain and offset errors introduced by the PGIA, and digitization errors introduced by the ADC. System noise is introduced in all parts of the analog signal path and it also adds to the uncertainty of the measurement. The total error of your measurement depends on the sum of these errors.

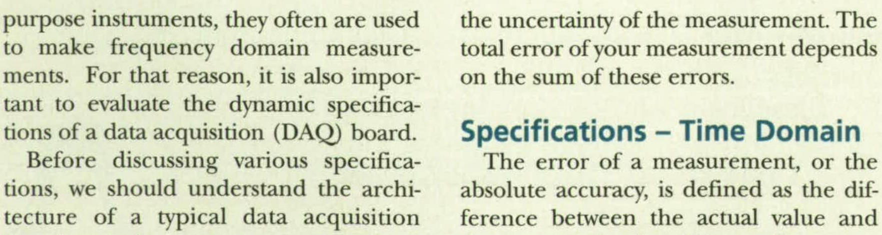


Figure 2 - Block diagram of DAQ board

Specifications – Time Domain

The error of a measurement, or the absolute accuracy, is defined as the difference between the actual value and the measured value. When taking measurements with DAQ boards or other computer-based measurement devices, the real-world analog value (voltage) is converted into digital codes by the ADC. The device's transfer function defines the conversion from voltage to digital codes. In general, as the input voltage to the device is increased, the ADC output codes should increase linearly. Any deviation from this stair-step "voltage vs. code" response results in inaccurate measurements. Noise in the device also can cause inaccuracy, which results in a converted signal that is composed of the original measurement plus some error. Finally, for the multiplexed architecture, you need to consider device-settling time when determining an accurate measurement. Because the PGIA and ADC are shared between multiple channels, there must be appropriate time for the inputs to settle to the correct value before the ADC converts the measurement. If the signal has not settled to its actual value, an incorrect reading is converted and returned by the device. Understanding the sources of these inaccuracies is an important step in determining if the device meets your measurement needs.

Absolute Accuracy

While it is important to understand how individual components contribute to the error, you must combine all of these effects to understand the overall, or absolute accuracy, of the device. The absolute accuracy of a computer-based measurement device is the maximum difference between the measured value returned by the device and the true value applied to the input. Ideally, a manufacturer provides absolute accuracy information for each of the input ranges and modes that the device can handle. By choosing the appropriate

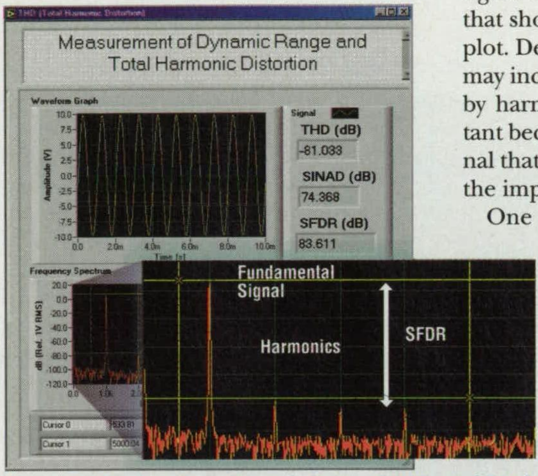


Figure 3. Spurious Free Dynamic Range, SINAD, and Total Harmonic Distortion Measurements.

input range for your signal, it becomes easy to calculate the absolute accuracy of your measurement. The absolute accuracy table that is given with a properly specified computer-based measurement device makes computing the total accuracy of your time-domain measurements a simple calculation.

Frequency Domain

The absolute accuracy specifications are ideal for determining the accuracy of your time-domain measurements. However, measurement devices that are optimized for frequency domain measurements, such as dynamic signal acquisition (DSA) boards, are designed with a different set of features, such as anti-aliasing filters, dynamic range, low noise, and low distortion. These features require a different set of specifications than time domain measurements. We will briefly discuss some of the more important specifications: dynamic range and distortion. These specifications typically are not given for general-purpose data acquisition boards, but we will show how these specifications can be evaluated.

Dynamic range is the frequency domain counterpart of resolution in the time domain. This is one of the most important specifications given for devices that are designed for frequency domain measurements, and it is typically expressed in dB. Dynamic range is defined as the ratio of the largest signal level a digitizer can handle to the smallest signal level it can detect. The smallest signal level usually is taken to be the system noise level. The spurious free dynamic range (SFDR) is the ratio of the largest signal level to the highest noise "spur" that shows up in the frequency spectrum plot. Depending on the definition, SFDR may include or exclude spurs introduced by harmonic distortion. SFDR is important because it represents the smallest signal that can be distinguished clearly from the imperfections of the digitizer.

One way to measure spurious free dynamic range is to input a pure sine wave signal into a digitizer and take a Fast Fourier Transform (FFT) of the digitized waveform (Figure 3). The specifications of the function generator should exceed the specifications of the digitizer; otherwise, it is impossible to tell if you are measuring the imperfections of the source or the digitizer. The power spectrum plot in Figure 3 shows the peak for the signal, at about 6 dB, and highest spur in the signal. The highest spur in this case is a harmonic that shows up at about -78 dB. The spurious free dynamic range is the difference between the peak and the highest spur in the signal. In the 16-bit DAQ board case illustrated in Figure 3, the spurious free dynamic range is approximately 84 dB.

When a signal is digitized and converted into frequency domain, components show up in the frequency spectrum that are not part of the original input signal. This effect is known as distortion. The majority of distortion effects show up at integer multiples of the frequency of the input signal (harmonics). Total harmonic distortion (THD) is measured by inputting a pure sine wave into the device and performing an FFT. If there were no distortion, the only data showing up in the frequency spectrum plot would be the spike at the frequency of the input sine wave and the system noise. However, if the input sine wave is distorted as it passes through the analog front end and ADC of the measurement device, the distortion will show up in the frequency spectrum as harmonics.

The THD measurement is made by adding up the size of the harmonics that appear. The ratio of the RMS sum of the harmonics to the signal is the THD. This usually is expressed in dB or percent. Figure 3 shows an example of a THD measurement. A software routine computes the THD based on the digitized input signal. Although there is not a direct relationship, the THD of a measurement device is strongly coupled to the linearity. If a device has poor dynamic nonlinearity, integral nonlinearity, or relative accuracy, it also will have poor THD.

Often, users are interested in a specification that includes the combined effects of distortion and noise. Total harmonic distortion plus noise (THD+N) is the RMS sum of all the harmonics, plus the noise in the signal. THD+N also may be expressed as the signal-to-noise and distortion ratio (SINAD), or effective number of bits (ENOB). THD+N, SINAD, or ENOB easily can be calculated by software routines, once an input signal is acquired.

All of the frequency-domain specifications mentioned (SFDR, THD, SINAD) can vary depending on the sampling rate, input voltage range, and input frequency. Good specifications from the vendor should include a range of conditions under which the specifications are valid.

Determining the important specifications for your measurement application depends on whether you are interested in time domain or frequency domain measurements. Time domain measurements require accurate measurements of the level and shape of the waveform. Your measurement accuracy is determined by how well the voltage measurements returned by the data acquisition device reflect the input signal. The most important specification that describes this uncertainty is the absolute accuracy. Ideally, the device vendor should supply a table of absolute accuracy specifications.

If your measurement application requires frequency domain measurements, you must look at a different set of specifications. Some of the important frequency domain specifications include spurious free dynamic range and total harmonic distortion ratio.

When evaluating different data acquisition devices, it is critical to carefully examine the specifications provided by the manufacturer. They must supply you with enough information to reliably determine the overall uncertainty of your measurements.

For more information, contact the authors of this article: Tom Magruder, Data Acquisition Product Manager; and Paul Packebush, Manager, Sustaining Engineering Group, National Instruments, Austin, TX; Tel: 512-794-0100; www.ni.com.

Partial Subtractive Dither for Lossy Data Compression

A new technique provides a compromise between benefits and costs of standard subtractive dither.

NASA's Jet Propulsion Laboratory, Pasadena, California

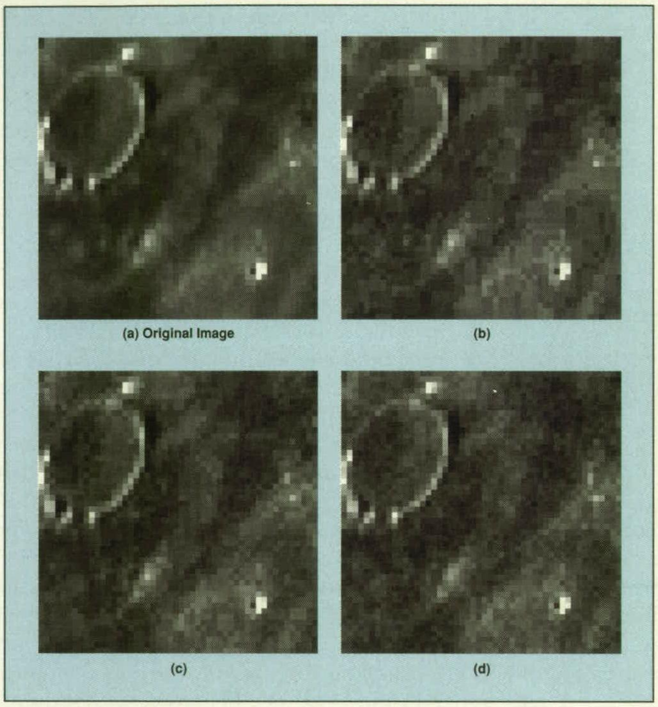
A technique of partial subtractive dither has been developed to improve the performance of any of a variety of near-lossless data-compression algorithms. The technique may be applicable to compression of scientific and medical image data.

To those skilled in the art of data compression, the use of subtractive dither to reduce the undesired quantization artifacts produced by lossy data-compression algorithms is well known. These artifacts include (1) biased average signal values in some regions of a signal, (2) steplike signal-value profiles in slowly changing portions of the signal, and (3) erasure of faint features that, if they occupied a sufficiently large area, would be detectable in the original signal.

The type of subtractive dither used heretofore, called "standard subtractive dither," involves a dither distribution that is uniform over a range equal to the quantization step size of the algorithm to which it is applied. Standard subtractive dither incurs costs in the form of an increase in rate (in other words, a reduction in compression) and an increase in distortion.

In the present technique of partial subtractive dither, the dither distribution is uniform over a range smaller than the quantization step size. The choice of a uniform distribution is motivated by a desire to optimally compromise between the benefit (reduction in quantization artifacts) and the costs (increases in rate and distortion) of standard subtractive dither. Under some reasonable assumptions, the dither distribution should be chosen to be uniform, with its range chosen according to the degree of dithering desired.

The figure shows the effects of compression followed by decompression of an image. As the degree of dithering increases from zero (no dither) through partial to standard, the appearance of streaks and artificial regions of constant intensity decreases, while the overall grainy appearance increases.



The **Original Image Was Compressed** with different degrees of subtractive dither, then decompressed. As dither increases, as shown in (b), (c), and (d), respectively, quantization artifacts are reduced, while graininess is increased.

This work was done by Matthew Klimesh 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 Information Sciences category.*

NPO-20964

Acquisition, Tracking, and Pointing in Optical Communication

NASA's Jet Propulsion Laboratory, Pasadena, California

A document in the form of lecture slides outlines a program of development of capabilities for acquisition of signals, tracking of signal sources, and pointing of transmitters and receivers in deep-space optical communications. Topics addressed on the first few slides include the benefits and challenges of optical communications and the historical and organizational background of continuing development efforts. Most of the remaining slides address selected technical aspects of acquisition, tracking and pointing (ATP) in various levels of detail; these aspects include basic principles of operation, beam-pointing requirements, sources of tracking and pointing errors, alternative approaches to tracking and pointing, concepts for the design and operation of ATP systems, and key technological developments that are necessary for attaining required levels of ATP performance. The last slide summarizes the major technical challenges; these include the difficulty of pointing the necessarily narrow transmitted laser beams, the need to suppress spacecraft vibrations in beam-pointing equipment, the need for bright beacons, and interference by scattered sunlight.

This work was done by Shinhak Lee, James W. Alexander, and Gerardo G. Ortiz of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the document, "Deep Space Acquisition, Tracking, Pointing (ATP) Technologies for Optical Communication," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*

NPO-20889

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For More Information Circle No. 553

Software for Preprocessing of Raw SAR Data

NASA's Jet Propulsion Laboratory, Pasadena, California

The SAR Processing System Raw Data Processor (SPS RDS) computer program is used in the Alaska SAR Facility (ASF) to scan and decode raw data that have been downlinked from the European Remote Sensing Satellite (ERS), the Japanese Earth Resources Satellite (JERS), and the RADARSAT (a Canadian Earth-observation satellite) and recorded on high-density digital tape or disk. ["SAR" means "synthetic-aperture radar."] In its scanning role, the program reads a recorded downlink bit stream, performs PRN decoding as needed, extracts auxiliary information to identify data-acquisition times, correlates this information with spacecraft state vector information to determine locations, and maps the locations to predefined fixed frames along an orbit track. These frames are stored in an archive as they become available, and are subsequently interrogated when requests for generation of image products are received. In its decoding role, this program converts a downlink bit stream that pertains to a requested frame into files that contain decoded engineering and SAR signal data that are compatible with the computers and programs used in further processing of SAR data into final image and image data products.

This program was written by Eugene Chu and Tuan Truong 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 Information Sciences category.*

This software is available for commercial licensing. Please contact Don Hart of the California Institute of Technology at (818) 393-3425. Refer to NPO-20711.

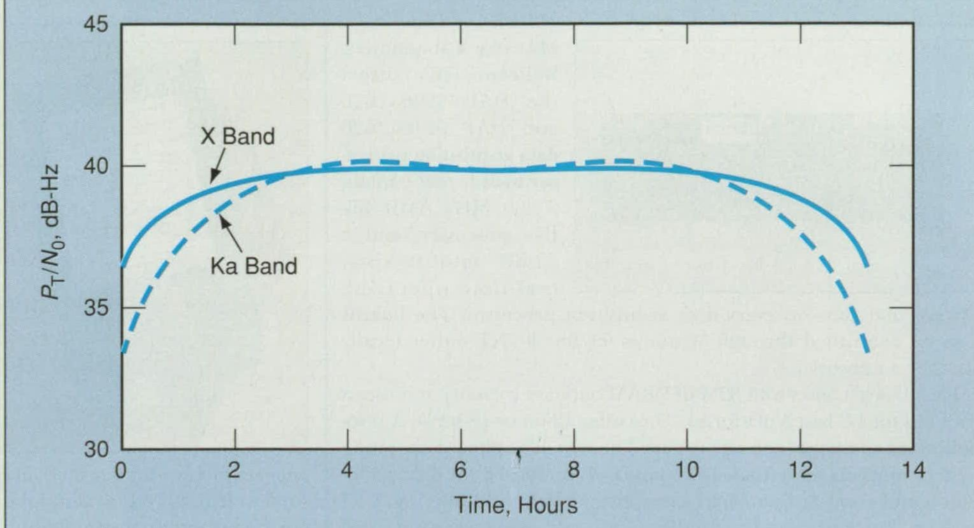
Variable Telemetry Playback Rate for Increased Data Return

The rate is adjusted nearly continuously according to a predicted signal-to-noise ratio.

NASA's Jet Propulsion Laboratory, Pasadena, California

In a scheme to increase the overall data return from a phase-modulation, suppressed-carrier telemetry transmitter, the telemetry playback symbol rate is adjusted essentially continuously. More precisely, the playback symbol rate is adjusted frequently (as often as once per symbol period) in small increments. The adjustment of the rate is made in accordance with the principle that the supportable data rate at any given instant is a function of the instantaneous total signal-power-to-noise spectral-density ratio (P_T/N_0) at the receiver. The scheme was devised for transmission of telemetric data from deep-space missions, but could also be applied to satellites in orbit around the Earth.

P_T/N_0 is a known function of the receiving-station gain-to-noise-temperature ratio (G/T), which, in turn, is a known function of the position of the transmitter relative to that of the receiver. Thus, once the trajectory of the transmitter relative to the receiver position has been predicted, then G/T or P_T/N_0 as a function of time can be estimated (see figure); this estimate can be computed aboard the spacecraft or uploaded to the spacecraft prior to a portion of a trajectory (a tracking pass) and the corresponding interval of time during which the telemetry signal is expected to be received. Then during the tracking pass, the playback symbol rate at the transmitter is adjusted in accordance with the predicted G/T.



This **Example of P_T/N_0 as a Function of Time** was computed for a representative case of a distant spacecraft at 25° declination, tracked by a Deep Space Network receiver at Goldstone, California.

Traditionally, the telemetry symbol rate (equivalently, the telemetry data rate) for a deep-space mission is either fixed or is changed only a few times during a pass. A change in the data rate often entails a large, instantaneous jump, which can sometimes cause the ground receiving system to lose symbol lock. Upon losing lock, the receiver begins to lose some or all of the incoming telemetry data and must go through a signal reacquisition process in order to regain lock. The time lost in reacquisition could be large enough to nullify any advantage gained by changing the data rate. Although there are ways to minimize the probability of losing receiver lock during data-rate changes, they are operationally complicated and often require very precise predictions of the times when the rate changes will take place.

In the present scheme, a precise prediction of the instantaneous data rate is not needed. [However, coarse data-rate predictions are needed for initial acquisition and for reacquisition after mode changes (not to be confused with rate changes).] In this scheme, the symbol clock in the transmitter has a continuous phase; in other words, even when the clock frequency changes abruptly, the clock phase remains continuous. Because of the continuity of phase and the smallness of the clock-frequency increments, the symbol-tracking loop in the receiver is subjected to only small transient phase errors that do not cause it to lose lock.

Experiments and computational simulations for some typical cases have shown that a receiver can, indeed, track the small frequent rate changes and that the telemetry returns achievable by use of this scheme exceed, by 1 to 2 dB, those achievable by use of the best-single-rate scheme.

This work was done by Miles K. Sue, Jeff B. Berner, Selahattin Kayalar, and Henry Hotz of Caltech; Peter Kinman of Case Western Reserve University; and Harry Tan of Q-Plus 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-21024

Software for Locating Heterogeneous Data in Different Places

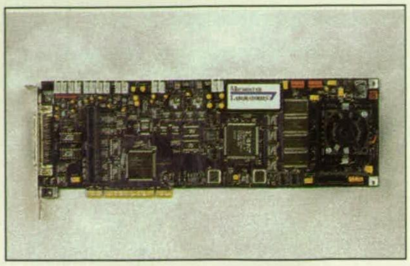
NASA's Jet Propulsion Laboratory, Pasadena, California

The Object Oriented Data Technology group at NASA's Jet Propulsion Laboratory is developing software for locating data — especially scientific data — stored in various formats on heterogeneous computer systems at different locations. The software is intended to exploit and extend advances in Internet software and in distributed object-oriented software to overcome the technological obstacles to integration of heterogeneous computing environments. The approach taken in this development involves refocusing effort on the development of metadata, which would be used to describe the available data resources and to support interoperability of computing systems. The software would manage a hierarchical conglomerate of data-set-resource definitions that would make it possible for application programs to locate the data that they require, without advance knowledge of which computer data systems and catalogs to search. This software would utilize the Extensible Markup Language (XML) and the Common Object Request Broker Architecture (CORBA) to support for interchange of data among heterogeneous sources. CORBA would enable over-the-wire exchange of XML-based profiles that would contain descriptions of data stored in remote computer systems.

This program was written by Daniel Crichton, John Hughes, Sean Kelly, and Jason Hyon 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 Information Sciences category.*

NPO-21045

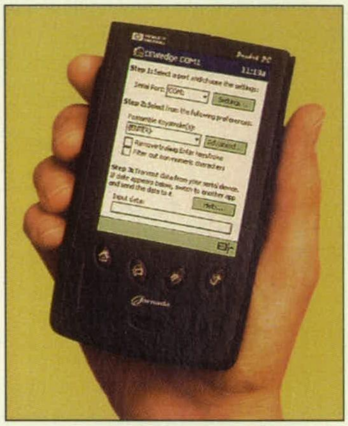
Special Coverage: Data Acquisition



Microstar Laboratories, Bellevue, WA, offers the DAP 5200a/626 and DAP 5216a/626 **data acquisition processor boards** that contain a 400 MHz AMD K6-III+ processor, and a 32-bit multitasking, real-time operating system that runs on every data acquisition processor. The boards can be controlled through Windows 95/98/00/NT either locally or over a network.

Each board comes with 32M of DRAM onboard memory and uses a PCI bus for PC-based platforms. They offer 12-bit or 16-bit D/A resolution for additional analog outputs. The system's onboard operating system supports more than 100 commands optimized for data acquisition and control. Command categories include DSP filtering, DSP spectral analysis, sensor conditioning, software triggering, and process control.

For More Information Circle No. 703



CE-Wedge **serial data acquisition software** from TAL Technologies, Philadelphia, PA, is designed for interfacing serial devices such as bar code scanners, calipers, micrometers, scales, and other devices, to any Windows CE program. Real-time serial data can be input directly into Pocket Excel, Pocket Word, or other Windows CE programs.

The software features a one-screen, one-minute set-up and converts incoming serial data to keystrokes so it appears in CE programs just like typed data. It adds additional keystrokes, if required, to serial data to automate data entry, and supports date and time stamping of data. The software features support for COM ports 1 to 4.

For More Information Circle No. 705

Veriteq, Richmond, BC, Canada, has released the Spectrum SP-1700-N series **thermocouple data loggers** that feature a 4-microvolt input resolution that can monitor temperature environments from -220 to +240°C. They are available in three models: the SP-1700-20N with a single thermocouple input, the SP-1700-30N with two thermocouple probe connections, and the SP-1700-50N with four thermocouple inputs.

All models have an input signal range of -7.2 to 8.8 millivolts. The miniature, standalone devices are designed for in-field recording of type J, K, S, T, E, and R thermocouple temperature probes. The units feature an integral battery and non-volatile memory, and are resistant to electrical interference and physical shock and vibration. Applications include diagnosis, verification, and documentation of systems, equipment, and processes.

For More Information Circle No. 701

Intelligent Instrumentation, Tucson, AZ, offers the LANpoint CE™ Windows CE **data collection computers** with NEMA-4/IP66 cases. They include a 1/2 VGA display and autoID technologies integrated into an open-architecture terminal. Also included are Web-enabled system administration tools, software programmability, and installation and accessory options.

The computers feature a built-in 10/100BaseT Ethernet adapter or IEEE 802.11 wireless Ethernet interface, and bar code decoding. Two COM ports are standard, and an optional digital I/O module provides eight opto-isolated digital inputs and eight digital relay outputs. One PCMCIA slot and integral connectors are included for adding a third-party external keyboard, mouse, or VGA monitor.

For More Information Circle No. 700

The CompuScope 14100 single-slot **data acquisition card** from Gage Applied, Lachine, QE, Canada, is an A/D and scope card for the PCI bus featuring 14-bit vertical resolution, capable of a 100 MS/s digitization rate. The card features 50 MHz bandwidth with over 70 dB dynamic range and 63 dB signal to noise ratio. It offers up to one billion samples of onboard memory.

Using Bus Mastering, data can be transferred from onboard memory to the PC's memory at rates up to 100 MB/s. Combined with GageScope for Windows software, the card can act as a digital oscilloscope, an FFT analyzer, a transient recorder, or a waveform analyzer. Applications include disk drive testing, wireless signal recording, ultrasound, imaging, RADAR, CCD testing, and RF receivers.

For More Information Circle No. 704

The Microlog CMVA 60 Version 3.81 **data collector/analyzer** from SKF, San Diego, CA, provides improved self-test capabilities, automatic triaxial data collection via a new Triax accelerometer, and new firmware with a Configuration Wizard™ feature. The Wizard allows users to store up to six user-defined preset application configurations. A saved configuration can be selected from a pull-down menu.

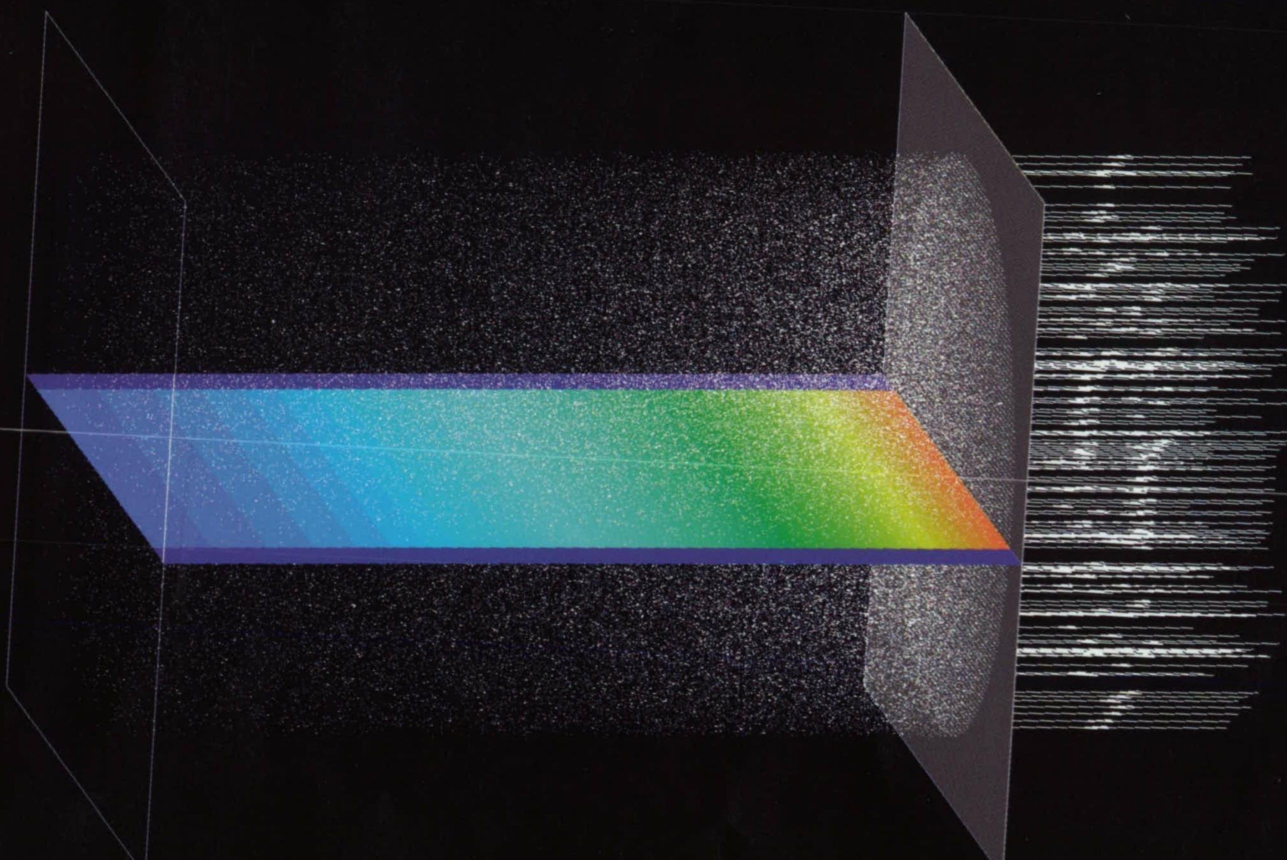
The Triax accelerometer is used in combination with the company's Stud Adapter and the MARLIN QuickConnect™ stud for automatic measurement of triaxial data, and is used in route-based applications where large volumes of data are collected. The studs are permanently located on the machine, eliminating the need to position the sensor for each measurement.

For More Information Circle No. 702

March 200

PHOTONICS Tech Briefs

PHOTONICS SOLUTIONS FOR THE DESIGN ENGINEER



Telecom Embraces Raman Fiber Lasers

New Products—*see page 24a*

www.ptbmagazine.com

PHOTONICS Tech Briefs

Supplement to *NASA Tech Briefs'* March 2001 Issue Published by Associated Business Publications

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Departments

***On the cover:** Breault Research Organization's ASAP 7.0 optical modeling software has added features, such as volumetric energy tracking. Cover photo courtesy Breault Research Organization.*

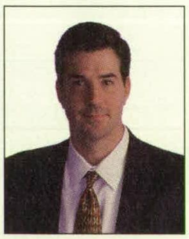
Photonics Tech Briefs 2000 Readers' Choice Product of the Year

Each issue of *Photonics Tech Briefs* in the year 2000 carried a Product of the Month, a photonics product the editors felt was of special interest and value to readers who work with lasers, optics, fiber optics, and video and imaging equipment. Winners were chosen by reader vote on *Photonics Tech Briefs'* web site from among the six Products of the Month. The 2000 winners were:

- **Gold Winner and Product of the Year:** PerkinElmer Optoelectronics (Santa Clara, CA) RID 1640 AF1/AL1 monolithic x-ray camera;
- **Silver Winner:** Burleigh (Fishers, NY) Gemini surface topography system; and
- **Bronze Winner:** Coherent Semiconductor Group (Santa Clara, CA) F-Package fiber-coupled laser diode system.

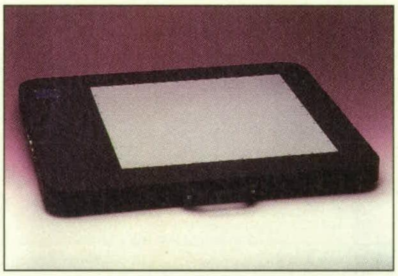
PerkinElmer Optoelectronics RID 1640 AF1/AL1 Monolithic X-Ray Camera

PerkinElmer describes its RID 1640 AF1/AL1 digital x-ray camera as the industry's first to offer a monolithic active detector area equal in size to conventional x-ray film. The company says that the 41-by-41-cm detector, coupled with its megapixel spatial resolution and 65,000 greyscale detectivity, produces images impossible to achieve using x-ray film. Because the camera is only 5 cm thick and less than 20 cm larger than the detector, the camera is easily transported. With a complete image available for viewing in less than half a second, the user can determine if the captured image is the desired one, and if not, take any number of others without having to once again pose the subject. The electronic capture is Internet-compatible, and compatible with all image analysis software and all PCs.



John Engel, President, PerkinElmer Optoelectronics

PerkinElmer Inc. is a $1.7-billion high technology company operating in four businesses: optoelectronics, life sciences, instruments, and fluid sciences. The company has operations in 125 countries, and is a component of the Standard and Poor 500 Index. Optoelectronics consists of three strategic business enterprises: lighting, imaging, and telecom. Optoelectronics employs approximately 5800 people in the United States, Europe, Canada, and Asia. Revenues in 2000 were $497 million. The RID 1640 AF1/AL1's amorphous silicon detector panel is produced in Optoelectronics' 80,000-square-foot headquarters facility in Santa Clara.



PerkinElmer Optoelectronics monolithic x-ray camera

Optoelectronics is a world-class provider of components for the telecom industry with expertise in optical semiconductors, micro-optic component integration, and high-volume manufacturing. The company offers customer solutions incorporating its xenon, mercury, metal halide, and fluorescent lighting technologies. Applications range from fiber optic illumination to advanced video projection and photographic flash systems.

A leader in amorphous silicon technology, Optoelectronics produces the semiconductor panels that are the critical components of digital x-ray systems. With its partner GE Medical Systems, it is currently having an impact in the medical and dental industries and nondestructive product testing.

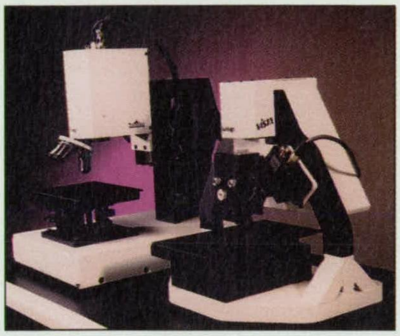
Burleigh Instruments Gemini Surface Topography System

Burleigh Instruments calls its Gemini surface topography system the first to combine an atomic force microscope (AFM) and an optical system profiler in one package. The Gemini includes Burleigh's Vista large-sample AFM and Horizon noncontact optical profiler, providing direct 3D measurements from the millimeter to the angstrom level. The Vista offers contact, AC, phase, and lateral force imaging modes with optional scanning tunneling mode. The Horizon offers the capability to measure areas as large as 2 mm square with a Z range of 100 microns, while also providing vertical resolution on the angstrom level. Thus the Gemini measures topographic features, surface roughness, friction, and compliance.

Founded in 1972, Burleigh Instruments is a leading manufacturer of dense wavelength division multiplexing (DWDM) wavelength measurement instruments and precision positioning equipment. Its products, used in basic and applied research, engineering, and production test environments, include laser test and measurement instruments, nanopositioning systems and micromanipulators, and surface imaging and measurement instruments. This wide range of products is based on similar technologies, such as precision mechanics, optical interferometry, and electro-active ceramic devices that display the piezoelectric effect.

In 1977 the company moved to "Burleigh Park," its present location in

Fishers, NY, about 20 miles east of Rochester. The facility, built on several acres of farmland, has grown to 20,000 square feet of manufacturing, laboratory, engineering, and office space, with more than 90 full-time employees. Burleigh products can be found in scientific research labs at



Burleigh Instruments Gemini surface topography profiler

most universities and government-supported research programs, including facilities of the National Institutes of Health, Department of Defense, Department of Energy, NASA, and all branches of the armed services.

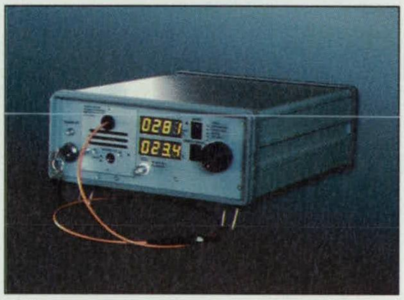
Late last year, Burleigh was acquired by EXFO Electro-Optics Engineering, of Quebec City, Canada, a manufacturer of fiber optic test equipment for R&D, manufacturing, and network installation and maintenance. According to EXFO, the merger will enable the acceleration of growth in those sectors of business that focus on the needs of manufacturers in the rapidly growing optical component and DWDM transmission system markets. Kessler Marketing Intelligence, a leading fiber optic research company, estimates that the global DWDM transmission system market will expand from U.S. $8.9 billion in 2000 to U.S. $54 billion in 2005.

Coherent F-Package Fiber-Coupled Laser Diode System

Coherent Semiconductor Group introduces the F-Package System, which it describes as a standalone microprocessor-controlled fiber-coupled laser diode system in wavelengths from 650 to 980 nm. Delivering its power through a 0.5-m-long large-core optical fiber, the module consist of a single-stripe laser diode, rated from 0.2 to 2.5 W depending on the configuration, mounted on an active air-cooled heat sink with an optional thermoelectric cooler capable of regulating case temperature from 10-40 degrees C, along with all necessary laser and TEC drive and control electronics. The F-Package system allows users to swap-out laser diodes at different wavelengths to support a wide variety of applications, including soldering, epoxy curing, medical therapeutics, graphic arts, and pumping solid-state laser media.

Coherent Semiconductor Group's resources include a world-class manufacturing plant at its headquarters in Silicon Valley, CA, an 80,000-square-foot growth capability in Tampere, Finland, an industry-leading Class 100 cleanroom facility, an extensive applications lab and a worldwide network of service offices. The Group's 650- to 1000-nm product line includes single-stripe devices, fiber array packages, stacked arrays, FAP systems, and integration devices such as laser diode drivers, optical imaging accessories, and thermal management platforms.

Coherent Semiconductor Group's parent company is Coherent, Inc., the largest laser manufacturer in the world. Founded in 1966, Coherent is



Coherent Semiconductor Group F-Package laser diode system

focused on two principal market segments: the electro-optical marketplace, which includes Coherent Semiconductor, and the medical market. In the electro-optical segment, which represents almost two-thirds of the company's business, the company targets such applications as semiconductor and printed-circuit-board manufacturing, micromachining, reprographics, imaging, spectroscopy, forensics, information storage, and multimedia entertainment.

Other finalists included New Focus (Santa Clara, CA) Models 102X and 14XX time-domain-optimized ultrahigh-speed detectors; Spectra-Physics (Mountain View, CA) BL6-355Q semiconductor-pumped solid-state laser; and Eastman Kodak Image Sensor Division (Rochester, NY) KAC-0310 CMOS VGA image sensor.

TELECOM TESTING EMBRACES RAMAN FIBER LASERS

WITH ITS HIGHER POWER, THE FIBER LASER IS CHALLENGING EDFAS BOTH AS A PUMP SOURCE FOR OPTICAL AMPLIFIERS AND AS A SOURCE FOR COMPONENT TESTING.

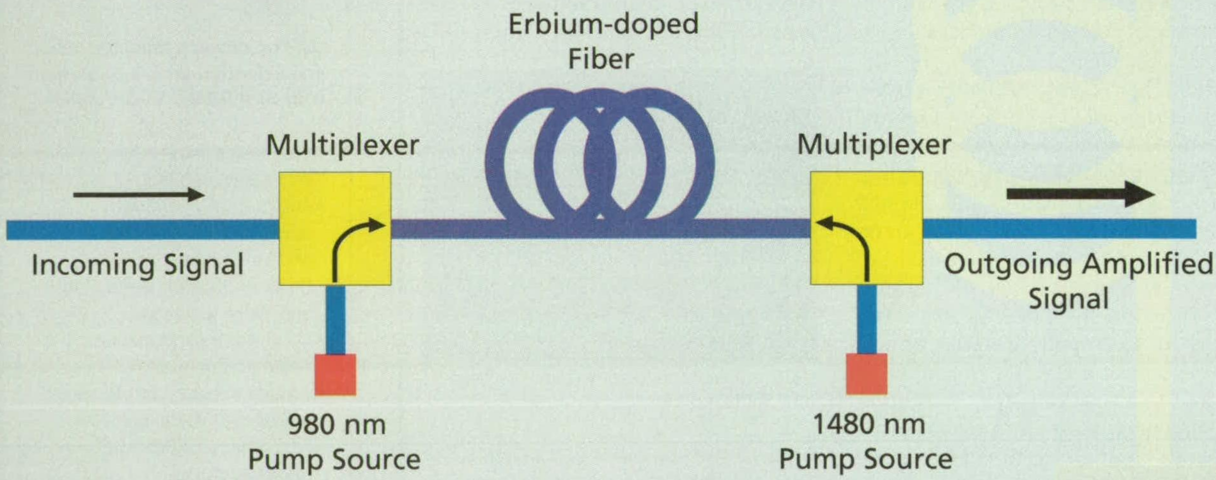


FIGURE 1. SCHEMATIC OF AN EDFA.

Optical amplifiers are one of the most important pieces of long-haul optical telecommunications technology under development at present. Part of the development process for new optical amplifier products requires high-power damage testing of their optical components. The Raman fiber laser has recently emerged as an excellent tool for such testing. It is also attracting interest for deployment in the field, as a pump source for both Raman and erbium-doped optical amplifiers.

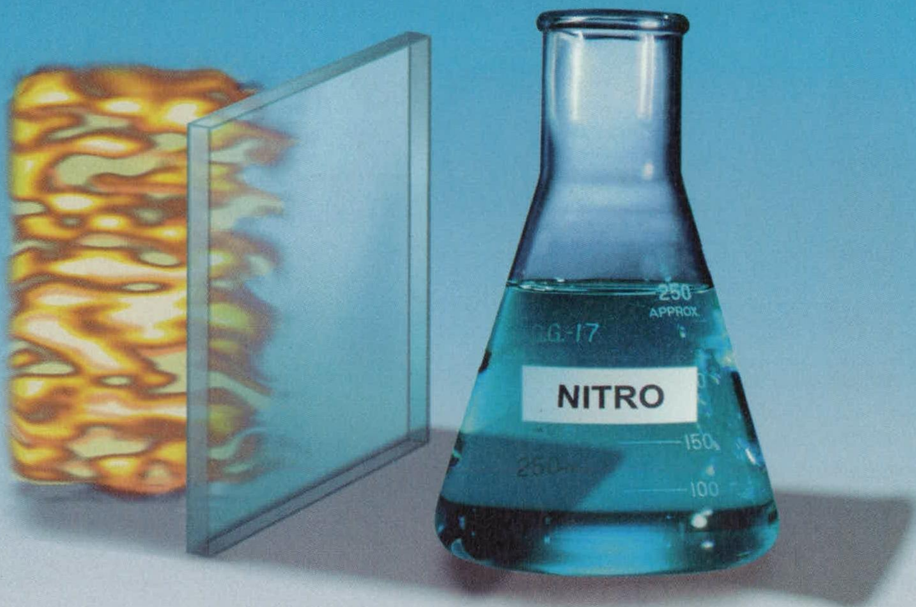
This article briefly reviews optical amplification and Raman fiber laser operation. The specific requirements of a Raman fiber laser for component testing purposes are then examined, together with an example of its use by a leading component manufacturer.

OPTICAL AMPLIFIERS: BACKGROUND

Optical amplifiers are used to directly amplify an optical signal, without requiring it to be detected, converted into an electronic signal, electronically amplified, and then reconverted back into an optical signal. The leading technology for performing optical amplification in a fiber optic cable is currently the erbium-doped fiber amplifier (EDFA). The Raman fiber amplifier, however, has recently gained in popularity, and shows significant promise as a complementary technology.

Figure 1 shows a simplified schematic layout of a single-stage EDFA. A length of erbium-doped silica optical fiber is spliced into a telecommunications fiber, which nominally carries a signal at 1550 nm. Pump light is introduced into the fiber through a wavelength multiplexer and absorbed by the erbium ions. This

Our Hot Mirrors clearly have explosive advantages.



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Crystal Clear Hot Mirrors

Guaranteed color neutral even at 5500° K, our crystal clear hot mirrors are perfect for applications such as entertainment lighting, biomedical applications and fiber optics. Guaranteed not to peel, fade or craze.

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- Ave. R ≥ 95% at 750-1150 nm
- Incident angle = 0°

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Our cold mirror filters reflect visible light and transmit IR. They are used in a wide variety of products from projectors to fiber optic illuminators.

- Ave. T ≥ 90% at 750-1200 nm
- Ave. R ≥ 95% at 420-650 nm
- Incident angle = 45°

UV Pass Hot Mirror

Designed to block IR and allow visible and UV light to pass through, these hot mirrors are especially well adapted for UV curing of inks, dyes and cements.

- Ave. T ≥ 85% at 245-680 nm
- Ave. T ≥ 86% at 245-400 nm
- Ave. R ≥ 75% at 800-1050 nm
- Incident angle = 0°

Extended Hot Mirrors

Similar to our crystal clear hot mirrors, our extended hot mirrors provide a wider range of IR protection. They are ideally suited for applications which also require reflectance from 1200 to 1600 nm. Guaranteed not to peel, fade or craze.

- Ave. T ≥ 85% at 425-675 nm
- Ave. R ≥ 95% at 750-1150 nm
- Ave. R ≥ 85% at 1200-1600 nm
- Incident angle = 0°

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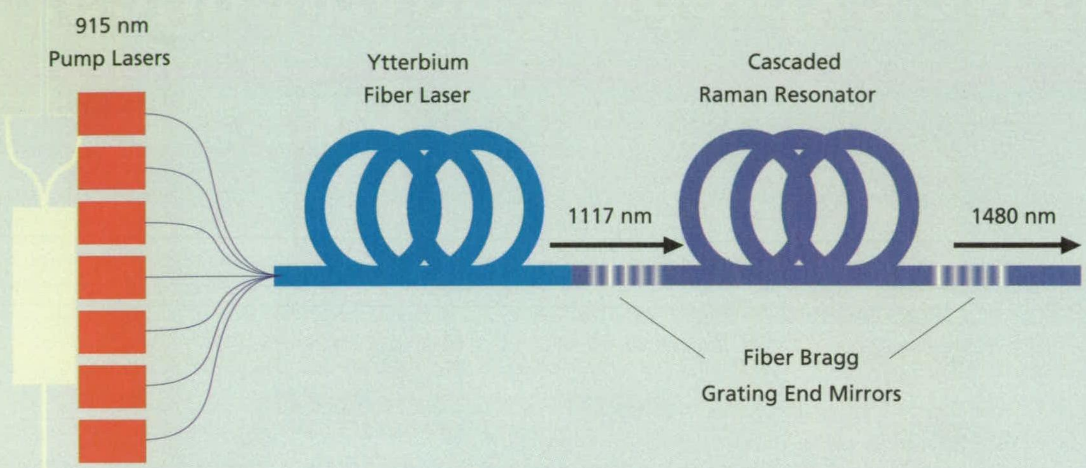


FIGURE 2. SCHEMATIC OF A RAMAN FIBER LASER.

pumping amplifies the 1550-nm signal photons, producing optical gain.

The erbium ions absorb strongly at two different pump wavelengths: 980 nm and 1480 nm. Systems utilizing either or both wavelengths are in use, because there are advantages to each. Typically, 980-nm pump light (from a semiconductor laser) is introduced at the front end of the system, and propagates in the same direction as the signal. This is called co-pumping. This architecture tends to minimize the noise characteristics of the EDFA, and is useful for preamplification purposes. In contrast, 1480-nm pump light (from a semiconductor laser or Raman fiber laser) is usually injected at the rear of the system. This counter-propagating arrangement is called counter-pumping. Counter-pumping at 1480 nm usually maximizes EDFA gain, but can compromise noise characteristics in the system, and is often used for booster amplification.

Raman amplification works in the actual in-ground optical communications fiber, unlike EDFAs, which require a special, discrete fiber. The technique is based on the phenomenon of stimulated Raman emission. An intense pump source at a shorter wavelength can coherently amplify an optical signal at a longer wavelength, providing the difference in the two photon energies matches a resonant vibrational frequency in the glass of the fiber core. This difference is roughly 100 nm at 1550 nm.

Raman amplification is a relatively weak effect, and can therefore occur over a very long distance within the fiber. Because of this, the technique is typically implemented using counter-pumping. The signal, traveling in the forward direction, gradually loses strength as it propagates down the fiber. The pump light, coming from the reverse direction, is strongest at the end of the fiber at which the signal has

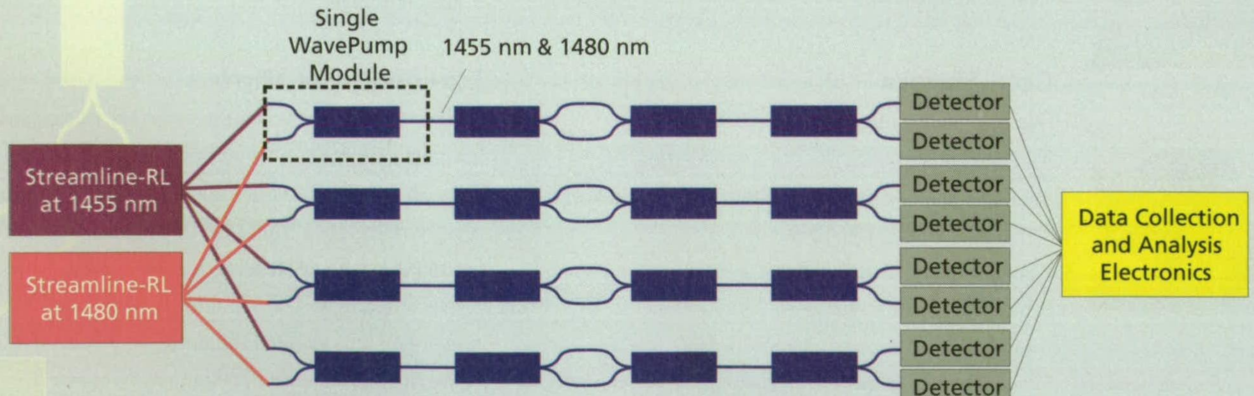


FIGURE 3. SCHEMATIC OF THE WAVEPUMP TEST SETUP.

become weakest. Thus, counter-pumping automatically delivers the greatest gain where it is most needed. It also greatly reduces the transfer of noise from the pump source to the signal.

An important characteristic and advantage of Raman amplification is that, by choosing the appropriate pump wavelength, it can be used to amplify any signal wavelength within the transmission band of the fiber. In the case of 1550-nm optical signals, a pump wavelength of about 1455 nm can be used. The use of different pump wavelengths, however, would enable S-band (1485-1520 nm) and L-band (1570-1610 nm) amplification. In contrast, the EDFA works only in the C band (1530-1562 nm) near 1550 nm.

Given the numerous benefits of Raman amplification, why did EDFA technology gain earlier acceptance in the market? The answer is that stimulated Raman scattering is a nonlinear optical effect, and thus needs high power to operate. So Raman amplification wasn't really practical until the advent of higher-power pump sources at 1450 to 1480 nm. In the long run, both techniques, which are somewhat complementary, will undoubtedly coexist.

RAMAN FIBER LASER OPERATION

A simplified schematic of a typical Raman fiber laser is shown in Figure 2. The outputs from several high-power 915-nm semiconductor lasers are combined and used to pump the outer cladding of an ytterbium-doped double-clad fiber laser. The fiber laser produces output at 1083 nm, 1100 nm, or 1117 nm, which is then coupled into a cascaded Raman cavity having fiber Bragg grating end mirrors. Inside this cavity, the light is Raman-shifted by an amount equivalent to the vibrational frequency of the core glass. Successive shifts produce a cascade, which can generate a wide range of wavelengths. In practice, this technique can be set to provide virtually any wavelength (defined by the Bragg mirrors) from the original input wavelength up to the limits of the fiber transmission.

For most EDFA applications, it is at present less expensive to multiplex several semiconductor lasers, rather than to use a single Raman fiber laser. But there are applications where it is desirable to use a single high-power 1480-nm Raman fiber laser and numerous beamsplitters to power banks of low-power EDFAs. Another popular application is using 1480-nm output of greater than 1 W for festooning (connecting coastal cities with underwater links) or remotely pumping submerged EDFAs. Here, the Raman fiber laser is a very practical alternative.

The Raman fiber laser is also attractive for Raman amplifier pumping. In this case, the laser's higher power translates into the ability to amplify large channel counts or be split to simultaneously provide Raman amplification to several fibers.

RAMAN FIBER LASERS FOR TESTING

The Raman fiber laser is already gaining acceptance as a superior source for component testing, where the requirements are different from those for field deployment. Specifically, in telecommunications systems, reliability is the key consideration. The use of multiple pump lasers enhances reliability, because the failure of a single unit doesn't cause catastrophic system failure. In contrast, when designing a Raman laser source for use in the development and testing of telecommunications components, higher output power is a more important consideration.

To meet the specific needs of the development and testing markets, Spectra-Physics recently introduced the Streamline-RL Raman fiber laser. This product incorporates a single 35-W semiconductor laser bar pump source instead of multiple individual lasers. Operated at a very conservative power level, this ytterbium fiber laser with a cascaded Raman cavity produces more than 5 W of output power at the 1450-, 1455-, or 1480-nm wavelengths. The 5-W output can be used either as a single high-power source or split to supply multiple lower-power sources for simultaneous development or component testing applications.

In addition to high power, the Streamline-RL has also been designed to provide development and test users with convenience and ease of use. For instance, it is offered with all the optics, electronics, and cooling packaged in a single box, incorporating closed-loop power control and an RS-232 interface. The unit operates off standard AC wall power and delivers its output through an SMF-28 single-mode optical fiber.

COMPONENT TESTING

WaveSplitter Technologies Inc. of Fremont, CA, develops high-performance optical components and modules based on fused fiber and planar-light-guide circuit technologies. One product, called the WavePump, utilizes the company's patented Fused Cascaded Fiber (FCF) approach to combine either EDFA or Raman amplifier pump wavelengths into a single fiber output for high-power amplifier applications. As an example, the WavePump has two fiber inputs, one for 1480 nm and one for 1455 nm, and a single output carrying the combined wavelengths.

Development of this device necessitates measuring its insertion loss and limiting power, as well as determining its appropriate rated lifetime. The company has found that the high power output of the Streamline-RL significantly aids in this work. The schematic of a typical test setup for the WavePump is shown in Figure 3. The output from two Streamline-RLs is split and used to supply the input to a number of devices under test. This same configuration can be used for both life testing and determining high-power durability.

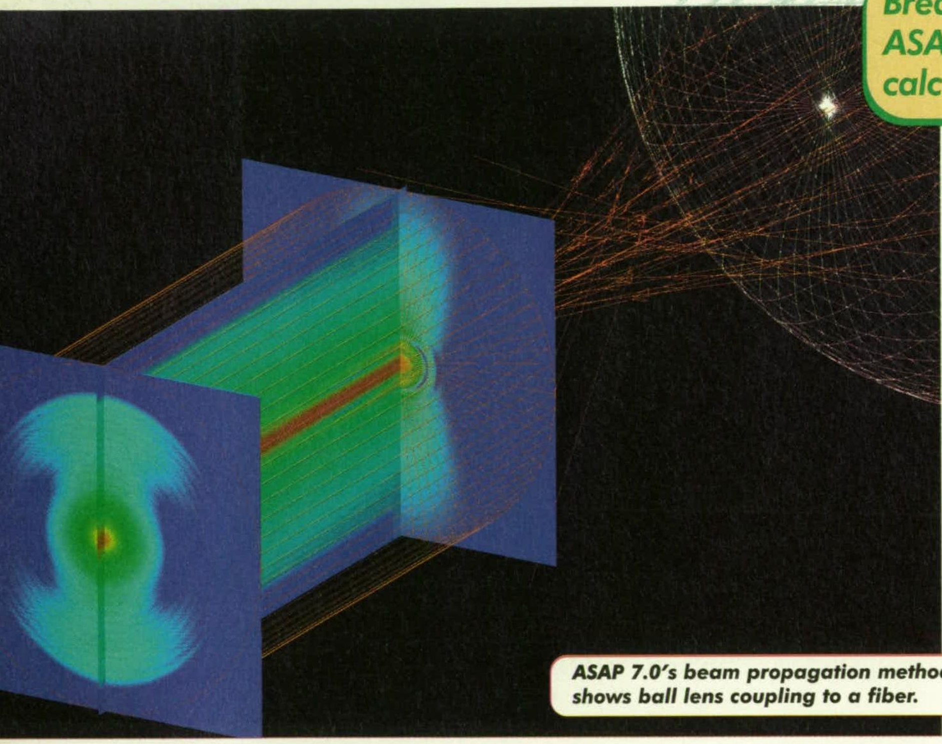
This type of testing was previously performed using Raman fiber lasers with a 1.5-W maximum output. The advantage of the more powerful Streamline-RL is that it enables testing of many more devices simultaneously, reducing testing time and equipment costs. Furthermore, when used to life-test just one or a few devices, the increased power accelerates the aging process, reducing development cycle time. Also, the high power available from the Streamline-RL makes it easier to determine device failure limits.

"The Streamline-RL's high power output has definitely allowed us to perform testing more efficiently, as well as more aggressively explore the performance limits of our designs," says Erkin Sidick, PhD, manager of advanced fiber optic devices at WaveSplitter Technologies. "In addition, the fact that it is a self-contained unit has been a real advantage. It allows us to move it around the lab whenever we need to, and even take it to customer demos."

For more information on the Streamline-RL, contact the coauthor of this article, Bill Holtkamp, director of sales, Spectra-Physics Telecom, 1335 Terra Bella Ave., Mountain View, CA 94043; (520) 746-6779; bholtkamp@splasers.com. His coauthor was Dirk Kuizenga, product manager.

Optical Modeling Software Moves Ahead

Breault Research Organization's ASAP 7.0 emphasizes volume calculations and graphics.



ASAP 7.0's beam propagation method shows ball lens coupling to a fiber.

ASAP 7.0, the latest version of the optical modeling software just released by Breault Research Organization (BRO) of Tucson, AZ, was the subject of a "Photonics Town Square" product forum demonstration by Carey Portnoy of BRO at SPIE's Photonics West conference and exhibition in late January in San Jose. The excerpts below are taken from that presentation. ASAP customers who have a current BRO maintenance agreement automatically receive software upgrades.

Kernel Features

The ASAP kernel is the ray-trace engine and computational powerhouse at the heart of the program. This version of the kernel includes both new features and significant enhancements to familiar tools. This time around BRO has emphasized volume calculations and graphics. Of the four major 7.0 kernel release features listed below, the first three fall into this category:

- Finite-difference wave-field propagation;
- Volumetric energy tracking;
- Inhomogeneous Monte Carlo volume scattering; and
- Local and global optimization of basic lens systems.

Finite-Difference Wave-field Propagation

Finite-difference wave-field propagation allows ASAP to enter the realm of single-mode fibers, splitters, couplers, and other guided-wave problems. ASAP 7.0 uses a unique beam-propagation method (BPM) that offers the best trade between speed and accuracy. Because finite-difference BPM is linked to the same basic data structures and analysis tools currently used by ASAP, it is relatively easy for ASAP to make the transition from the bulk media to small-scale geometrical structures and back. Unlike most other BPM products with limited geometrical options, the user can generate arbitrary optical structures using either ASAP geometrical entities or CAD-generated shapes.

Volumetric Energy Tracking

New energy tracking features within ASAP allow you to visualize, and quantitatively analyze, the way energy moves through, or is deposited within, your system. Divide the space containing your system into volume elements, or "voxels," to analyze and visualize volume absorption, fluence, and irradiance within the three-dimensional space. Use the ASAP 3D Viewer and other ASAP graphical tools to visualize the result interactively.

This new capability, in conjunction with methods already built into previous versions of ASAP, makes it easier to turn volumes or areas that have absorbed energy into emitters — sources of new rays with flux proportional to the deposited or fluent energy. This results in improved modeling of fluorescence and related emission phenomena.

Inhomogeneous Monte Carlo Volume Scattering

By popular demand, ASAP 7.0 also offers more direct volume scattering features. Rays within an object can be scattered according to a model that depends on the three-dimensional position within the volume. Specify the angular distribution of the resulting scattered rays as isotropic (as predicted by MIE theory, Henyey-Greenstein distributions), or a user-defined function.

Local and Global Optimization of Systems

A lens can be optimized using a brute-force algorithm that finds either the nearest minimum or the global minimum, without requiring the merit function to be continuous. This technique also allows constraints to be handled in a straightforward and exact manner. All

this is made possible by an extremely fast method in ASAP for determining the RMS spot size at any field location. On a typical system, over a million merit-function evaluations per minute can be achieved, independent of the number of fields. This ASAP feature quickly gets close to new solutions, which can then be tweaked elsewhere if necessary.

Other Kernel Features

ASAP has always emphasized ray-tracing speed. Now the user can specify one hundred percent memory-resident ray files to speed up ray tracing and other commands that use the ray file intensively. This feature can dramatically speed up ray-file access in computers with plenty of available RAM space (one gigabyte or greater).

User Interface Features

Whether the user works with pull-down menus, the ASAP Builder, or the script Editor, he is communicating with the ASAP kernel via the user interface (UI). ASAP 7.0 uses the latest compiler technology to produce a multiple-document interface tuned to the various styles of BRO's user base. It includes the very latest features available to Microsoft® Windows® programs. A few of the most important improvements are:

- Customization with persistence;
- Workspace window power;
- New Editor features;
- Plot Viewer improvements and enhancements;
- Integrated 3D Viewer; and
- New bidirectional scattering distribution function (BSDF) fitting features.

Customization with Persistence

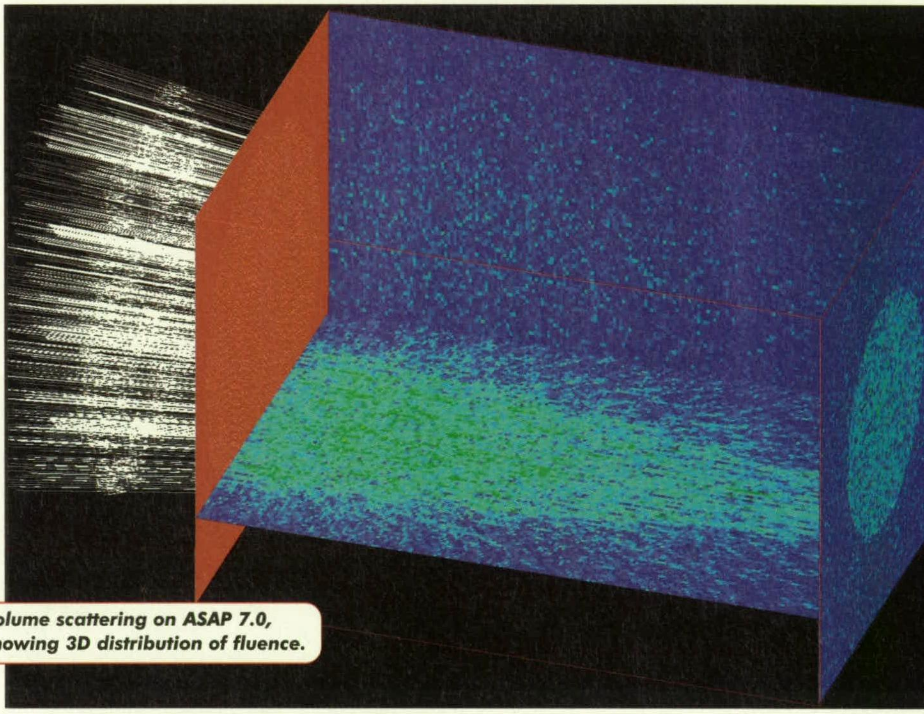
Perhaps the most appreciated characteristic of the new ASAP user interface will be the ability to move in and make it the user's own. If you don't like a window "docked" against some particular edge of the workspace frame, move it somewhere else or allow it to float. Do you dislike toolbars? Turn them off. If you like buttons, five more "custom" buttons are available. Best of all, next time you start ASAP, everything will be just the way you left it.

Workspace Window Power

One of the new windows the user will see at startup is the ASAP Workspace. It has several tabs that show important information about the current state of ASAP. The Views tab shows what types of documents are currently open. The Objects tab shows the tree of all currently defined objects. A check box on each individual object or assembly shows which ones are currently "considered" by the ASAP kernel, and allows the user to effect changes by adding or removing check marks. This feature updates in real time, and is disabled only while a script is running. If you load projects, a third tab, Files, displays your project files.

Menu Redesign and Reorganization

ASAP 7.0 introduces a more intuitive menu system. Common functions that once took visits to several different dialog boxes can now be accomplished with one dialog full of intelligent defaults. The ray-tracing dialog is a good example. The default settings to this single dialog box allow the user to trace the rays from the beginning to the end of the system, producing a graphic including the rays and the system geometry. If that isn't quite what you wanted, all of the original flexibility is just a few clicks away in the same window. A new button called "script" is available in every dialog box, allowing the user to see what ASAP commands are being generated by this particular function. You can easily cut and paste these commands into your own script file if you want to write your own ASAP scripts.



Volume scattering on ASAP 7.0, showing 3D distribution of fluence.

New Editor Features

For those who live in the script Editor, there are many new enhancements. Bookmark positions are saved for each file opened, as well as the last cursor position. When you leave and return to file, it will be like you never left. Color-coding of commands and arguments now print in color as well.

Plot Viewer Improvements

Users may choose to have all plots sent to a single window, since it is now easy to recover and compare previous results. You can click through historic plots from within that single window, or access specific plots from the project view. Zooming is also easier. Just drag the mouse to select a section, and ASAP expands the area of interest. The original view is always one click away.

Integrated 3D Viewer

The 3D Viewer is now fully integrated into the ASAP environment. With this one tool, the user can view his geometry, rays, and the results of analysis together or in isolation.

New BSDF Fitting Features

The ASAP philosophy has always been that accurate, quantitative scatter and stray light analysis cannot be done with rough approximations to the scattering behavior of surfaces. BRO recommends that representative samples of surfaces be measured and modeled in order to get valid results.

To facilitate this, ASAP 7.0 has expanded the bidirectional scattering distribution function fitting capability built into ASAP. You can interactively fit efficient, realistic functions to measured data from a range of surfaces, including polished glass, vacuum molded plastics, many diffusers, and painted surfaces.

For more information please contact Breault Research Organization, 6400 East Grant Rd, Suite 350, Tucson, AZ 85715; (800) 882-5085; outside U.S. & Canada: 1-520-721-0500; fax 1-520-721-9630; www.breault.com.

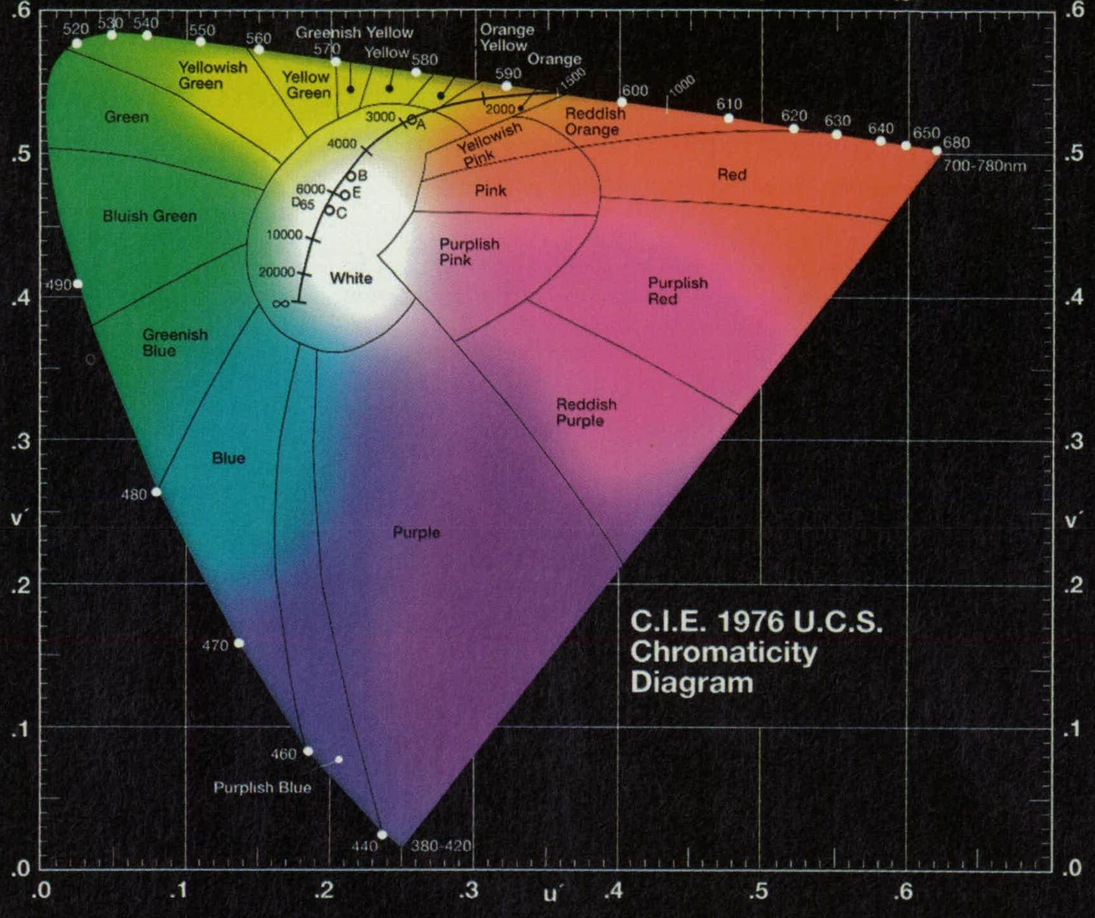


Diagram courtesy of Photo Research, Inc., "The Light Measurement People."

Magnetic Microimagers Based on Giant Magnetoresistance

Uses could include mineralogical exploration, detection of cracks, and reading magnetic cards.

NASA's Jet Propulsion Laboratory, Pasadena, California

Integrated-circuit imaging devices of a proposed type would contain planar arrays of microscopic sensors that would exploit giant magnetoresistance (GMR). Each GMR sensor in such a device would define one pixel in an image with a pixel pitch of the order of tens of microns. With the difference that the GMR sensors would respond to local magnetic fields instead of to locally incident light, they would perform essentially the same role as that played by photodetectors in familiar optoelectronic imaging devices. Indeed, the arrays of GMR sensors could be deposited on readout integrated circuits similar or identical to those on which, heretofore, visible and infrared photodetectors have been deposited. The proposed devices could be used, for example, as conventional magnetometers and gradiometers, magnetic microscopes for examining small ferromagnetic particles or cracks in ferromagnetic materials, imagers for mineralogical exploration, and readers of magnetic inks and magnetic cards.

A typical GMR sensor according to the proposal (see Figure 1) would comprise several layers of magnetic materials separated by layers of nonmagnetic materials, all supported by a silicon substrate. With the exception of the substrate, the thicknesses of the layers would be of the order of tens of nanometers or less. The layers could be grown on the substrate by vacuum deposition, sputtering, or even electroplating. The growth and other fabrication steps would involve delicate nanotechnological techniques.

The antiferromagnetic FeMn layer would serve to pin the orientation of the magnetization of the Co layer. The Co layer would be regarded as magnetically hard in that the applied magnetic field that one seeks to sense would not be strong enough to change the direction of magnetization of the Co layer. The NiFe layer, designated as the sensing layer, would be regarded as magnetically soft in that its coercivity would be less than that of the pinned (Co) layer and its direction of magnetization could be affected by the applied magnetic field that one seeks to sense.

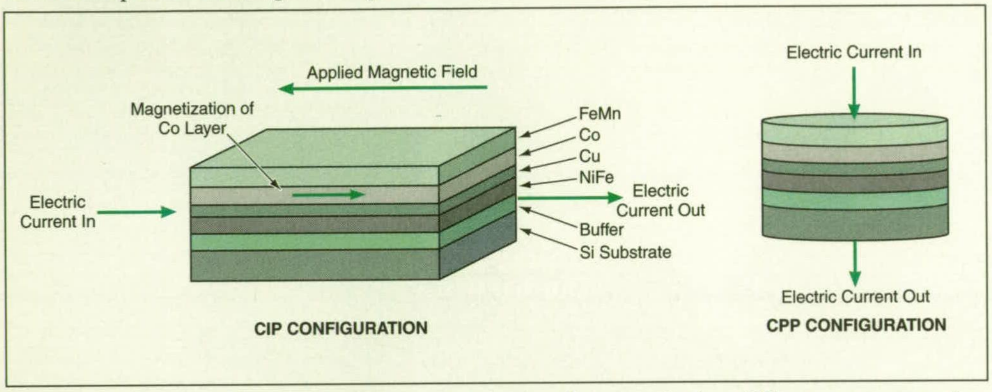


Figure 1. A **Typical GMR Sensor** would be constructed in either the current-in-plane (CIP) or current-perpendicular-to-plane (CPP) configuration. The electrical resistance of the device would vary with the applied magnetic field.

GMR is a large change in electrical resistivity in response to a magnetic field applied along an axis of sensitivity that would lie in a plane parallel to the layer planes and that would be determined by the direction of magnetization in the pinned layer. GMR is the macroscopic electrical manifestation of a phenomenon that is known as spin-valve action and that involves differential scattering, by the magnetic fields of the various layers, of electrons with different spin polarizations. In order to obtain GMR in the proposed device, the separated magnetic layers would have to be antiferromagnetically coupled. Inasmuch as the coupling between two magnetic layers oscillates from ferromagnetic to antiferromagnetic as the thickness of the intervening nonmagnetic layer is varied, it would be necessary to tailor the thicknesses of the nonmagnetic layers precisely in order to obtain the antiferromagnetic coupling needed to realize a highly sensitive GMR sensor.

Figure 2 shows the geometric relationship between an applied magnetic field, *B*, and the components of the magnetic field parallel and perpendicular to the axis of sensitivity of a GMR sensor, which could be one of many such sensors arrayed in the x-y plane. The sensor would respond only to the component B_y because the axis of sensitivity as depicted here is oriented parallel to the y axis. In order to sense the component B_x, it would be necessary to rotate the sensor 90° about the z axis to make the axis of sensitivity lie parallel to the x axis. Similarly, in order to sense B_z, it would be necessary to rotate the sensor 90° about the x axis to make the axis of sensitivity lie parallel to the z axis. Alternatively, it should be possible to construct an imaging device containing a two- or three-dimensional array of GMR sensors with orthogonal axes of sensitivity, so that it would be possible to sense B_x and B_y or even B_x, B_y, and B_z, simultaneously.

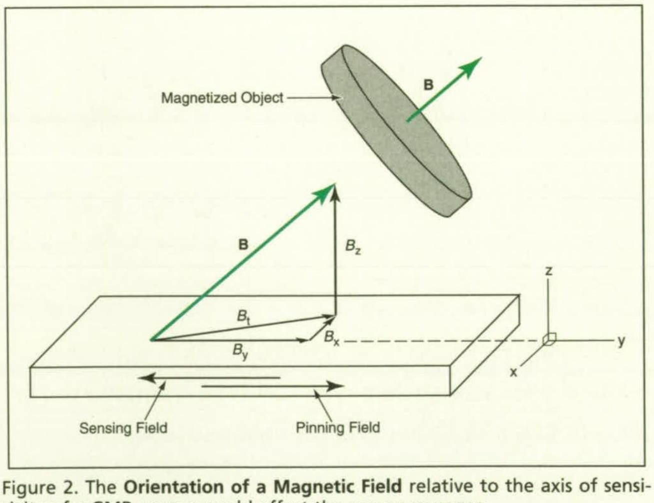


Figure 2. The **Orientation of a Magnetic Field** relative to the axis of sensitivity of a GMR sensor would affect the sensor response.

This work was done by Sir B. Rafol 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-20925

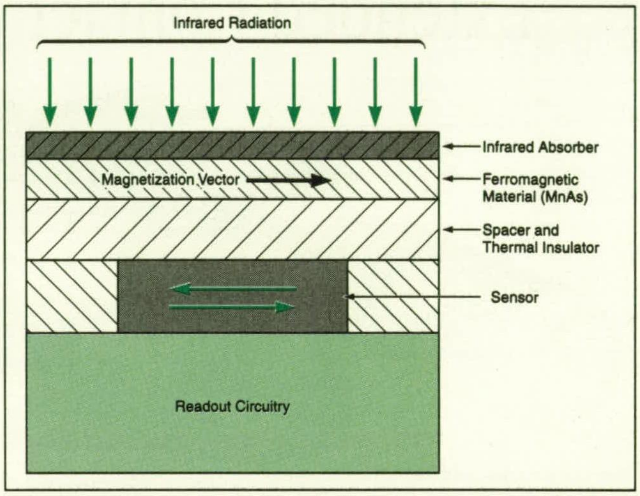
Using Ferromagnetism and Giant Magnetoresistance To Sense IR

Proposed sensors and imaging devices could operate at room temperature.

NASA's Jet Propulsion Laboratory, Pasadena, California

Infrared (IR) sensors of a proposed type, and integrated-circuit imaging devices containing planar arrays of such sensors, would be based on a combination of (1) temperature-dependent ferromagnetism and (2) the use of giant magnetoresistance (GMR) to detect changes in ferromagnetism. Unlike many infrared sensors, the proposed sensors would not have to be cooled to very low temperatures; indeed, they could be designed for optimum performance at room temperature.

A sensor according to the proposal (see figure) would include a layer of ferromagnetic material coated with an infrared-absorbing material. The ferromagnetic material would be heated by incident infrared radiation. The chosen ferromagnetic material would be one with a Curie temperature (T_c) somewhat above the intended operating temperature; for example, MnAs (T_c = 318 K) would probably be suitable for room temperature (≈293 K). The reason for this choice is that the magnetization of a ferromagnetic material decreases sharply with increasing temperature as the temperature approaches T_c, so that the magnetic field produced by such a material can serve as a sensitive indicator of temperature in the range just below T_c. Hence, one would expect the magnetic field of the ferromagnetic material to decrease when the material was heated by incident infrared radiation.



Infrared Radiation would be absorbed, causing warming of the ferromagnetic layer to near its Curie temperature and thus a decrease in magnetization. The GMR portion of the sensor would sense the change in magnetization.

A GMR sensor is a multilayer device (for example, see the preceding article) that exhibits a change in electrical resistance when exposed to a change in a magnetic field. Some GMR sensors are

capable of detecting changes in magnetic-flux density as small as 1 milligauss (10^{-7} Tesla). The GMR portion of the proposed sensor would sense the temperature-dependent change in the magnetic field of the ferromagnetic layer. The ferromagnetic layer would be separated from the GMR layers by a nonmagnetic layer with a thickness chosen to provide both magnetic coupling and sufficient thermal insulation to enable the temperature of the ferromagnetic layer to rise appreciably upon exposure to infrared radiation.

One of the advantages of both ferromagnetic materials and GMR sensors is that they can be engineered to operate at a chosen temperature with acceptably high sensitivity. Furthermore the layers of a GMR sensor are easily grown by sputter deposition and molecular-beam epitaxy. According to the proposal, the GMR layers would be deposited directly on a readout integrated circuit, followed by deposition of the nonmagnetic, ferromagnetic, and infrared-absorbing layers.

This work was done by Sir B. Rafol 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-20929*

Leakage-Compensated, Frame-Differencing APS Imager

This imager would also provide frame summing and suppression of fixed pattern noise.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed complementary metal oxide/semiconductor (CMOS) integrated-circuit imaging device of the active-pixel sensor (APS) type is capable of simultaneously generating the pixel-by-pixel sum and difference of two successive image frames at high speed for real-time operation, while compensating for leakage and suppressing fixed pattern noise (FPN). Frame differencing (and, to some extent, summing) is used in a variety of image-processing applications, including surveillance, range mapping, detection of motion, discrimination against background, compression of image data, and for solar-Doppler magnetographs.

Heretofore, it has been common practice to compute frame differences in software after acquiring image data, but such computation tends to be too slow for real-time operation and to contribute undesirably to the complexity and power demand of an image-data-processing system. In an effort to overcome these disadvantages of frame differencing in software, APS circuits that incorporate capacitive memory elements and associated frame-differencing circuitry within pixels have been demonstrated. Unfortunately, these circuits have been susceptible to unwanted coupling of present-frame pixel signals into pixel memory elements and consequent corruption of the stored previous-frame pixel values. Often, true frame differences are smaller than amounts of leakage, so that the very purpose of frame differencing is defeated. The problem of correcting frame-difference errors is compounded by a need to avoid contributing to FPN through inaccurate subtraction of pixel offsets. Regarding on-chip summing of successive frames: heretofore, there has been no circuitry capable of performing this function.

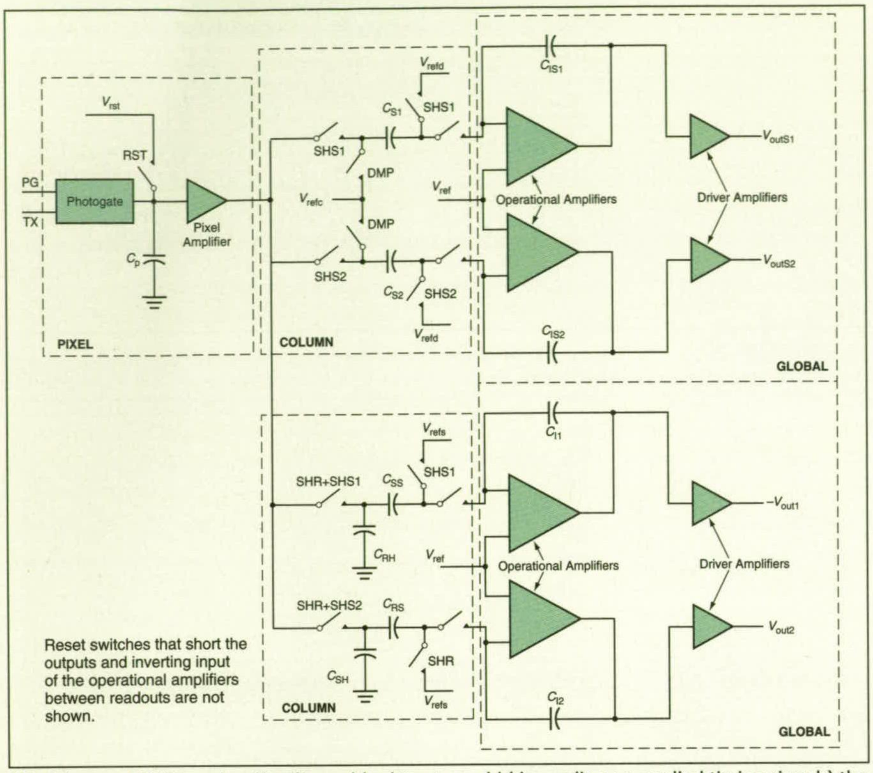
The proposed imager would include pixel circuitry like that of prior CMOS APS imagers. It would differ from the prior imagers by incorporating redesigned column and global signal-processing circuits that would contain switched-capacitor gain stages (see figure on page 22a). These redesigned circuits would (1) compute frame signals differentially to eliminate FPN; (2) provide different gains for present and preceding frame signals after FPN has been eliminated, in order to compensate for leakage; and (3) sum successive frames by use of modified gain-stage timing.

During exposure of the present frame, charge from the present frame leaks (by optical coupling or diffusion) into the in-pixel storage capacitor, C_p, corrupting the signal stored during the preceding frame. The effect of the leakage is equivalent to that of multiplying the present- and previous-frame signals by different voltage gains prior to the analog computation of the difference between them. Hence, the effect of leakage could be compensated by use of modified gains; in particular, if δ is the fraction of signal charge from the present frame that leaks into C_p, then one could compensate for the leakage by making the gain for the present frame 1 + δ times that for the preceding frame.

In the proposed circuit, the outputs from the pixels in a given row would be sampled simultaneously at the bottoms of the corresponding columns in column sample-and-hold capacitors (C_{S1} and C_{S2}). These capacitors would then be successively switched into the global switched-capacitor gain stage, which would include operational amplifiers, feedback capacitors (C_{IS1} and C_{IS2}), and transistor switches. The gain in each branch would be governed by the ratio between its capacitances. These ratios (C_{S1}/C_{IS1} and C_{S2}/C_{IS2}, respectively) would be chosen to obtain the different gains needed to compensate for leakage. The gains could be varied by changing capacitor sizes, by digital switching for parallel connection or disconnection of capacitors in increments of 0.01 × a base capacitance.

In order to suppress FPN, it is necessary to effect pixel-to-pixel offset correction and suppression of flicker noise, and this necessitates equal gains. In the absence of a further correction, the use of different gains to compensate for leakage would contribute to FPN. In the proposed circuit, this correction would be effected by reading out each frame pixel value differentially with respect to an externally generated reference potential (V_{refc}), and storing the differential value in the charge domain on capacitors. Thus, offset would be corrected for each frame pixel value independently. The offset-corrected charge would then be appropriately amplified by the global switched-capacitor gain stage.

Generation of the sum of pixel values from two successive frames would involve sampling in different ways during the two frames. The signal from the preceding frame, already stored in C_p, would be captured by sampling that signal first, followed by the reset. Inasmuch as the same reset level would be used for computation of the pixel value of the present frame, sampling of the current frame would begin with sampling of the reset voltage first, followed by sampling of the signal voltage. As a result, signals of opposite polarities would be generated in the two branches. Thus, when the difference between global differential outputs is computed, the result would be the sum of succes-



This **Advanced APS Imaging Circuit** would subtract or add (depending on applied timing signals) the pixel values of successive frames, using variable gain to compensate for leakage and a differential readout technique to suppress fixed pattern noise.

sive frame pixel values instead of the difference between them. Additional capacitors (C_{RH} and C_{SH}) would be needed in every column in order to store all four samples for a given pixel while individual columns were scanned out. Measured results indicate residual error of <1 percent, which is constant across the entire illumination range.

This work was done by Bedabrata Pain, Guang Tang, Monico Ortiz, and Suresh Seshadri 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.*

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

Technology Reporting Office
JPL
Mail Stop 249-103
4800 Oak Grove Drive
Pasadena, CA 91109
(818) 354-2240

Refer to NPO-21049, volume and number of this NASA Tech Briefs *issue, and the page number.*

Software for Analyzing Telecommunication Link Performance

NASA's Jet Propulsion Laboratory, Pasadena, California

The Telecom Forecaster Predictor (TFP) is a multi-mission computer program for analyzing deep space telecommunication links. Analysts use the TFP for link planning, performance prediction, and post-pass trending analysis. For each mission, multiple users access a controlled set of TFP software and models, but can customize their own TFP sessions. Built upon the popular MATLAB software platform, the TFP provides an environment for high-performance numerical analysis and display of results. Link configurations are specified through a user-friendly Graphical User Interface (GUI), and navigation inputs are provided through standard JPL NAIF SPICE ephemeris and attitude files, which the TFP can read directly. The TFP's building blocks are models which are created and examined using the TFP's model editing tool. Multi-mission models shared by all TFP users are provided in a carefully managed common library to avoid errors and duplication of effort. Sharing models and modeling architecture greatly accelerates the development of adaptations to support new missions. Software flow is visually traceable using the TFP's model tree. After execution, results are viewable in plot or tabular form using TFP's data visualization tools. Snapshots of link performance at a given time are provided in link budget tables.

This program was written by Kevin Tong and Ramona Tung 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.*

This software is available for commercial licensing. Please contact Don Hart of the California Institute of Technology at (818) 393-3425. Refer to NPO-20875.

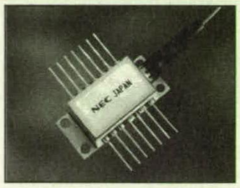
New Products

For more information on the products below, go to www.ptbmagazine.com/products.

Product of the Month

Automated Process Metrology Tool

Veeco Metrology Group, San Jose, CA, announces the Optium™ laser diode inspection system and the Optium thin-film filter inspection system, metrology tools for opto-telecom component manufacturing. The diode inspection system measures at the wafer, three-sided bar, and individual diode levels, while the filter inspection system checks high/low pass, DWDM, and gain flattening. The diode inspection system automatically locates and identifies coating, cleave, and crystal growth defects on the epi surface and facet ends, and also measures and analyzes critical lateral dimensions such as ridge width and height. The filter inspection system checks both the filter and AR sides for chips, cracks, scratches, coating defects, or contamination.



DFB 1550-nm CW Sources

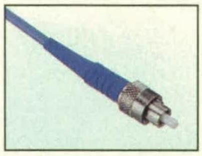
California Eastern Laboratories (CEL), Santa Clara, CA, is making available the NEC NX8562LB and NX8563LB laser diode modules. These InGaAsP distributed feedback lasers, with 10 and 20 mW power respectively, are designed to serve as 1550-nm continuous-wave light sources. CEL recommends them for long-haul DWDM, metro networks and access, and other OC-48 transmission systems in which external modulators are used. The devices are housed in hermetically sealed 14-pin butterfly packages that feature internal thermoelectric coolers and internal isolators. Spectral line width is 2 MHz.

Add/Drop WDM Products

Edmund Industrial Optics, Barrington, NJ, releases a set of high-isolation add/drop WDMs available in three wavelengths: 1310 nm, 1550 nm, and 1310/1550 nm. The product line features an insertion loss of <1.0 dB. The 1310- and 1550-nm products allow dual wavelength signals to be transmitted through the same fiber, and the combined product allows both wavelengths to be dropped and new signals added before being recombined. Operating bandwidth is ±40 nm, and wavelength isolation is >40 dB. All of the devices are compatible with PC-type FC connectors.

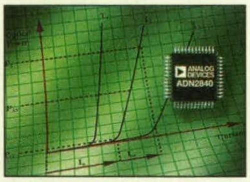
High-Power UV Spot Light Sources

Hamamatsu Corp., Bridgewater, NJ, introduces the Lightningcure LC5 UV spot light sources, which the company says is well suited for UV curing of optical parts, fiber optic connectors, and medical supplies, as well as for surface-mount device bonding and sealing of liquid crystal and other electronic parts. Hamamatsu calls the 3000-hour average life cycle the industry's best. Using a 200-W Hg-Xe lamp, the Lightningcure LC5 series delivers UV intensity of 3.5 W/cm² at 365 nm. The series is available in two models: the L8222, which permits front-panel lamp replacement, and the L8333 for rear-panel replacement.



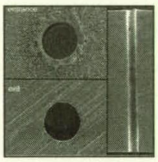
Ceramic Polarization-Maintaining Connectors

The new ceramic-ferrule FC-PC and FC-APS polarization-maintaining connectors from Rifocs Corp., Camarillo, CA, were designed for telecommunications, medical, and military applications. The cable assemblies use a stressed optical fiber and a tunable connector to control the alignment of light waves traveling down the optical path. Polarization-maintaining connectors differ from their standard counterparts in that the ferrule can be rotated around the axis of the fiber during assembly. The cable assemblies are available for 630-, 850-, 1300- and 1550-nm operating wavelengths.



Dual-Loop Laser Diode Driver

Analog Devices, Norwood, MA, calls its ADN2840 product the first 2.5-Gbps dual-loop laser diode driver in the fiber optics communications market. The company says the patent-pending design monitors and controls average power and extinction ratio by correcting for variations caused by changes in operating temperature and laser-diode degradation over time. Other features include 80-mA maximum modulation current, 100-mA maximum bias current, and 80-ps typical rise time. Applications include SONET and SDH transmitters operating at or near OC-48/STM-16 data rates.



Industrial-Grade DPSS Laser

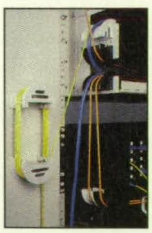
Lambda Physik, Ft. Lauderdale, FL, says its PowerGator™ IR, the latest in its series of industrial-grade DPSS lasers, microfabricates high-aspect-ratio features in hard materials more than 1 mm thick. According to the company, the laser's short 15-ns pulses improve plasma penetration, yielding features deeper than long-pulsed 1064-nm systems. The TEM_{00} near-diffraction-limited beam quality enables excellent focusability and high fluence levels of about 1 kJ/cm², Lambda Physik says. PowerGator IR was developed specifically for laser-micromachining small features of less than 50 micrometers in ceramics, silicon, and metal alloys from 0.75 mm to 1.5 mm thick.

Right-Angle Surface Mount LED

The new patented SMF-LX2432 Series right-angle surface mount LEDS from Lumex Inc., Palatine, IL, feature a 1.4-mm distance between the LED's light center and the top of the circuit board, as opposed to the more common 0.6 mm. Lumex says these LEDs allows designers of panel or fault indicators, backlighting overlays, and keypad edge-lighting systems more off-the-board height to enhance visibility away from the edges of the case. All SMF-LX2432 units feature AlInGaP or InGaN die formulations for maximum light efficiency, according to the company.

LED Ringlights

The range of compact light-emitting diode (CRL range) ringlights from StockerYale, Salem, NH, contain 100 chip-on-board LEDs combined with a single aspherically corrected lens. This architecture, the company says, gives very bright illumination with excellent uniformity and long lifetime. The standard ringlights are available in white, red, green, or blue, and custom multicolor versions are available.



Fiber Optic Radius Control

Device Technologies, Marlborough, MA, introduces a radius control module (RCM) designed to provide BICSI-recommended minimum bend radius for fiber optic cables. NEBS-compliant, the control module's snap-in-place design helps speed wiring integration efforts, the company says. The line comes in three different widths: 3.00 in. (76 mm), 1.75 in. (44 mm), and 1.00 in. (25 mm). Typical applications in telecom and datacom networks include fiber system patch panels, fiber interconnect panels, switches, routers, and multiplexers.

Diode-Pumped Solid-State Laser

The new S-Series family of lasers from Cutting Edge Optronics, St. Charles, MO, is a continuous-wave diode-pumped solid-state line that has multiple triggering options and field-replaceable components. They deliver up to 50 W continuous-wave, or they can be AO Q-switched from 1 to 50 kHz, delivering up to 35 W. Several models are available, including a TEM_{00} unit. The company says that these units will operate maintenance-free in the dirtiest industrial environments.

Measuring Contact Angles of a Sessile Drop and Imaging Convection Within It

Ordinary and laser-shadowgraph images yield valuable information.

John H. Glenn Research Center, Cleveland, Ohio

Figure 1 depicts an apparatus that simultaneously and synchronously records magnified ordinary top-view video images and laser-shadowgraph video images of a sessile drop. The real-time values of contact angle and rate of evaporation of the drop as functions of time can be calculated from the apparent diameters of the drop in the sequences of the images. In addition, the shadowgraphs contain flow patterns indicative of thermocapillary convection (if any) within the drop. These time-dependent parameters and flow patterns are important for understanding the physical processes involved in the spreading of evaporating liquids in such diverse technological applications as coating (including painting), film cooling, processing of materials, lubrication, and boiling. Study of the spreading of drops can also contribute to understanding of the spreading of biological cells.

The apparatus includes a combination light source of a collimated white-light beam and a collimated laser beam (omitted from the figure), which are used to observe the ordinary top-view images and the shadowgraphs, respectively. Charge-coupled-device (CCD) camera 1 acquires the ordinary top-view video images, while CCD camera 2 acquires the shadowgraphs. The drop acts as a plano-convex lens, focusing the laser beam to a shadowgram on the projection screen in front of CCD camera 2.

The equations for calculating the contact angle and rate of evaporation of the drop are readily derived, starting from the basic equation for the focal length of a plano-convex lens with the drop size. The derivation is simplified by invoking the assumptions that (1) the mass of the drop is sufficiently small that its shape closely approximates a section of a sphere and (2) the drop is thin enough that its focusing action can be represented adequately by the thin-lens approximation. Omitting intermediate steps of the derivation for the sake of brevity, the results are the following:

The time-dependent radius of curvature of the spherical drop surface is given by

$$R(t) = (n-1)(s+p)\frac{d(t)}{d(t)+D(t)}$$

where n is the index of refraction of the liquid in the drop, s and p are constant dimensions indicated in the figure, d is the time-dependent diameter of the

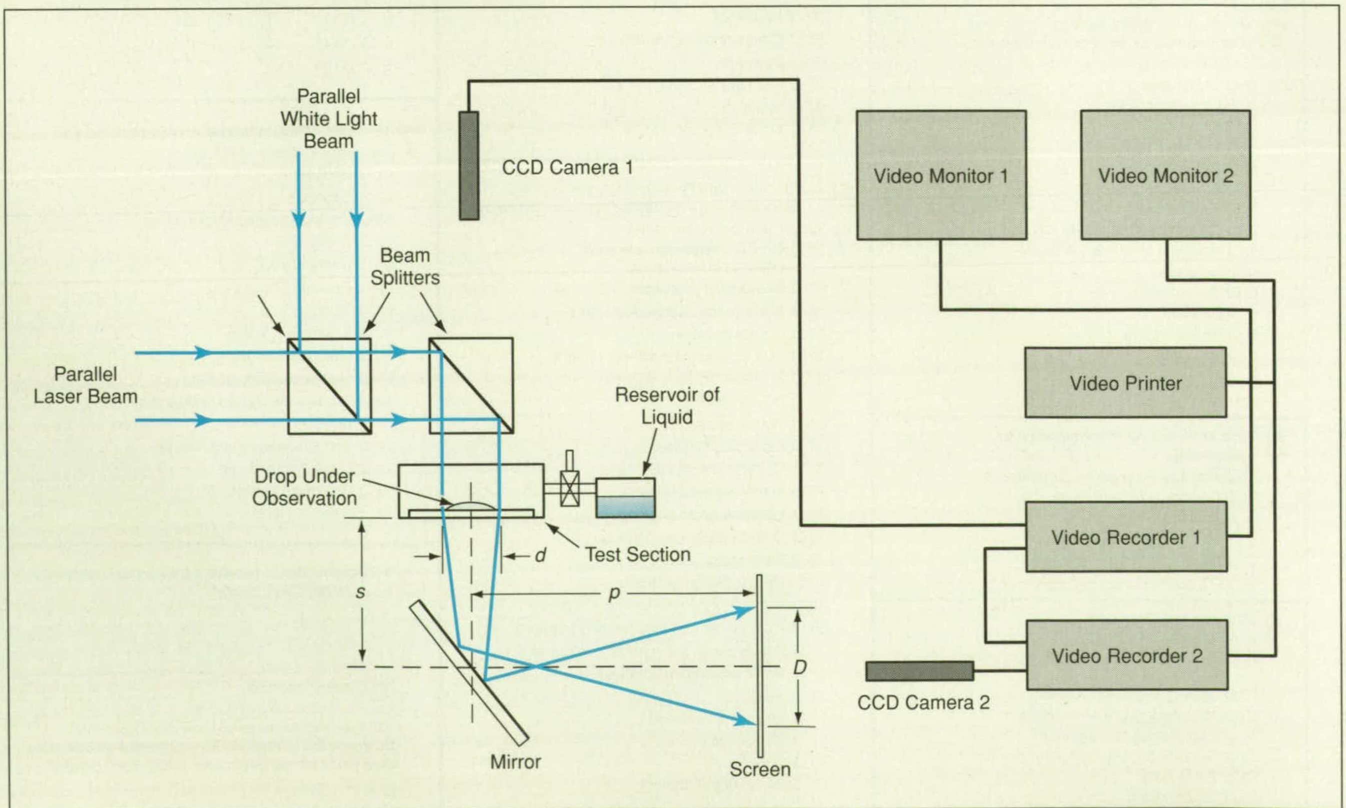


Figure 1. The **Time-Dependent Diameters *d* and *D*** measured in images acquired by cameras 1 and 2 can be used to calculate the contact angle and rate of evaporation of the drop in the test section.

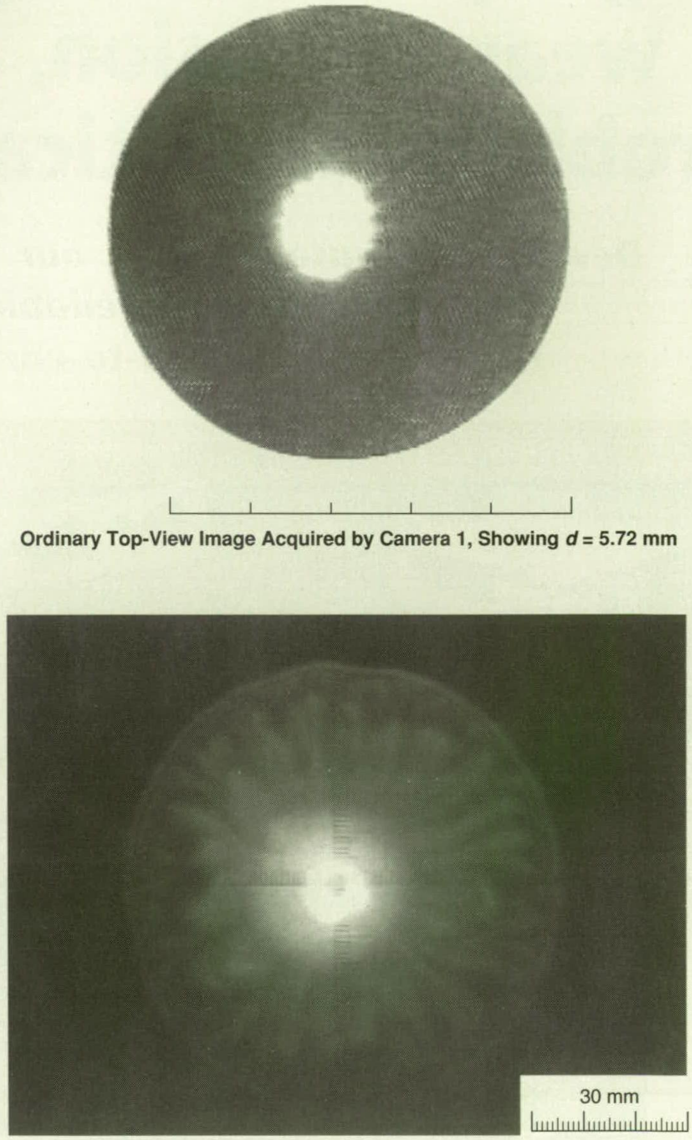


Figure 2. **These Images Were Acquired Simultaneously**, by use of the apparatus of Figure 1, during observation of an evaporating sessile drop of trichlorotrifluoroethane.

drop as measured in the ordinary image acquired by CCD camera 1, and D is the time-dependent diameter of the shadowgram as measured in the image acquired by CCD camera 2 (see Figure 2).

The time-dependent contact angle is given by

$$\theta(t) = \arcsin\frac{d(t)}{2R(t)}$$

The rate of change of volume of the drop (the negative of the rate of evaporation) is given by

$$\dot{V} = 2\pi h\dot{h}\left(R - \frac{h}{3}\right) + \pi h^2\left(\dot{R} - \frac{\dot{h}}{3}\right)$$

where

$$h = R - \sqrt{R^2 - d^2/4}$$

and the overdot signifies differentiation with respect to time.

This work was done by David F. Chao of **Glenn Research Center** *and Nengli Zhang of Ohio Aerospace Institute. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Test and Measurement 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-17075.

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Improved Encryption-Mode GPS Receiver

An auxiliary antenna is used to improve the estimate of the GPS A-code.

NASA's Jet Propulsion Laboratory, Pasadena, California

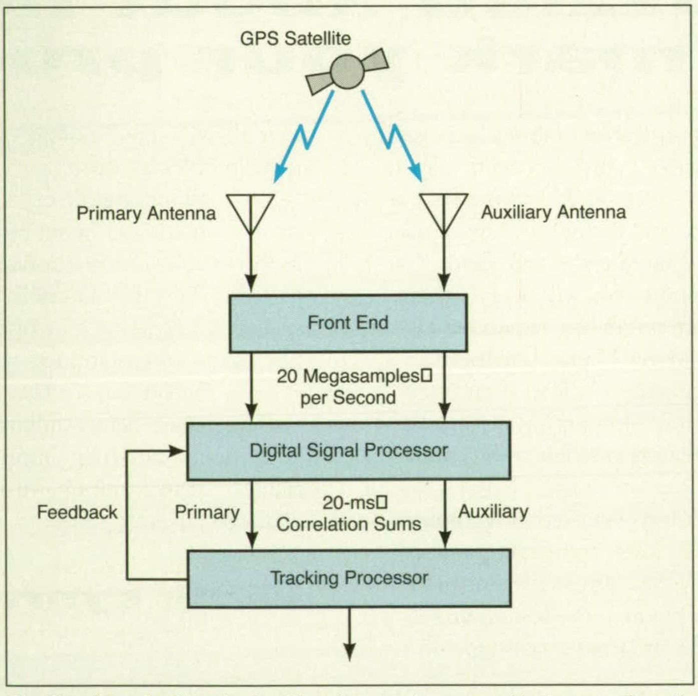
An improved Global Positioning System (GPS) receiver, which processes an encrypted P-code signal without knowledge of the encryption code (denoted here as A-codeless mode), includes an auxiliary antenna and associated additional signal-processing circuitry. The improved design of this receiver makes it possible to achieve signal-to-noise ratios (SNRs) greater than that of prior A-codeless-mode GPS receivers, especially when GPS satellites appear at low elevation angles.

The GPS P-code signals are sometimes modulated by a secret binary code, denoted here as the "A-code," for use in sensitive military and other government applications to prevent jamming signals from being accepted as GPS satellite signals. Full precision in timing and positioning measurements can be obtained by correcting for the A-code, if it is known. In the absence of knowledge of the A-code, one can still obtain useful precision by estimating the A-code.

The need for the improved design arises because, in the A-codeless mode, performance deteriorates significantly when antenna gain is low. For example, the choke-ring antennas customarily used in some GPS receivers are designed to have very low gains at low elevation angles in order to reduce multipath errors. These low gains result in low SNRs, particularly in the A-codeless mode.

The basis of the improved design is the following: The A-codeless-mode SNR of a GPS receiver can be greatly increased at low elevation angle or low gain, without compromising the multipath rejection of choke-ring antenna, by use of an auxiliary antenna with a gain pattern that complements that of the choke-ring antenna; that is, with a high gain at low elevation angles. The signal received by the auxiliary antenna is used solely to improve the estimate of the A-code in the signals received by the primary antenna. The signals received by the choke-ring or other primary antenna are subjected to the customary GPS processing to obtain delays and phases, but now the estimates of the delays and phases are improved by use of the improved estimate of the A code.

The auxiliary antenna is either placed near the primary antenna or else is part of the primary antenna structure. In the front end of the receiver (see figure), the radio-frequency signal collected by the auxiliary antenna is down-converted to baseband and converted to digital samples in the same fashion as that of the signal from the primary antenna. The resulting quadrature baseband samples are fed to a digital signal processor (DSP), where they are processed in a separate channel with the same operations as those performed on the signal from the primary antenna.



The **Signal Received by the Auxiliary Antenna** is processed to improve the estimate of the GPS A-code in the signal received by the primary antenna. The net result is an increase in the effective SNR.

The DSP operates in a feedback relationship with a tracking processor, wherein the main and auxiliary signals are tracked in separate channels by use of separate tracking loops for delay and phase in each channel. As is typical in a GPS receiver when in lock, the in-phase (I) component in each antenna channel contains almost all of the counterrotated signal strength, while the quadrature (Q) component is small and reflects the phase-tracking error.

When the stand-alone SNR of the primary channel is approximately equal to or less than the stand-alone SNR of the auxiliary channel (as when the GPS satellites appear at low elevation angles), the effective SNR for phase and delay in the primary channel can be increased by making use of the prompt I component in the auxiliary channel to improve multiplicative corrections in the primary channel that tend to remove the A-code signal from I and Q components. Logic circuitry in the tracking processor determines when and how to use the prompt I component in the auxiliary channel for this purpose. A description of how this is done would greatly exceed the space available for this article. Suffice it to say that the effective SNR for phase and delay can be increased by an amount that typically lies between 0 dB (for an auxiliary signal weaker than the primary signal) and approximately 14 dB (for an auxiliary signal stronger than the primary signal).

This work was done by J. Brooks Thomas, Thomas Meehan, and Lawrence Young 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-20784*

Low-Power, Sparse-Sampling GPS Receiver

Performance can approach that of a heavier, higher-power, full-fledged GPS receiver.

NASA's Jet Propulsion Laboratory, Pasadena, California

The term "microGPS" denotes a Global Positioning System (GPS) receiver design concept that combines relatively simple, lightweight, low-power-consumption hardware with portable, efficient software. The power demand of a microGPS receiver can be made low because it is designed to sample sparsely; that is, to "awaken" from a "sleep" mode only occasionally to sample GPS signals during short intervals. MicroGPS was conceived for navigational use aboard some small Earth-orbiting satellites for which full-fledged GPS receivers would be too complex, massive, and power hungry, and for which positioning errors as large as a few hundred meters would be acceptable as part of the price of low mass and low power consumption. The microGPS concept may also prove attractive for terrestrial applications that involve similar design tradeoffs.

The hardware of a prototype microGPS receiver aboard the Student Nitric Oxide Explorer (SNOE) spacecraft consists of a lightweight patch antenna and receiver circuits that include an inexpensive oscillator, a down-converter/sampler, and a memory chip. The receiver circuits consume a peak power of 875 mW during acquisition of samples of GPS signals and a power of 75 mW during standby (with the oscillator running, ready for commands). For the SNOE mission, GPS signal data are acquired during sampling periods 20 ms long, once every 15 minutes (about 6 times per orbit). The volume of data is about 450 kilobytes per day. The GPS samples are stored in the memory chip for subsequent processing.

In order to offer maximum flexibility in satellite design, the microGPS orbit-determination software is designed for execution either aboard the spacecraft or on the ground. In the latter case, the sparse GPS samples are telemetered to the ground and processed in post real time to compute spacecraft orbits that can be uploaded to the satellite and projected ahead for use in real time. Aboard the spacecraft, the software could be executed either in the flight computer of the spacecraft or in a special-purpose processor within the microGPS hardware unit (with slight increases in mass and power consumption).

The mass of the receiver, including the patch antenna, is only 595 g. The aspect of the receiver design that makes it possible to achieve such a low mass is a modified architecture in which all of the GPS-specific signal processing typically implemented in parallel on special-purpose hardware in other GPS receivers is, instead, implemented serially in software. Moreover, whereas the amount of computation to acquire signals in other GPS receivers is approximately proportional to N^2 (where N is the number of discrete time samples), the amount of computation is proportional to $N\ln(N)$

in this receiver due to the use of frequency-domain processing.

The sequential time-tagged GPS signal samples are down-converted, filtered, and quantized to a single bit. The receiver samples the signal at a rate of about 20 MB/s but can be programmed to perform a sum-and-dump filtering and decimation function to reduce the data rate to about 2 MB/s. The sampled data are searched in Doppler shift (over a range of ±45 kHz) and in delay [over 1 repeat cycle (1 ms) of the Coarse-Acquisition (C/A) code]. The search for GPS signals and the extraction of observables (Doppler shifts and pseudoranges) is effected by use of a Fourier-transform-based technique of time-domain correlation.

There is an important distinction between the usual GPS pseudorange and the pseudorange in microGPS: Whereas the usual GPS pseudorange represents absolute, unambiguous range (plus transmitter and receiver clock offsets), the reliability of the pseudorange in microGPS is limited by an ambiguity of 1 ms (300 km); this is because the 20-ms sampling period is not long enough for either decoding the GPS navigation-data message (and thus GPS time is unavailable) or reliably determining the times of the bit transitions of the message.

The range ambiguity is resolved by further processing in three steps. First, a crude (accurate to within 50 km) orbit is computed by use of the Doppler data from multiple GPS satellites. Next, a set of unambiguous range data is computed from a combination of this crude orbit and the GPS-satellite orbits, which are known to far better accuracy. Finally, the ambiguity is resolved by direct comparison of this unambiguous set of computed range data with the ambiguous microGPS pseudorange data.

This work was done by Stephen Lichten, Thomas Meehan, Jeffrey Srinavasan, Sien-Chong Wu, and Lawrence Young 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.*

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-20835, volume and number of this NASA Tech Briefs *issue, and the page number.*

Software

Software Models Spacecraft Dynamics and Space Environment

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Toolbox for MATLAB reduces control-system design time and cost.

Princeton Satellite Systems, Princeton, New Jersey

The Spacecraft Control Toolbox (SCT) helps design control systems and attitude estimators, analyze station-keeping requirements, generate fuel and pointing budgets, and analyze spacecraft dynamics. The SCT provides a comprehensive set of over five hundred functions including:

- Attitude dynamics modeling including flexible and multi-body spacecraft
- Orbit dynamics analysis and simulation
- Spacecraft control system design and analysis
- Attitude estimation
- Ephemeris calculation
- Environmental modeling including atmospheric, gravitational, and magnetic field
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- Spacecraft visualization
- Extensive database of useful parameters

Princeton Satellite Systems (PSS), in cooperation with Innovation Chain, has made a number of these functions available for general use through the *NASA Tech Briefs* Model and Simulation Exchange website (http://nasatech.innovationchain.com/first.asp). The "Jacchia 1970 Atmospheric Model" and the "Keplerian Elements to Radius and Velocity Vectors Model" (http://nasatech.innovationchain.com/solution.asp?SN=202) are two of the SCT functions available.

The Jacchia 1970 Atmospheric Model computes the atmospheric density using Jacchia's 1970 model as presented in "Models of the Earth's Atmosphere (90-2500 km)," NASA Publication SP-8021. Users enter the desired orbital location (latitude, longitude, and altitude), date, and time, as well as the geomagnetic and solar flux conditions. The model calculates the atmospheric density at that location. The model also outputs the atmospheric temperature, mean molecular mass, and number densities of nitrogen (N_2), helium (He), and oxygen (O and O_2). It is valid for altitudes between 90 km and 2500 km.

You can use the results of this model to calculate atmospheric drag forces and torque on a particular spacecraft. These values allow you to size actuators and generate fuel budget. The Spacecraft Control Toolbox provides a number of additional functions to simplify these calculations. You also can perform combined altitude and orbit simulations with environmental disturbances to verify the performance of your control systems.

The "Keplerian Elements to Radius and Velocity Vectors Model" is one of the many conversion utilities in the SCT. To use it, you enter the Keplerian orbital elements of a satellite and the function converts these elements into orbital radius and velocity vectors in the Earth-Centered-Inertial (ECI) frame. A complementary function performs the reverse conversion. These utility functions, along with the many others available in the Spacecraft Control Toolbox, enable users, even non-specialists, to quickly and easily convert between the various coordinate systems that astrodynamicists and attitude control engineers use.

The models presented on the *NASA Tech Briefs* Model and Simulation Exchange (http://nasatech.innovationchain.com/first.asp) are a sample of the full functionality of the SCT. The complete toolbox enables you to design and test control systems in hours, instead of days or weeks. Among the other sophisticated models in the toolbox is a topological tree multi-body model.

This work was performed by employees at **Princeton Satellite Systems.** *For more information on the Spacecraft Control Toolbox, contact Derek Surka at dmsurka@psatellite.com, or visit the PSS web site at www.psatellite.com.*

Software for Parallel Adaptive Refinement of Meshes

NASA's Jet Propulsion Laboratory, Pasadena, California

A software library has been developed for adaptive refinement of unstructured (that is, irregular) tetrahedral or triangular meshes that define two- or three-dimensional coordinates or volume elements used in parallel (that is, multiprocessor) finite-element or finite-volume computations. This library contains a suite of well-designed and efficiently implemented software modules that perform the operations of typical parallel adaptive-mesh-refinement (AMR) processes. An especially notable one of these operations is mesh quality control, typically guided by a local-error estimator, during successive parallel adaptive refinements. Another is balancing of computational loads among parallel processors. The library is robust and is scalable to different numbers of processors. The software in this library was developed in Fortran 90, plus a message-passing interface (MPI) sublibrary. The design of this library supports code efficiency, modularity, and portability. At present, the library is in use on a Cray T3E and SGI Origin computers and on a Beowulf-class cluster of personal computers.

This program was written by John Z. Lou and Charles Norton 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 Software category.*

This software is available for commercial licensing. Please contact Don Hart of the California Institute of Technology at (818) 393-3425. Refer to NPO-20948.

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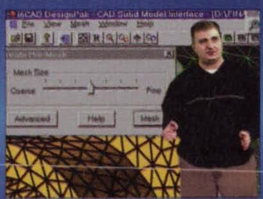
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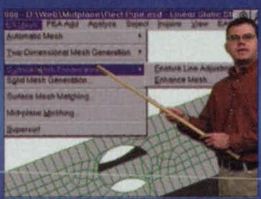
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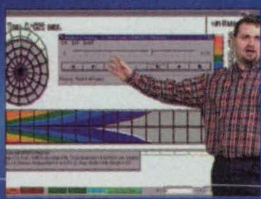
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Web-Based Software for Distributed Planning

NASA's Jet Propulsion Laboratory, Pasadena, California

The RecDel System is a low-cost software application that helps different groups of a complex project negotiate interfaces between interdependent schedules. The RecDel system is based on a concept of distributed planning, wherein the cognizant persons retain control over, and responsibility for, their own work; this contrasts with traditional centralized planning, in which responsibility and control are effectively transferred to central planners. RecDels are products, which flow between different areas of a project. The RecDel System makes it possible to identify product-specification and delivery-schedule disputes easily, solve problems quickly, eliminate schedule confusion, and verify receipt of deliveries. The RecDel System also supports action-item tracking as well as a limited earned-value capability. The outputs of the RecDel System include metric charts, Gantt charts, and a variety of text reports. Schedule reports can be generated at any time on any computer by any user for any level of the work breakdown structure. The RecDel System aids projects to effectively meet the demand for Faster, Better, Cheaper.

This program was written by Jacqueline Dunn, Steve Friedman, Glen Gira, Mark Girdner, Cate Heneghan, Michael W. Hughes, Richard G. Markley, Jancis Martin, Siuan McGahan, and Karen Morrissett 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 Software category.*

This software is available for commercial licensing. Please contact Don Hart of the California Institute of Technology at (818) 393-3425. Refer to NPO-20915.

Software for Detecting Tones in Beacon Monitoring

NASA's Jet Propulsion Laboratory, Pasadena, California

A software package for use in a ground receiving station detects a beacon-monitor tone transmitted by a spacecraft. To recapitulate from previous *NASA Tech Briefs* articles on beacon monitoring: An onboard computer processes data from onboard sensors to summarize the condition of the spacecraft in terms of one of four standard statuses, then a message is transmitted on a radio-frequency carrier as phase modulation at one of four subcarrier frequencies that correspond to the four statuses. The present software implements a weak-signal-detection algorithm. The received signal is heterodyned at nine frequencies and recorded into nine corresponding frequency bands. Nominally, there is a center carrier and four pairs of symmetrical status bands. After recording, each frequency band is subdivided into subbands with a fixed temporal duration. Within each frequency subband, there is a bank of time-sequenced subband processors. The optimal linear path in the corresponding time-frequency band space is obtained by maximizing the summed squared signal amplitudes. The maximum summed subband-processor output is selected and compared to a predetermined threshold to determine whether the corresponding status message should be deemed to have been transmitted. The frequency drift of the status tone signal must be small enough to allow the search algorithm to detect the signal over a time long enough to provide a low signal-detection threshold.

Contributors to the development of this software package were Sue Finley, Gabor Lanyi, Robert Sherwood, Miles K. Sue, John Szijjarto, and E. J. Wyatt 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 Software category.*

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Automated Real-Time Spacecraft Navigation System

NASA's Jet Propulsion Laboratory, Pasadena, California

The Automated Real-Time Spacecraft Navigation (ARTSN) system is a prototype of a class of software systems for automated navigation and monitoring of spacecraft from stations on the Earth. The system processes radio metric tracking data (principally, range and Doppler measurements) in real time to generate updated spacecraft navigation solutions (including projections of trajectories into the past and future), and associated covariances. The ARTSN system enables the navigation operations analyst to identify and respond to anomalies in nearly real time, when such action is most effective. In this system, validation of data and estimation of parameters for real-time trajectory and target updates are data-driven; these functions are triggered by receipt of radio metric tracking data. The system provides "one step" access to important information; the traditionally separate software components that effect the functions of generating trajectories, computing observable parameters, filtering, and mapping are integrated into the one "engine," which can be queried in real time (or off line) by a shell command (or function call) to provide state, partial-derivative, or covariance information.

This work was done by Laureano Cangahuala, Theodore Drain, Paul Burkhart, and Vincent Pollmeier 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 Software category.*

This software is available for commercial licensing. Please contact Don Hart of the California Institute of Technology at (818) 393-3425. Refer to NPO-20426.

Metal-Supported Catalyst Beds for Reacting CO_2 With CH_4

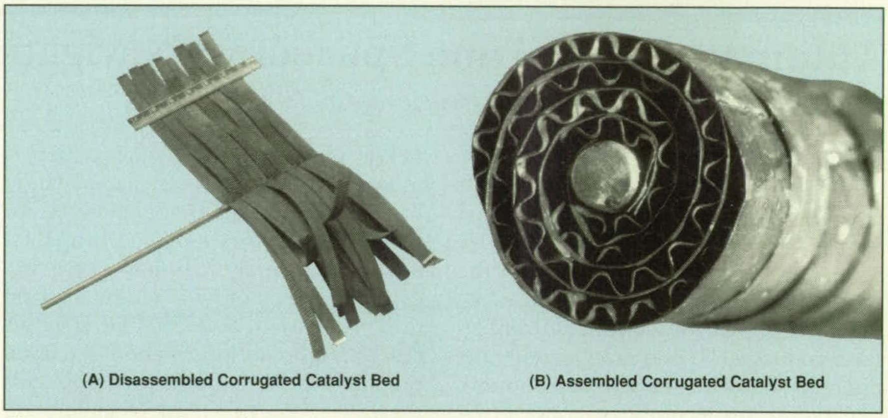
The beds are heated internally, by passing electrical currents through the supports.

NASA's Jet Propulsion Laboratory, Pasadena, California

Metal-supported catalyst beds with improved thermal and flow characteristics for promoting endothermic chemical reactions are undergoing development. In the proposed original application, catalyst beds of this type would be used on Mars to produce hydrogen from an endothermic reaction between carbon dioxide and methane. The empirical equation for this reaction is:

$$CO_2 + CH_4 \rightarrow 2CO + 2H_2$$

(The subsequent reaction of carbon monoxide with water will generate additional hydrogen as shown in $CO + H_2O \rightarrow CO_2 + H_2$.) Hydrogen is then available as a propellant for launching payloads from the Martian surface or as a fuel for fuel cells generating power for surface mobility or stationary electricity.



This **Prototype Catalyst Bed** contains overlapping pairs of smooth and corrugated metal strips. The strips are covered by a washcoat of alumina, in which particles of platinum and rhodium (the catalysts) are dispersed.

The basic principles of operation of these catalyst beds are also applicable to steam reformers and other catalytic reactors used on Earth to produce fuels and some specialty chemicals. With respect to endothermic reactions that one seeks to catalyze, the developmental catalyst beds offer advantages over traditional packed catalyst beds, as explained below.

In a typical traditional case, the heat needed for an endothermic reaction is generated outside a reactor and transferred through the reactor wall to a bed of packed catalyst particles inside the reactor. The energy efficiency of the reactor is diminished because (1) the thermal resistance of the wall and (2) the parasitic loss of heat from the external heater to the environment.

A catalyst bed of the type now undergoing development consists of a metal support coated with a material that consists of, or contains, one or more catalyst(s). The center mandrel and the outside wall of the metal support are connected to a source of dc electric power. In operation, the metal support is heated by passing an electric current through it. Efficiency is increased because the losses associated with the thermal resistance of the reactor wall and parasitic transfer of heat from an external heater to the environment are eliminated. In addition, because heat is supplied to the catalyst more directly, it is possible to exert better control over the endothermic reaction.

The metal support is corrugated (see figures) to make the reactants flow turbulently; this feature enhances (relative to the packed-bed case) both the mixing of the reactants and the transfer of heat from the support to the reactant mixture. As a result of the combination of internal electrical heating and turbulence, the overall conversion efficiency for a reactor of a given size is increased or, equivalently, the size of the reactor needed to achieve a given conversion efficiency is reduced. Moreover, the degree of utilization of catalyst applied to the surface of the internally heated support is greater than the degree of utilization of catalyst in or on conventional catalyst rings, cylinders, and pellets, so that less of the catalyst is needed to drive a reaction with a given conversion efficiency.

This work was done by Gerald Voecks 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 Materials category.*
NPO-20484

Chemical Reactors Based on Catalyzed Wires

These reactors could offer advantages over traditional packed catalyst beds.

NASA's Jet Propulsion Laboratory, Pasadena, California

In catalytic flow-through chemical reactors being explored for space vehicle applications, the catalysts would be supported on the surfaces of wires, instead of on particles, as are typically used in traditional packed beds. The original intent of the proposal was to make it possible to build controllable, efficient catalytic hydrazine-decomposition microthrusters for small spacecraft. The basic concept of the proposal should also prove applicable to other flow-through catalytic reactors; for example, reactors that could be used in removing trace contaminants from the environment.

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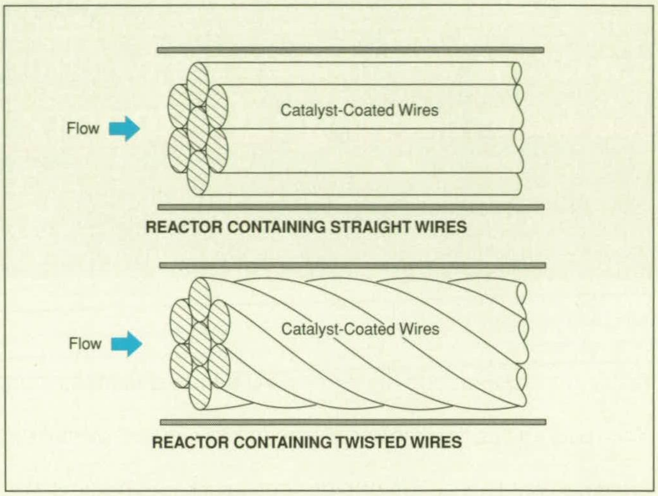

Catalyst-Coated Wires would be placed in tubular reactors, where they would make contact with flowing reactants. The wires could be straight or twisted, depending on the required characteristics of the flow. Other aspects of the wire and tube geometries and the nature of the catalytic coating(s) could also be chosen to suit the application.

Traditional packed catalytic beds have several disadvantageous characteristics that make control difficult and that pose obstacles to scaling down to the microthruster size range. These characteristics include high back pressures through the beds, attrition due to friability and spalling of catalyst particles, and difficulty of fabrication in small sizes. Usually, as a result, it becomes necessary to make the beds larger than desired, with the further result that propellant is wasted and thermal masses are large (and therefore response times are undesirably long).

The basic concept of the catalyzed-wire reactor allows for adaptation to numerous variations. A reactor of the proposed type could be as simple as a straight tube containing a single catalyst-coated wire suspended on the cylindrical axis. The wire and catalyst could be made of any of a variety of materials; for example, in one application, there might be a need for a tungsten wire with a washcoat (e.g., alumina) supporting a catalyst like platinum. In most cases, multiple catalyst-coated wires would likely be needed. Different wire material could be coated with different catalysts that would be optimized for different reaction temperatures. Catalyst preparation procedures (i.e., washcoat, catalyst, inclusion, etc.) would follow the protocols typically described for metal-supported catalysts. Wires could be made straight or twisted (see figure), wires could be all of the same diameter or of different diameters, and wires could be spaced apart at various distances; the foregoing choices could be made in conjunction with the choice of the shape and inside dimensions of the reactor, all in an effort to optimize the flow or to accommodate a wide range of flow variables in the reactor.

This work was done by Gerald Voecks, J. Morgan Parker, Amy Herr, and Juergen Mueller 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 Materials 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

Technology Reporting Office
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Pasadena, CA 91109
(818) 354-2240

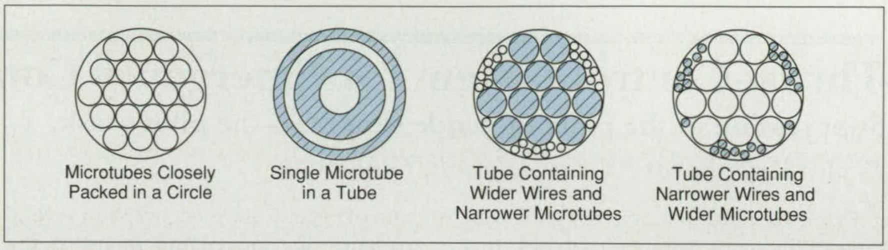
Refer to NPO-20507, volume and number of this NASA Tech Briefs *issue, and the page number.*

Chemical Reactors Based on Catalyzed Microtubes

Microtubes would help to damp pressure excursions that disturb desired flows.

NASA's Jet Propulsion Laboratory, Pasadena, California

In an extension of the concept reported in the preceding article, catalytic flow-through chemical reactors of a proposed type would contain catalyst-coated microtubes, possibly in combination with catalyst-coated wires. In addition to the advantages afforded by the catalyst-coated wires described in the preceding article, the microtubes would offer a capability to damp sudden increases in pressure.



Catalyst-Coated Microtubes would be placed in tubular reactors, possibly along with wires. The sizes, shapes, and materials of the reactor components would be chosen to obtain the desired combination of fluid-dynamic, thermal, and chemical characteristics.

In the original rocket-thruster application, such a pressure excursion can occur upon ignition of a propellant fluid in a catalytic reactor; the pressure excursion can cause blow-back and/or pooling of propellant fluid in the propellant-supply system and/or in the reactor; this causes a departure from the desired mode of operation. Therefore, it is desirable to damp the pressure excursion.

In designing such a reactor according to the proposal, one would provide that the microvoids in the microtubes contain sufficient volume to accommodate the rapid expansion that occurs upon ignition of the propellant. The basic concept of catalyzed-microtube reactors admits of numerous variations, including variations like those described in the preceding article for catalyzed-wire reactors. In addition, a reactor could contain one or more microtube(s), possibly with one or more wire(s). Diameters of tubes and/or wires could be varied to allow cross flow in addition to the main flow along the reactor. Some wires and/or tubes could be catalyzed and some uncatalyzed. Some could be thermally conductive, some thermally insulating. These and other variations could be effected in an effort to optimize the fluid-dynamic, thermal, and chemical aspects of operation over the anticipated range of flow variables.

This work was done by Gerald Voecks, J. Morgan Parker, John Blandino, and David Bame 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 Materials category.*

NPO-20508

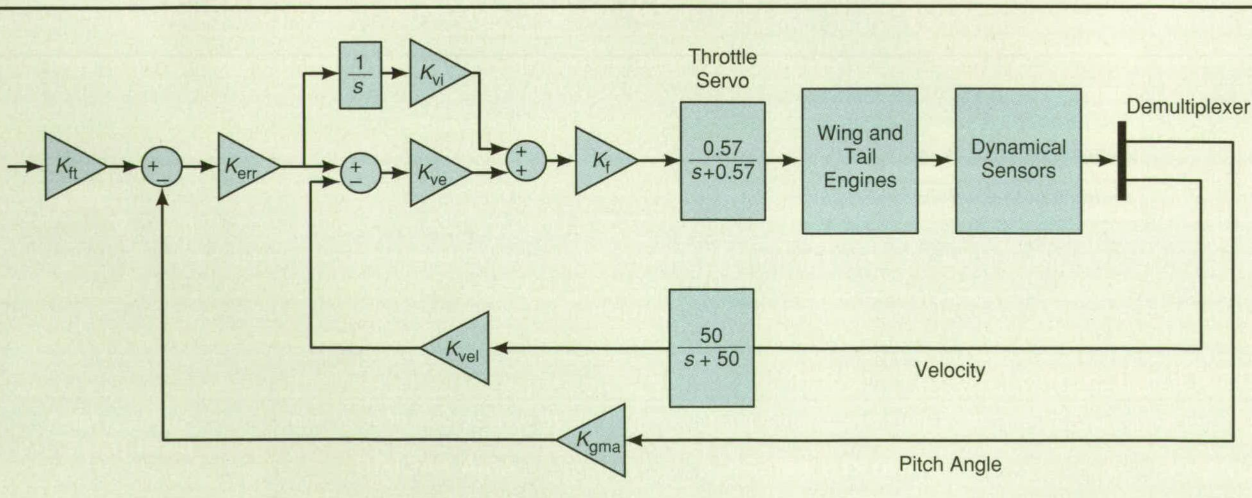
Thrust-Control System for Emergency Control of an Airplane

Suppression of the phugoid mode simplifies the pilot's task.

Dryden Flight Research Center, Edwards, California

Extensive redundancy is designed into aircraft flight-control systems to ensure a low probability of failure. During recent years, however, major failures of flight-control systems have occurred in several airplanes, leaving engine thrust as the flight-control mode of last resort. In some of these emergency situations, engine thrust was successfully modulated by the pilots to maintain flightpath or pitch angle, but in other situations, lateral control was also needed. In the ma-

MD-11 AIRPLANE LANDING UNDER THRUST CONTROL ONLY
(CONTROL SURFACES NOT MOVING)



AUTO-THROTTLE SERVOCONTROL SYSTEM

Figure 1. This **Auto-Throttle Servocontrol System** responds to velocity and pitch-angle feedback by modulating engine thrust to damp the phugoid oscillation and maintain a commanded pitch angle, making it possible to land the MD-11 airplane by use of thrust control only.

jority of such cases, crashes resulted, and over 1,200 people died because of control-system failures.

Thus, the challenge has been to create sufficient thrust-modulation control to safely fly and land an airplane. A thrust-modulation control system designed for this purpose was flight-tested in a propulsion-controlled aircraft (PCA) — an MD-11 airplane. The results of the flight test showed that without any operational control surfaces, one can land a "crippled airplane" (U.S. Patent 5,330,131). This flight program also verified that the

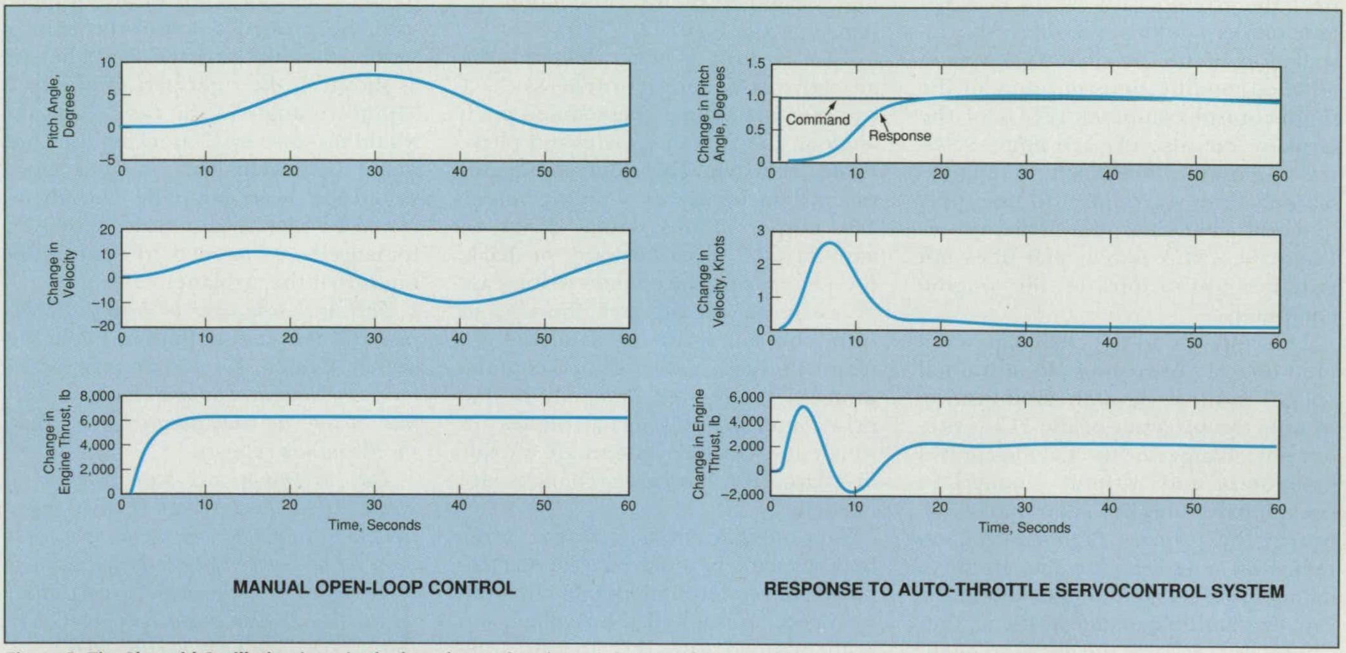


Figure 2. The **Phugoid Oscillation** is excited when the engine thrust is increased in manual open-loop control. The plots in the left part of this figure represent the dynamics of an MD-11 airplane in which the thrust of each of the wing engines has been increased by 6,000 lb (≈27 kN). On the other hand, the phugoid oscillation is suppressed when the system of Figure 1 is used to control the wing and tail engines.

"weak link" is the phugoid mode, which is also known as the long-period pitch mode. The low phugoid damping and a high pilot workload made manual landings exceedingly difficult near the ground. However, a PCA system makes landings feasible. The installation of the original PCA system entailed modifications not only of the flight-control computer (FCC) of the airplane but also of each engine-control computer. Inasmuch as engine-manufacturer warranties do not apply to modified engines, the challenge was to create a PCA system that does not entail modifications of the engine computers.

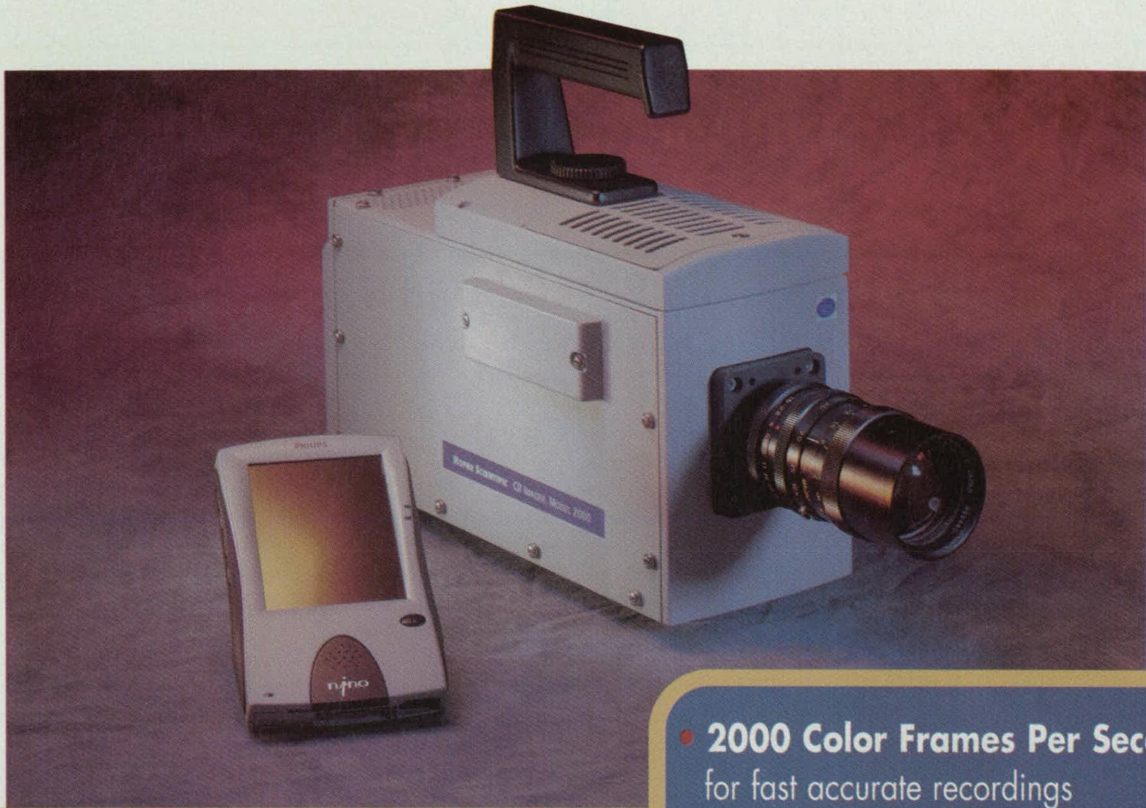
The response to the challenge was a method of providing longitudinal (pitch) control through modification of only the program of the FCC, without any changes in the engine-control computers and without changes in cockpit hardware. In the event of a failure in the primary flight-control system, the engines can be used to dampen the phugoid mode, and in the case of a multiple-engine airplane, they can be used to land the airplane safely. This method relieves the pilot of the longitudinal-control task, enabling the pilot to concentrate on using differential thrust to keep the wings level for landing. This may seem difficult at first, but lateral control is made simpler when the phugoid motion is highly damped by the closed-loop system shown in Figure 1.

This control system, denoted the auto-throttle servocontrol system, strives to maintain a commanded pitch angle in the face of velocity and pitch-angle feedback. The pilot commands this system by use of a thumb wheel. The output of this system drives an auto-throttle servo forward or back, thereby causing the engines to increase or decrease thrust, and thereby, in turn, controlling the pitch of the airplane in such a way as to keep the phugoid mode well damped. In the many multiple-engine airplanes in which auto-throttle systems are already in place, no hardware changes are needed.

Suppose that one were flying a wide-body airplane in which control surfaces had been rendered inoperable by a full hydraulic failure and the airplane was not equipped with the present auto-throttle servocontrol system. In order to increase the pitch angle, one would slowly increase the thrust, as shown in the left part of Figure 2. As the thrust was increased, the phugoid mode would be excited, causing the pitch and velocity to oscillate. On the other hand, if the airplane were equipped with the present auto-throttle control system, then the airplane would behave as shown in the right part of Figure 2. The pitch angle in the case illustrated would increase by 1°, tracking the command very well. The phugoid mode would be well damped. The thrust would be increased and decreased automatically, as needed to control the motion of the airplane.

This work was done by John J. Burken and Bill Burcham of **Dryden Flight Research Center.** *For further information, access the Technical Support Package (TSP) free on-line at* ***www.nasatech.com*** *under the Mechanics category.*

This invention has been patented by NASA (U.S. Patent No. 6,041,273). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to Technology Commercialization Office, Dryden Flight Research Center; (661) 276-3720. Refer to DRC-96-07.



Weld Repair of a Directionally Solidified Superalloy Article

The weld is also directionally solidified to preserve the desired grain structure.

John H. Glenn Research Center, Cleveland, Ohio

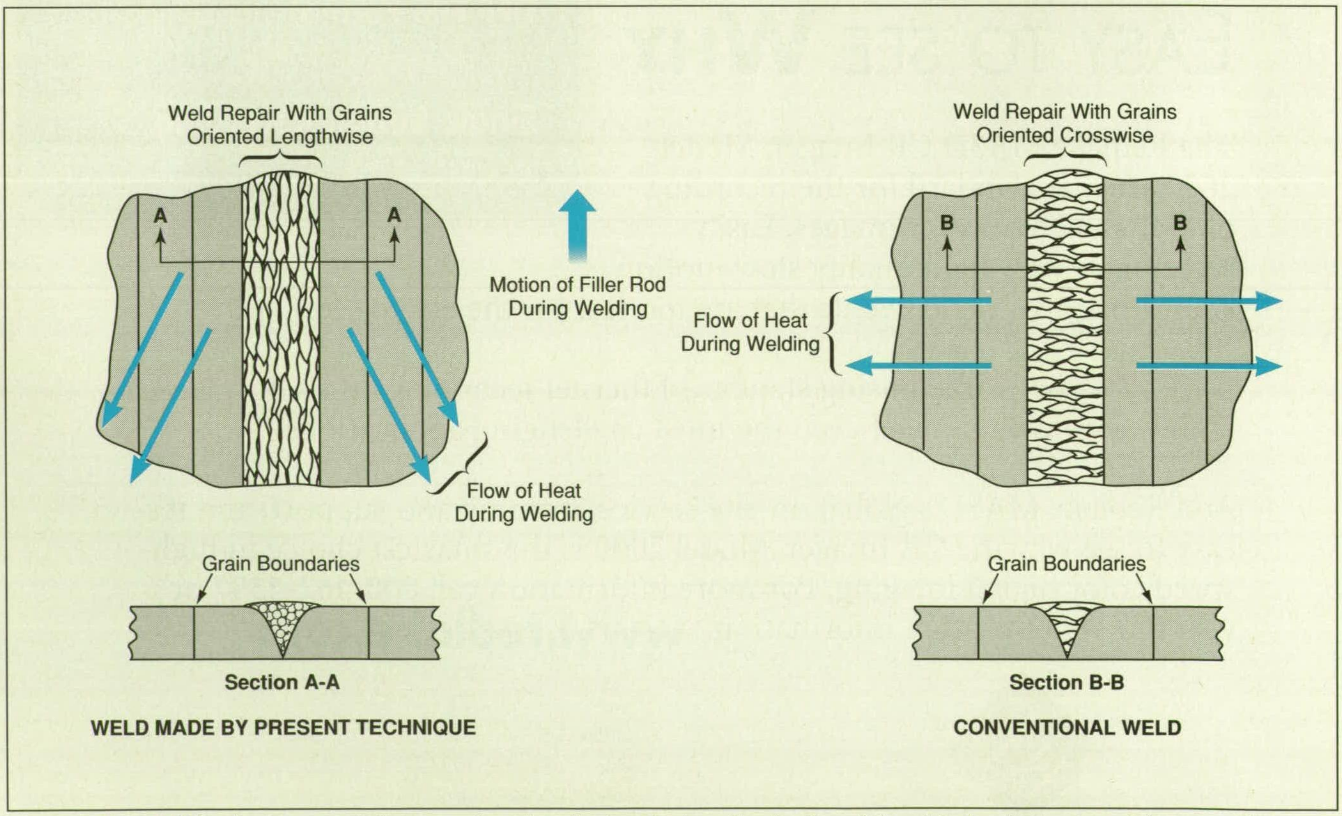
An arc-welding technique for repair of a directionally solidified (DS) nickel-base superalloy article (e.g., a turbine blade or vane) has been devised. The technique equally is applicable to a part as cast or a part that has been damaged in use. Unlike ordinary gas tungsten arc (GTA) welding, this technique results in a predominantly DS microstructure in the repaired region, similar to the microstructure of the DS casting. In addition, whereas ordinary GTA welding often involves the use of a filler material different from that of the workpiece, the weld filler material used in the present technique is of the same composition as that of the DS casting, so that undesired localized chemical differences are not introduced into in the repair region.

In this technique, the weld-repair area is shielded from atmospheric contamination; typically, shielding is accomplished by placing the article in a chamber that contains a protective argon atmosphere. To minimize residual stress and distortion, the article is maintained at a high temperature (approaching the liquidus of the DS material) while the weld is being made. After the welding arc is struck, the weld filler rod is moved along the repair region parallel to the direction of the original grain structure of the article. The filler material solidifies by epitaxial nucleation and growth of grains as typically observed on most weld repairs.

The unique feature of this technique is the combination of the directional deposition of the filler material and the high process temperature. This feature promotes directional grain growth parallel to the original DS grain structure. As shown in the figure, this is much different from the microstructure of a conventional GTA weld, in which there are typically two rows of converging, columnar grains, the major axes of which are perpendicular to the direction of the original DS structure.

This work was done by Russell Wayne Smashey, John Herbert Snyder, and Bruce Leanard Borne of General Electric Co. for **Glenn Research Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Manufacturing/Fabrication 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-16865.



The **Grains in a Weld** by the present technique are oriented predominantly along the direction of the original grain structure of the surrounding material, whereas the grains in a conventional GTA weld are oriented perpendicularly.

Field-Reversed Magnetic Mirrors for Confinement of Plasmas

The mirror magnetic-flux density needed for confinement would be reduced.

Marshall Space Flight Center, Alabama

A field-reversed configuration (FRC) has been proposed for a magnetic mirror — a solenoidal electromagnet configured and operated in such a way as to effect at least partial confinement of a plasma. Magnetic mirrors had been investigated for potential use as plasma-confinement devices in nuclear fusion reactors, and had been largely rejected for that use because, as explained below, they allow too much plasma to escape. The proposed FRC is intended to increase the degree of confinement achievable by a mirror magnetic field of a given flux density and/or to reduce the flux density needed to obtain a given degree of confinement. (Whether the increase in effectiveness of confinement would be sufficient to justify the use of magnetic mirrors in fusion reactors remains to be seen.)

The figure depicts baseline and FRC versions of a typical magnetic mirror at one end of a fusion reactor. In the baseline version, the magnetic mirror is only partially effective in that a substantial amount of plasma escapes along the magnetic field lines at the outer end. Efforts to reduce the rate of loss of plasma by increasing the mirror magnetic field have been unsuccessful because the required mirror magnetic-flux density is unrealistically high. Other measures intended to reduce the width of the throat through which the plasma escapes have been only partially successful; these measures include the use of multiple mirrors and of various types of thermal barriers.

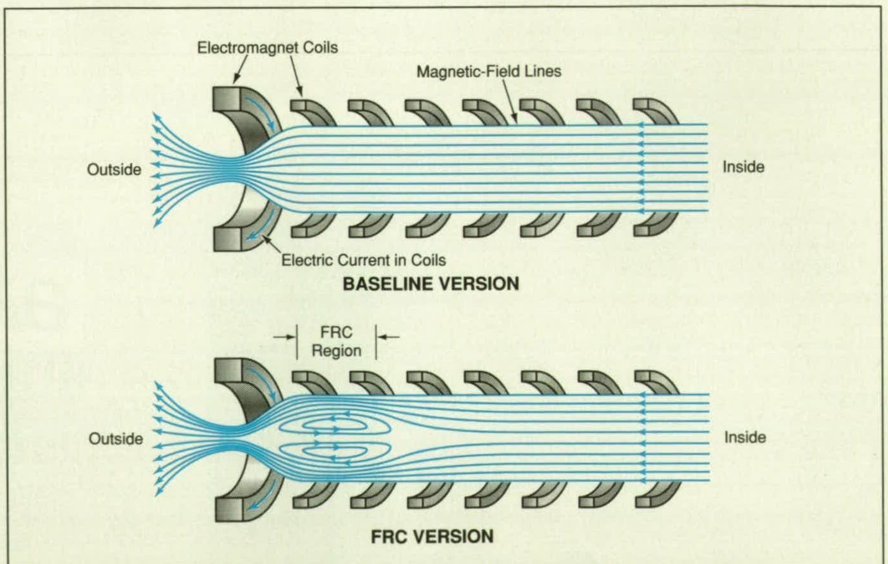
In the terminology of plasma science as applied to a magnetic mirror like the one shown in the figure, "field-reversed configuration" ("FRC") refers to a family of compact toroidal magnetic-field/plasma formations in which an azimuthal electron current flows and gives rise to a poloidal magnetic-field component that can be strong enough to reverse the polarity of the magnetic induction along the cylindrical axis. FRCs have been investigated previously, but not for the use proposed here.

According to the proposal, the FRC would reduce the loss of plasma by at least partly plugging the throat of the magnetic mirror. The requirement for design and operation of the magnetic-mirror magnets would be reduced to one of constricting the throat (as defined by the magnetic-field lines) just enough to prevent expulsion of the FRC plug; it should be considerably easier to satisfy this requirement than to attempt to reduce the loss of plasma by applying a magnetic field strong enough to constrict the throat severely.

Further research will be necessary to identify the best technique for effecting the FRC. One notable technique, pioneered at the University of Washington, involves the superposition of a magnetic field that rotates at a frequency between the electron and ion gyrofrequencies. Under some circumstances, such a magnetic field can give rise to a stable, persistent FRC.

This work was done by William J. Emrich, Jr., of **Marshall Space Flight Center**.

This invention is owned by NASA, and a patent application has been filed. For further information, contact Sammy Nabors, MSFC Commercialization Assistance Lead, at (256) 544-5226 or sammy.nabors@msfc.nasa.gov. Refer to MFS-31289.



A **Toroidal Plasma/Magnetic-Field Plug** would be formed in the FRC version and would retard the loss of plasma through the magnetic mirror.

Updated Multidisciplinary Optical-System-Analysis Software

NASA's Jet Propulsion Laboratory, Pasadena, California

Version 5.0 of the Integrated Modeling of Optical Systems (IMOS) software has been released. A previous version was described in "Software for Multidisciplinary Analysis of Optical Systems" (NPO-20536), *NASA Tech Briefs*, Vol. 24, No. 11 (November 2000), page 36. In both versions, IMOS is a MATLAB™ computer program that provides many functions for analysis of a system represented by mathematical models of its thermal, structural, control, and/or optical aspects. IMOS is unique in making it possible to perform the entire multidisciplinary analysis in one program. The new features incorporated into version 5.0 include a capability for calculating stresses in rods and beams, a utility subprogram that generates equivalent properties of laminates, a three-dimensional-viewing subprogram, a provision for temperature-dependent heat input for thermal analyses, a provision for a simulated stiffness for the drilling degree of freedom of a plate structural element, a provision for a lumped-mass formulation for a beam, a capability to orient properties of materials with respect to plate structural elements, plate-to-acoustic and beam-to-acoustic connections for statistical energy analysis, geometric stiffnesses for plate elements (for buckling analysis), subprograms for translation from the SINDA program to IMOS and from IMOS to the NASTRAN program, and greatly improved subprograms for translation from IMOS to SINDA and from NASTRAN to IMOS.

This program was written by Laura Needels, Hugh C. Briggs, Daniel Eldred, Robert Glaser, Andrew Kissil, Marie Levine, James Melody, Mark Milman, Robert Norton, Miltiadis Papalexandris, Terry Scharton, Samuel Sirlin, Tricia Sur, Wan Tsoi, and Walter Tsuha 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.*

This software is available for commercial licensing. Please contact Don Hart of the California Institute of Technology at (818) 393-3425. Refer to NPO-20849.

RVSM Certification of Dryden DC-8 Airborne Laboratory

A required pressure-altitude accuracy of ±160 ft (±49 m) has been achieved.

Dryden Flight Research Center, Edwards, California

The NASA Dryden DC-8 Airborne Science Laboratory (see Figure 1) performs research around the globe, recently in support of the SAGE III Ozone Loss and Validation Experiment (SOLVE). This experiment operated in the North Atlantic airspace region, which is subject to reduced vertical separation minimum (RVSM) requirements (see Figure 2). These requirements allow aircraft traffic to be separated vertically by a minimum of 1,000 ft (304.8 m) at altitudes between 29,000 and 41,000 ft (between 8.84 and 12.50 km) above mean sea level, in contradistinction to the usual vertical separation of 2,000 ft (0.61 km). RVSM non-group aircraft compliance requires a pressure-altitude accuracy within ±160 ft (±49 m). RVSM allows greater traffic density while maintaining safe aircraft separation.

A commercial service for RVSM certification was considered, but involved significant modification of the aircraft, high cost, and an unacceptable effect on the schedule of airborne scientific research for which commitments had been made. Instead, it was decided to perform the RVSM certification internally, with insignificant modification of the aircraft, at minimal cost, and with little effect on the schedule. The objective of the certification effort was to achieve the required accuracy of ±160 ft (±49 m) through an airdata calibration of the DC-8 static-pressure system.

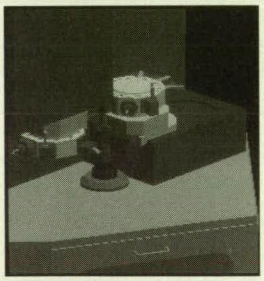
RVSM-quality airdata computers were installed in the DC-8 airplane, and the data were recorded by use of a data-acquisition and -distribution system (DADS) that is part of the standard laboratory equipment in the aircraft. These airdata computers have a worst-case avionics error of 85 feet (26 m) after 24 months. For the calibration flights, a carrier-phase differential Global Positioning System (DGPS) receiver and antenna were employed. The DGPS gave geometric altitude of the aircraft to an accuracy better than 2 feet (0.6 m). A pressure calibration of the atmosphere on flight-test days was

Figure 1. The **NASA Dryden Airborne Science Laboratory** is contained in a DC-8 airplane (N817NA).

This Month in Rapid Product Development online

The web publication for *NASA Tech Briefs* readers

NASA Tech Briefs' *all-digital publication, Rapid Product Development Online (**www.rapidproducts.net**), helps engineers develop better products faster by providing immediate 24-hour access to the latest information on CAD, FEA, modeling, mold-making, reverse engineering, and rapid prototyping tools and techniques. This month's RPD Online includes:*



GibbsCAM Advanced Turning/Multi-Task Machining (ATM/MTM) and Machine Simulation modules for programming CNC multi-task machine tools. The software, available from Gibbs and Associates, Moorpark, CA, provides a drag-and-drop graphical user interface for synchronizing multiple moving elements of a multi-task machine tool, and transferring work-in-process pieces. The Machine Simulation module identifies potential part/tooling/machine interferences in programs before being run on the machine. A 4-axis Wire-EDM module and a library of post processors also are included in the Windows-based software.

Altia, Colorado Springs, CO, has helped DaimlerChrysler's Jeep® Interior Electrical and Electronics Systems eliminate ten weeks of hardware mock-up time and expense in the design of a new lift gate for a sport utility vehicle. The hardware mock-ups were replaced with software simulations from Altia Design, a software tool that provides an interactive graphic front end to simulation and modeling tools. The software enabled the Jeep engineers to create a virtual prototype that could test the lift gate under different programmed conditions as linked to the models in the simulation software.

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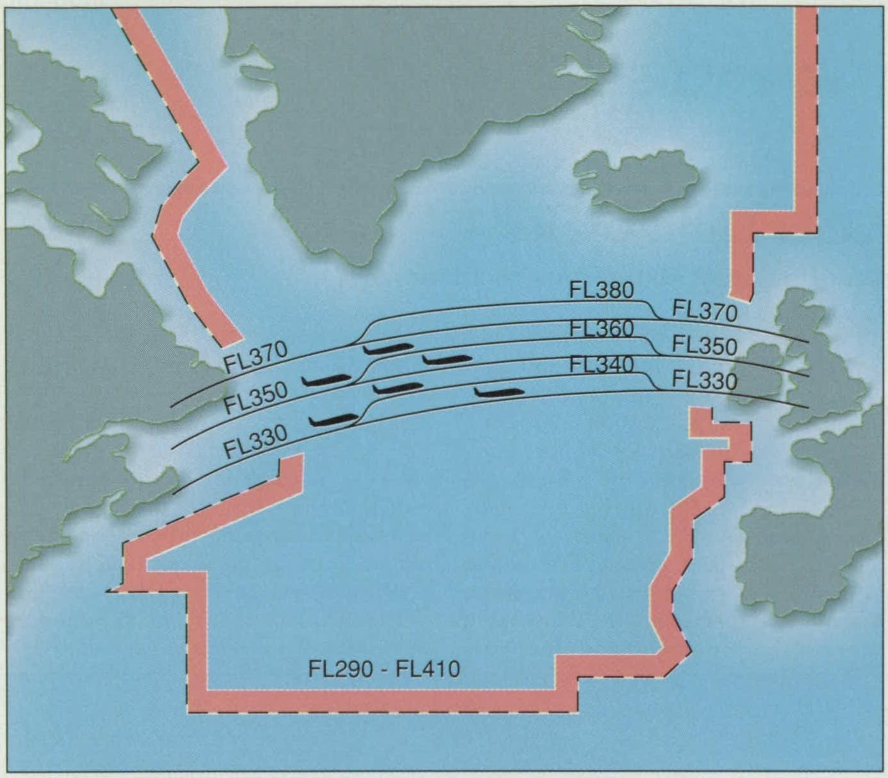

Figure 2. This **Map Depicts the RVSM Airspace** in the North Atlantic.

determined by data from a network of rawinsonde weather balloons, synoptic analysis, and surface observations.

By combining DGPS geometric altitude with the pressure calibration of the atmosphere, the true pressure altitude of the aircraft was determined. This was compared to the airdata computer measurement with no error corrections to determine the static source error correction (SSEC) required to null the pressure-altitude errors. (The SSEC is a function of the mach number only.) The SSEC for both the pilot and copilot systems were then incorporated into the airdata computers and checked on a verification flight.

The DC-8 airplane was flown at an altitude of 500 ft (152 m) above Rogers Dry Lakebed near maximum speed (mach 0.48 to 0.54) in steady flight. These data gave the SSEC with minimal uncertainty of the atmospheric pressure calibration. The remaining majority of flight data were taken at altitudes from 29,000 to 41,000 ft (8.84 to 12.50 km) in stabilized flight between mach 0.51 and mach 0.86. The near-ground data were used to adjust the high-altitude data for small temperature biases on the rawinsonde balloons. DGPS data taken during constant-airspeed turns were used to measure winds independent of the rawinsonde balloons. Autopilot operation was verified during stabilized flight to conform to an RVSM requirement of ±65 ft (±20 m).

One calibration flight was for the purpose of determining the SSEC required to null pressure-altitude errors with the aircraft in a clean configuration. The data obtained on this flight yielded residual errors of ±15 ft (±4.6 m) for both the pilot and copilot static-pressure systems.

On a verification flight, the aircraft was instrumented with a variety of external scientific probes, including a large nacelle about 5 ft (1.5 m) from the static-pressure ports. This configuration of probes constituted a near worst-case configuration for possible SSEC shifts. The maximum residual error on this flight was 73 ft (22 m) and, when combined with the worst-case avionics error of 85 ft (26 m) and the DGPS error of 2 ft (0.6 m), resulted in a total error of 160 ft (49 m), just satisfying the RVSM requirement. The errors would be considerably less if the airborne scientific probe near the static ports were removed or relocated. Autopilot operation was demonstrated to be within ±30 ft (±9 m). RVSM certification was granted on November 18, 1999.

This work was done by Edward A. Haering, Jr., Edward H. Teets, Jr., and David A. Webber of **Dryden Flight Research Center.** *DRC-00-11*

Wavelet Analysis To Predict Limit Cycles

It is possible to predict the airspeed of onset of dangerous oscillations.

Dryden Flight Research Center, Edwards, California

A method to predict the onset of a limit cycle for an aeroelastic testbed has been developed. The prediction is based on wavelet processing of measurement data that have been recorded under various flight conditions. The method has been considered for only a small testbed; however, the concepts may lead to techniques that could assist in prediction of the aeroelastic behaviors of aircraft during flight testing.

Some background information is prerequisite to an explanation of this development. The term "wavelet" denotes a signal that is nonzero for a short time. The relevant wavelet in the present case is the Morlet wavelet, which is essentially a windowed sinusoidal signal of finite length. The Morlet wavelet is a function of parameters, called scale and position, that affect, respectively, the period of the sinusoidal component and the time upon which the nonzero component is centered. Wavelet processing involves computation of the magnitudes of correlation between a measured signal and wavelets of different scales and positions. The wavelets with the highest correlation magnitudes represent dominant features in the measurement data.

Wavelet analysis is useful for extracting features in data that relate to nonlinear dynamics. These features can be used to

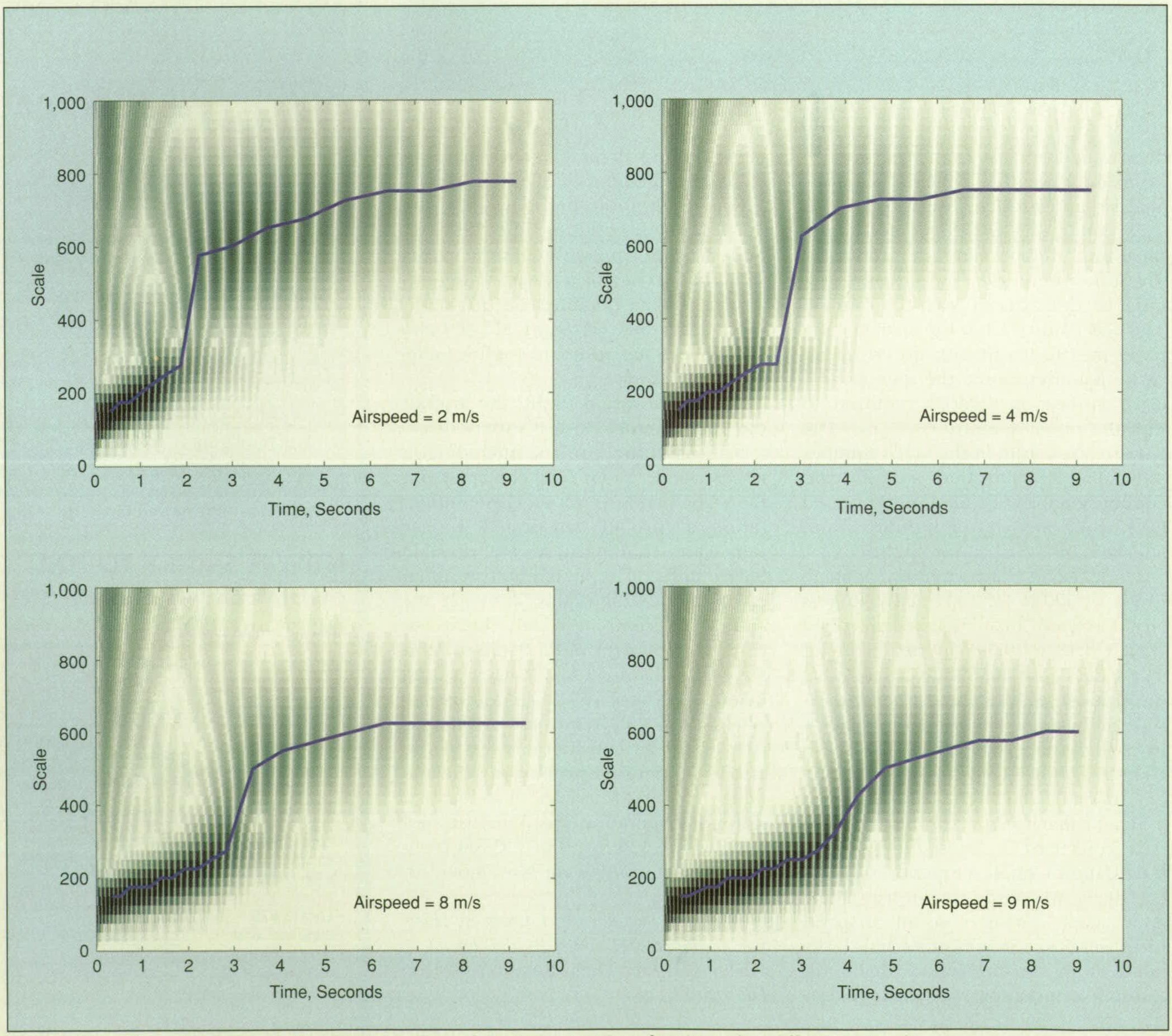

Figure 1. These **Maps Were Generated by Wavelet Analysis** of the pitching motion of a wing at four different airspeeds.

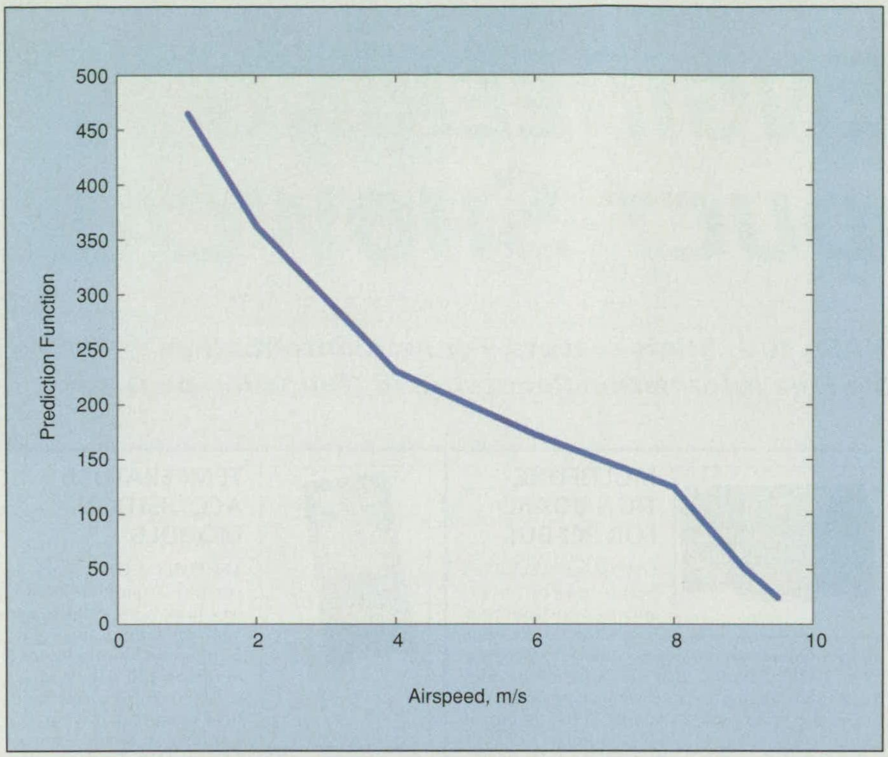

Figure 2. The **Prediction Function**, when linearly extrapolated, becomes zero at an airspeed close to the measured value (9.8 m/s) for the onset of the limit cycle.

indicate the nature of nonlinearities in an aeroelastic testbed, as reported, for example, in "Characterizing Nonlinear Dynamics by Use of Wavelet Analysis" (DRC-98-42), *NASA Tech Briefs*, Vol. 23, No. 9 (September 1999), page 70. These features are also the main mathematical tools used in the present method for predicting limit cycles.

In a typical application that involves aeroelasticity, for the purpose of the present method, limit cycles are behaviors that basically consist of steady oscillations of parts of an aircraft. These oscillations are usually stable in the sense that they are of a fixed amplitude; however, they are highly dangerous in flight because of their effect on the pilot and the stress caused to the airframe. It is particularly difficult to predict the onset of limit cycles because they are associated with nonlinearities that are often poorly represented in analytical models.

In the present method, responses from an aeroelastic testbed are analyzed at a series of increasing airspeeds in order to develop an ability to predict the onset of a limit cycle. The testbed is a standard wing section that undergoes pitching and plunging motions. The wing is also equipped with a nonlinear spring that affects the pitching motion and provides the dynamics for the limit cycle. This limit cycle occurs at an airspeed of 9.8 m/s.

Figure 1 shows the maps that result from wavelet processing of pitch measurements at different airspeeds. The color varies from white to black to indicate low to high magnitude of correlation between the signal and the wavelets. Of particular interest is the peak level of correlation at each point in time. This feature is indicated by the solid curved lines through the maps.

The feature associated with the peak level of correlation seems to be related to the airspeed. Notably, the responses at low airspeeds show a sudden and large change in scale of peak correlation after a time interval of 2 seconds, whereas at high airspeeds, the change is more gradual and occurs at later times.

A prediction function for the limit cycle can be computed as a ratio between (1) the magnitude of the maximum change in scale and (2) the time when this change occurs. A plot of this function (see Figure 2) clearly demonstrates a trend toward zero as the airspeed increases. A linear extrapolation of the function becomes zero near 9.8 m/s; thus, the wavelet approach appears to enable correct prediction (through extrapolation) of the onset of the limit cycle.

This work was done by Rick Lind and Martin Brenner of **Dryden Flight Research Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Information Sciences category.*
DRC-01-10

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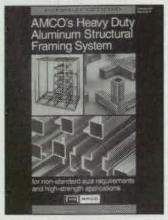

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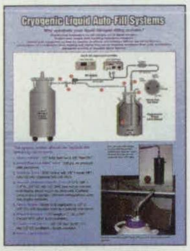

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The 2001 Reid Tool Supply catalog has just been released. Catalog offers over 45,000 items of tooling components and equipment. The 480-page catalog includes items such as handwheels, handles, knobs, spring and ball plungers, leveling pads, clamps, set up accessories, locating devices, latches, hinges, thread inserts, bearings, metric items, and more. All items are in stock for same-day shipment with no minimum order requirement. Reid Tool Supply Company, 2265 Black Creek Rd., Muskegon, MI 49444; Tel: 800-253-0421; Fax: 800-253-0421; www.reidtool.com

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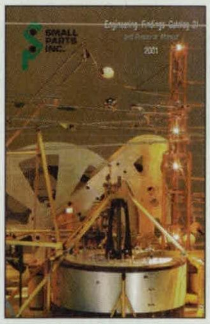

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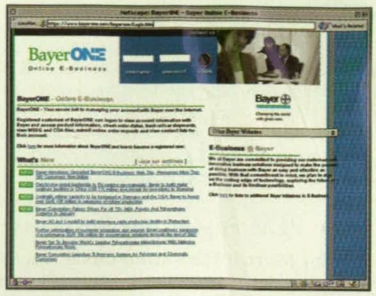


The BayerONE (Bayer Online E-Business) web site from Bayer Corp., Pittsburgh, PA, offers a portal through which the company's polymers and chemicals customers can access information such as online ordering, forecasting, material safety data sheets (MSDS), certificates of analysis, order tracking, and event notification. Customers can download reports or have them automatically compiled and delivered via e-mail. **www.bayerone.com**

Electronics Products

Contact Electronics, West Caldwell, NJ, has renovated its web site to include a Product Group Selector for linking to its online catalog, and a Part Number/Key Word Search feature. The online catalog includes the EPIC® line of rectangular, circular, and solenoid connectors, as well as remote access port interface products and custom cable products. A Distributor Locator feature provides sales information. Other areas provide company, product, and trade show information.
www.contactelectronics.com

Sensors and Transmitters

A redesigned web site from Burns Engineering, Minnetonka, MN, offers listings of the company's line of temperature sensors and transmitters, organized by industry. Also included are downloadable catalogs, configuration programs and instruction manuals, links to manufacturing representatives, and expanded contact information.
www.burnsengineering.com

Tooling and Components

EROWA Technology, Arlington Heights, IL, has updated its web site with a Marketplace feature that links the user to a list of specially priced tooling and component products. The Marketplace is divided into four categories: EDM tooling, WEDM tooling, Robotics, and Preset Equipment. The equipment list is updated weekly, and also includes components from the company's ITS tooling system, set-up stations, pre-set stations, and EasyHand and EasyChange robots.
www.erowatech.com

New on the MARKET

Desktop Visualization

SGI, Mountain View, CA, has released the V10 and V12 Vpro graphics options to its Octane2™ visual workstation. The new graphics offer support for 48-bit red, green, blue, and alpha (RGBA) color, double-buffered with 16-bit z-buffer. Other features include hardware acceleration of OpenGL® 1.2 core features, hardware accelerated specular shading, 12-bit per-component RGBA, and configurable graphics memory. The Octane2 workstation is used in MCAD, visual simulation, medical imaging, and geosciences markets. **Circle No. 723**

Pulse Generator

Quantum Composers, Bozeman, MT, has introduced the 9500 series multichannel digital pulse generator available in 2-, 4-, or 8-channel versions. The generators feature 20-ns resolution, RS-232 computer interface, selectable delay and pulsewidth, and the ability to gate any or all channels. The units offer independent delay and width selection on each channel, as well as selectable TTL/CMOS or adjustable amplitudes to 15V. Flexible operating modes include continuous, burst, and single-shot with external trigger/gate. **Circle No. 725**

Electronic Shielding

Form/Met® from Shielding for Electronics, Sunnyvale, CA, is an electromagnetic interference (EMI) shielding product used for electronic devices. The material is based on the vacuum metalization of thermoformed structures designed to fit within plastic housings and around a printed circuit board or other substrate. It provides shielding performance of up to 40-70 dB, electrical conductivity of less than 0.2 ohms per square, and is designed to replace conductively painted plastic housings, gaskets, and cans for shielding electronic products. **Circle No. 726**

Remote Charge Converter

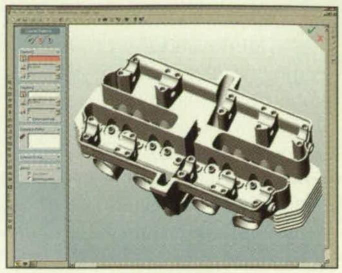
Endevco Corp., San Juan Capistrano, CA, offers the Model 2771B remote charge converter, a two-wire, single-ended device for use with piezoelectric transducers, transforming the transducer's high-impedance charge output to a low-impedance voltage. Frequency response is 1 to 40 kHz, and operation is within a range of 4 to 20 mA. The system has the ability to store and recall TEDS (Transducer Electronic Data Sheet) data, reducing test set-up time. **Circle No. 727**

Process Controller

The CN1462 microprocessor-based single-loop process controller from OMEGA Engineering, Stamford, CT, features programmable setpoint profile programs. The unit can execute one of eight setpoint programs or operate as a basic process controller using manual setpoint changes. Programs have an adjustable range of 1 to 16 segments. Each segment can be a ramp, soak, join, or end. The device is used to control or program temperature or other process variables. The unit is available with two 4-20mA current outputs for control and a third current output for retransmission. Other features include universal sensor inputs, a 90-264 VAC power supply, and programmable display. **Circle No. 728**

New on DISK

Solid Modeling



SolidWorks 2001 solid modeling software from SolidWorks Corp., Concord, MA, features a "heads-up" user interface consisting of visual display and mouse-driven control capabilities that reduce design steps, minimize dialog boxes, and reduce visual clutter. Enhanced drag handles let users make edits without relying on the dialog entry of parameters. Other features include a new mode for creating 2D geometry, new sheetmetal capabilities, enhanced surfacing tools, and the ability to mirror components in an assembly. Also included are a new import wizard for DWG/DXF files, 3D Instant Website that lets users instantly create and publish live web pages with SolidWorks models, and 3D Meeting, which lets users view and collaborate in real time over the Internet. **Circle No. 708**

CAD/CAM/CAE

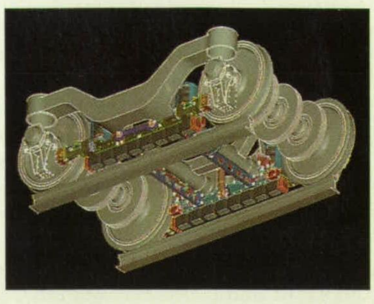
Version 5 Release 5 of CATIA CAD software from Dassault Systemes and IBM, Armonk, NY, incorporates ten new products. The program is available on both Windows and UNIX platforms, and includes a new mold tooling product that allows creation and associative modification of mold tooling by using libraries of standard components. Enhanced capabilities in welding and tolerance, sheetmetal production, freestyle sketching, shape design and styling, and machining are included. **Circle No. 709**

SMP Library

Numerical Algorithms Group, Downers Grove, IL, offers the NAG Fortran SMP Library, which includes more than 220 routines optimized to maximize performance on shared memory parallel (SMP) systems. The software contains 123 newly enhanced routines covering ODEs, PDEs, optimization, and multivariate statistics. A new feature contains 40 parallelized Random Number Generators that can be applied in large-scale simulations. **Circle No. 711**

Simulation and Analysis

ANSYS 5.7 simulation and analysis software from ANSYS, Canonsburg, PA, allows users to predict real-world conditions and simulate single and complex multi-physical phenomena. With the software's Probabilistic Design System™, finite element analysis input variations can be taken into account, letting users address how products behave in real-world conditions. Other features include a shared memory solver and a distributed memory solver, thermomechanical contact, and enhanced material models for analyzing hyperelasticity, plasticity, and viscoplasticity-related designs. **Circle No. 712**



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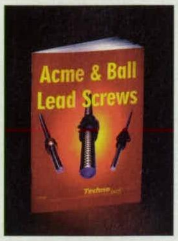


Acme and Ball Lead Screws

A 48-page catalog on acme and ball lead screws has been released by Techno-Isel, New Hyde Park, NY. The catalog features more than 950 components for linear systems, automated production systems, inspection machinery, and other products that require linear motion. A 15-page technical data section covers the sizing and selection process for lead and ball screws. **Circle No. 715**

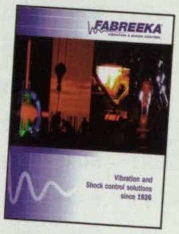
Self-Calibrating Indicator

Sensotec, Columbus, OH, offers a brochure detailing the SC series of self-calibrating, digital transducer indicators. The five new models contain plug-in signal conditioner cards and application-specific programs, and can accommodate up to 14 plug-in signal conditioner cards. The indicators offer an optional quad-line version and five different calibration methods. **Circle No. 716**

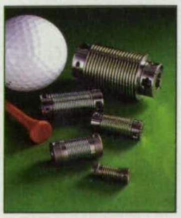
Cords and Cordsets

A six-page brochure describing Interpower™ Schuko molded cords and cordsets is available from Panel Components Corp., Oskaloosa, IA. The brochure describes both straight and angled plugs, with straight and angled IEC 60320 C13 and C19 connectors. The cords and cordsets are available in a variety of lengths. **Circle No. 717**

Vibration/Shock Control



Fabreeka, Stoughton, MA, has released a brochure on vibration and shock control solutions, including Fabreeka Pads, Fabcel, and other padding materials for placement under most types of equipment. Also described are engineered systems for vibration and shock control in test stands, machine tools, and lab equipment. **Circle No. 718**



Shaft Couplings

Servometer Corp., Cedar Grove, NJ, offers a six-page brochure illustrating SMC zero-backlash flexible shaft couplings that absorb angular and parallel misalignments in combination with axial movements. The joints are used for coupling to encoders and resolvers in precision positioning applications. **Circle No. 719**

Machinery Automation

A CD-ROM from ORMEC, Rochester, NY, examines industrial networking for automation machinery builders. The presentations provide an overview of industrial PC-based controllers and the company's ServoWire™ drive technology. The CD includes an archive of articles, application stories, and technical information. **Circle No. 720**

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