June 1999 Vol. 23 No. 6

TECH BRIEFS

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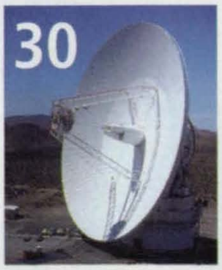
FEATURES



BRIEFS

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SPECIAL SUPPLEMENTS

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PRODUCT OF THE MONTH

Parker Hannifin introduces Spectrum Series thermoplastic couplings.

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ON THE COVER

The PDK Series of Panel Development Kits from WinSystems, Arlington, TX (www.winsystems.com), provides the necessary system components and cables for stringing together a power supply, touchscreen, and flat panel display. The PDK is built upon an aluminum A-frame that holds the LCD panel, backlight inverter, the touchscreen and its controller, plus the panel adapter card and cable. More innovations in computers and related equipment are described in the Special Coverage on Computers & Peripherals, beginning on page 65.

(Image courtesy of WinSystems)

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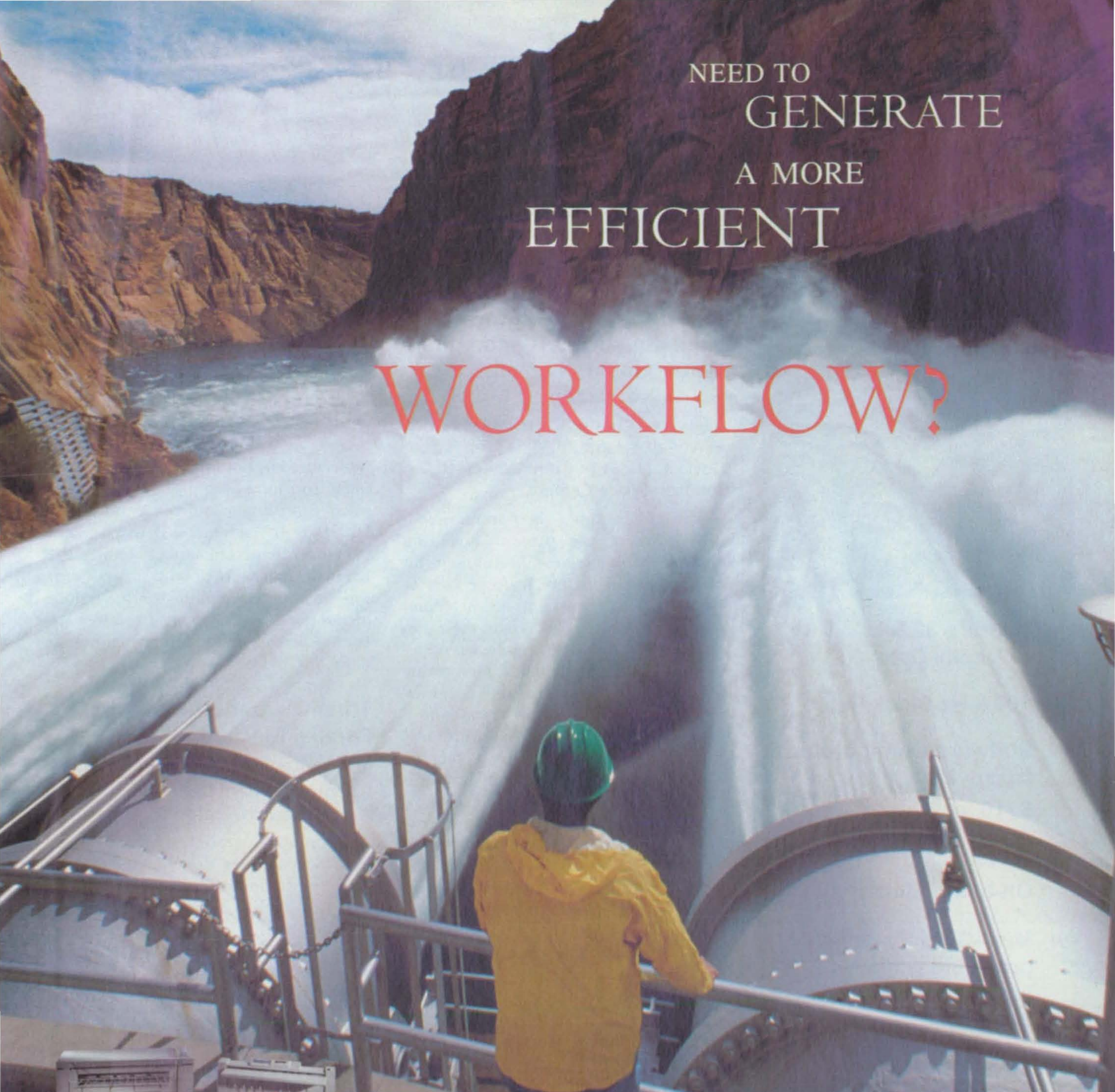

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NASA Patents

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:

Fiber-Optic Chemiluminescent Biosensors for Monitoring Aqueous Alcohols and Other Water Quality Parameters

(U.S. Patent No. 5,792,621)

Inventors: Charles E. Verostko, James E. Atwater, James R. Akse, Jeffrey L. DeHart, and Richard R. Wheeler, Johnson Space Center

The fiber-optic chemiluminescent biosensors of the present invention embody a "reagentless" technology for quantitation of ethanol, hydrogen peroxide, D-glucose, and important water-quality parameters with extremely low detection limits. The technology is useful in both flight water-quality monitoring aboard spacecraft and in on-line monitoring of ethanol and glucose for control of fermentation bioreactors in brewing, pharmaceutical, and other biotechnological applications. Sensor operation is based upon the enzymatic oxidation of ethanol or other target species to produce hydrogen peroxide, which then reacts with luminol to produce light. The light intensity, which is directly proportional to the concentration of the target compound, is measured by a photomultiplier tube. The light-emitting reactions are promoted by using immobilized enzymes and solid-state flow-through modules that contain the required reactants. The luminescent reactions are electrically catalyzed.

Fire Resistant, Moisture Barrier Membrane

(U.S. Patent No. 5,789,025)

Inventor: Terry L. St. Clair, Langley Research Center

The present invention meets the continuing need for improved waterproof/breathable laminates for high-performance fabrics that are fire-resistant and either do not present or significantly reduce the danger of toxic compound production. Such military and industrial objects as military tents, gear, and shoes, airplane seat covers, and clothing for firefighters or industrial workers exposed to high heat sources require such films. The requirement is met with a waterproof and breathable fire-resistant laminate comprising a silicon rubber and a polyimide powder, the latter made up of a plurality of polyimide particles suspended in the rubber so that pathways are created through the laminate to allow the passage of water vapor molecules but not liquid water. The laminate is formed by applying a slurry of a silicone precursor and the powder to a fabric or other suitable material, and concurrently or sequentially setting the laminate thermally or with a catalyst or with moisture, depending on the nature of the precursor. Beneficial results have been achieved using the polyimide powder LARC™-IA.

Three-Degree-of-Freedom Parallel Mechanical Linkage

(U.S. Patent No. 5,816,105)

Inventor: Bernard D. Adelstein, Ames Research Center

A unique parallel mechanism or interface couples three-degree-of-freedom translational displacements at an endpoint such as a handle, a hand grip, a robot tool, etc., to link rotations around three axes that are fixed with respect to a common base or ground link. The mechanism provides a new overall spatial linkage composed of a minimal number of rigid links and rotary joints that are arranged in three closed chain loops of six binary (two-joint) and four ternary (three-joint) links. The mechanism conveys mechanical power bidirectionally between the human operator and electromechanical actuators. The mechanism can be constructed solely of rigid links and revolute pairs, and does not require gears, belts, cable, screw or other types of transmission elements. Consequently it is useful in applications requiring full backdrivability, and can serve as the mechanical linkage for actively powered devices such as compliant robotic manipulators and force-reflecting hand controllers, and passive devices such as manual input devices for computers and other systems.

For more information on the inventions described here, contact the appropriate NASA Field Center's Commercial Technology Office. See page 14 for a list of office contacts.

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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: Fluid Dynamics; Life Sciences; Earth and Atmospheric Sciences; Information, Communications, and Intelligent Systems; Human Factors.
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Dryden Flight Research Center
Selected technological strengths: Aerodynamics; Aeronautics Flight Testing; Aeropropulsion; Flight Systems; Thermal Testing; Integrated Systems Test and Validation.
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Goddard Space Flight Center
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Jet Propulsion Laboratory
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Larry Viterna
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Marshall Space Flight Center
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sally.little@msfc.nasa.gov

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

NASA Program Offices

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

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

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THE **ULTIMATE** DESIGN MACHINE

For More Information Circle No. 541

PRODUCT OF THE MONTH

The Spectrum Series Couplings from Parker Hannifin's Quick Coupling Division, Minneapolis, MN, combine compact size, high flow capability, and lightweight design to meet a range of coupling applications. The series is available in three material options: Acetal, PVDF, and PVDF+. The acetal coupling is used for general applications; the PVDF body material has 316 stainless steel springs for chemical compatibility; and the PVDF+ uses PEEK springs, eliminating metal components. The couplings all feature a push-to-connect design, and have a variety of port options. The couplings are available valved or unvalved, and can withstand operating temperatures to 250°F.

For More Information Circle No. 748

Team Up for Smooth Sailing

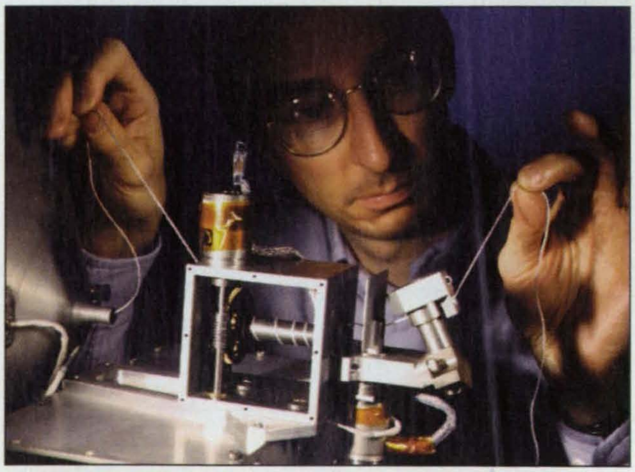
Want to meet a team of American heroes whose enterprise has profited from collaborative engineering? *NASA Tech Briefs* is proud to co-sponsor with Hewlett-Packard a one-day conference on June 30 for product design and IT managers. "Charting the Course of Collaborative Product Development" will feature the development managers and chief technology officer for the 12-meter yacht, AmericaOne, discussing how collaborative engineering set the course for smoother sailing in the design of the most technologically advanced challenger in the America's Cup 2000 race. Held at the St. Francis Yacht Club in San Francisco, the event is free of charge and by invitation only. Participation is limited, so to reserve your spot, visit www.hp.com/go/dce_conferences, or call 1-888-249-4989.

Tethered Transportation

NASA plans to lasso energy from Earth's atmosphere with a tether as part of the first demonstration of a propellant-free space propulsion system, which potentially could lead to a revolutionary new space transportation system. Scientists and engineers at NASA's Marshall Space Flight Center in Huntsville, AL, are experimenting with tethers as part of an effort to reduce the cost of space transportation. ProSEDS (Propulsive Small Expendable Deployer System) is scheduled for demonstration in August 2000.

The experiment will demonstrate the use of an electrodynamic tether — a long, thin wire — for propulsion. An electrodynamic tether uses the same principles as electric motors in toys, appliances, and computer disk drives — when a wire moves through a magnetic field, an electrical current results. When electrical current flows through a tether connected to a spacecraft, the force exerted on the tether raises or lowers the orbit of the satellite. "Tether propulsion requires no fuel, is completely reusable and environmentally clean, and provides all three features at low cost," explained Les Johnson, principal investigator for ProSEDS.

Launched on a Delta II rocket, ProSEDS will deploy a 3.1-mile, bare-wire tether connected with a 6.2-mile nonconducting tether from the Delta II second stage to lower its orbit. "More than 40 percent of launches projected over the next ten years have payloads with intended destinations beyond low-Earth orbit," said Leslie Curtis, manager of Marshall's Space Transfer Technologies project. "Low-cost upper stages and on-board propulsion systems are critical elements in reducing space transportation costs."



Les Johnson of NASA Marshall inspects the nonconducting part of a tether as it exits a deployer similar to the system to be used in the ProSEDS experiment.

For more information on the Advanced Space Transportation Program, visit the web site at: http://astp.msfc.nasa.gov; for information on space tethers, visit the web site at: http://infinity.msfc.nasa.gov

Reader Forum

Reader Forum is devoted to the thoughts, concerns, questions, and comments of our readers. If you have a comment, a question regarding a specific technical problem, or an answer to a question that appeared in a recent issue, send your letter to the address below.

I am looking for information on low-speed boat propellers that would be suitable for human-powered watercraft. Propeller speed is expected to be under 250 RPM. Though I'd like to have a prop pitch of 24", I don't know if that is feasible for hand operation. Any assistance would be appreciated.

Steve Higbee
Banning, CA
909-849-6620
higbee@pe.net

I am an electrical designer and I've been a subscriber to NASA Tech Briefs for a long time. Your magazine has been providing me with invaluable information and new technologies. I would like to thank you for doing such a good job. Thanks to the education I received in the United States, and from studying numerous issues of NASA Tech Briefs, I was able to develop an 8X51 microcontroller programmer in 1997 that can program many kinds of 8051-compatible MCUs.

Guo-Yin Xu
Electrical Designer
Houston, TX
713-741-3125

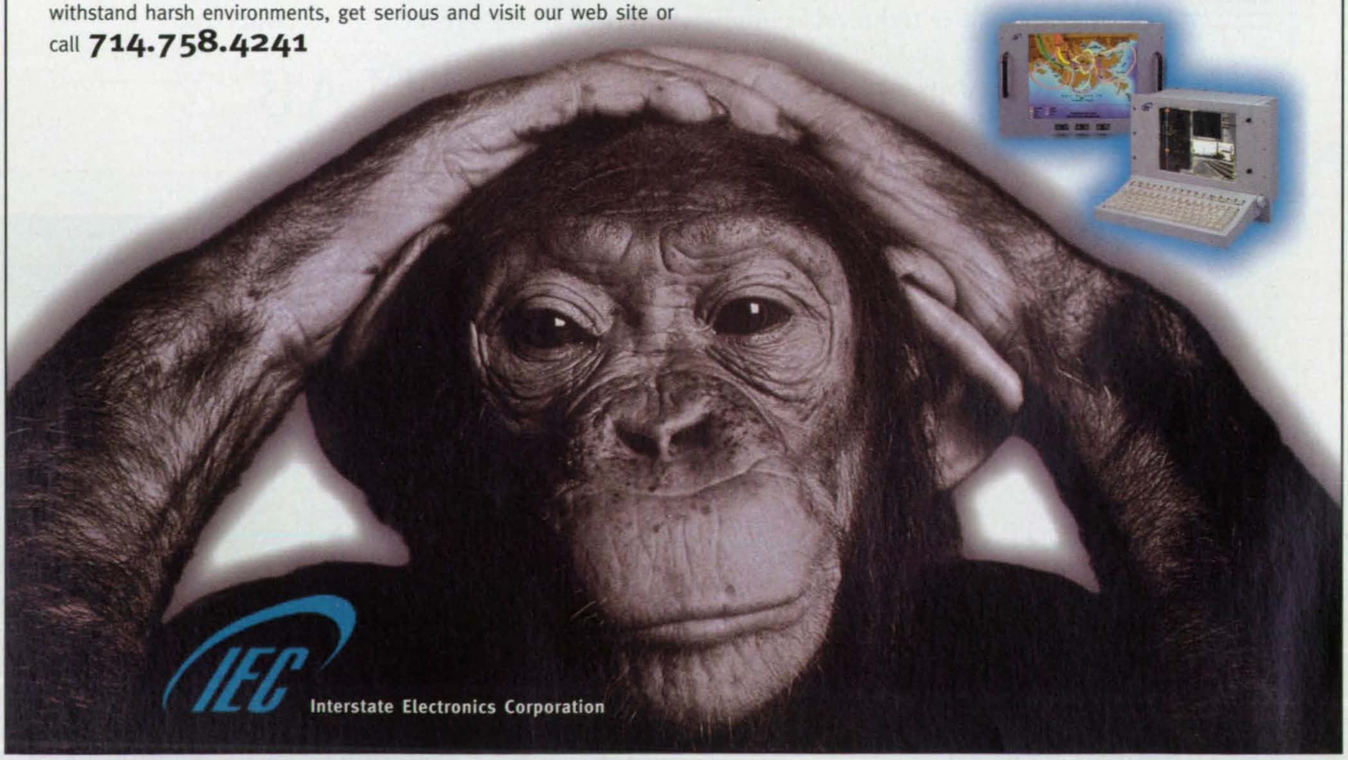
I'd like to respond to a letter in the March Reader Forum from Bob Pekowski, who was looking for information on sources for ceramic honeycombs. Porous ceramic materials can be made by extrusion (like Corning's catalytic converters), or by coating a fugitive, porous substrate with ceramics and burning out the substrate. These are called reticulated ceramic foams and are very useful and available in many compositions. The foam types are more cost-effective and more easily available. Try Vesuvius High-Tech Ceramics at 607-587-9146.

Paul Chayka
pchayka@atmi.com

Through NASA Tech Briefs, I have learned about and am currently using 3M composite tapes for sealing carbon fiber panels in race car bodies. I'm also using self-locking fasteners I found in your magazine to save time and eliminate extra parts. Thanks for the information.

S. Topolski
Brotherhood Enterprises
Desert Hot Springs, CA
760-327-5060

Post your letters to **Reader Forum** on-line at: **www.nasatech.com** or send to: Editor, *NASA Tech Briefs,* 317 Madison Ave., New York, NY 10017; Fax: 212-986-7864. Please include your name, company (if applicable), address, and phone number or e-mail address.



CAE and Collaborative Engineering:

Working Together in the Real World

An interactive audioconference sponsored by Hewlett-Packard, and co-sponsored by ANSYS and Co-Create, was held on March 30 from Livonia, MI, in conjunction with the HP MCAE Symposium. The following excerpts include a look at real-world integration of distributed analysis and design data with collaborative engineering, as described by the expert panelists. The collaborative engineering process continues to emerge as a vital part of connecting the supply chain, cutting development costs, increasing product quality, and reducing supply chain time-to-market.

The audioconference moderator was Bill Neill, Program Manager, Design Chain Engineering, for Hewlett-Packard. Panelists were Dr. Marc Halpern, Director of Research, Engineering, Manufacturing & Design, D.H. Brown Associates; Rich Smith, Network Services Manager, Crane National Vendors; Gregory Roth, Senior Engineering Specialist, Virtual Prototyping, Eaton Corporation's Innovation Center; Doug Johnson, General Manager, Shared Information Division, Co-Create; and Paul Bemis, Vice President, Marketing, ANSYS.

Dr. Halpern: When we talk about collaboration, we talk about communication and defining common objectives. And of course, it always helps to have the right set of software and hardware in your infrastructure to support the type of process you want to enable.

In the course of our research on CAE effectiveness, we've uncovered four key guidelines that are important to enable collaborative engineering across CAE and design. Number one is that engineers must manage and monitor CAE simulation use. If you want collaboration between CAE simulation and design, never forget that these tools were written for engineers. It is up to the engineers to provide interpretation so that a designer can get value out of their use.

Over the past decade, there's been a lot of talk about designers doing CAE directly. Yet, in our research, we continue to see that the mandate really is for collaboration between engineers and designers regarding these tools, as opposed to the designers using them directly. Even if designers can set up the problems and the simulation correctly, they still have to know how to interpret the results. And that interpretation really does require engineering expertise. Only one out of every four engineers is qualified to use these tools.

When you're employing simulation to solve a problem for the first time, you're in a learning mode, and the engineer has to be involved in that learning mode. Later, the experience can be reused in what I call the rapid mode. If this type of problem is recurring, you should be able to reuse that experience.

Number two is that role definitions must encourage collaboration. All companies know that CAE should be done up front. So they get started on the right foot, and they do CAE up front for the conceptual design. But all of a sudden, they have their production schedules. So they get involved with the designers, who are primarily responsible for getting packaging out. They finally build that first prototype and they test it. And what they discover is that the test results do not correlate with the CAE simula-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For More Information Circle No. 528

CAE and Collaborative Engineering: Working Together in the Real World

tion that was done up front. Since the designer is not really familiar with all of the engineering principles, when they make these changes, they've actually modified mechanical performance design variables. The CAE specialist is left in the cold, and the real added value they can provide isn't delivered because they're not involved in the process.

Part of this has to do with the performance metrics by which these operational people are being measured. For example, designers very often are measured by how quickly they produce their CAD models, and CAE specialists simply by how quickly they perform a CAE simulation. You have to have new role definitions and new measures of performance in order to enable collaboration. A designer should be responsible for the performance of the product and components they design throughout the life cycle of that product. By the same token, the CAE specialist should not be responsible just for validation simulation. They should be responsible for optimizing the design for robustness.

Number three is that CAE effectiveness must align with the business objectives. Collaboration will never work unless it has support of management at the highest level.

Number four is that you have to have the right infrastructure to enable collaboration. We've been monitoring, for the last ten years, the performance of these tools out in the field, and what we found was from 1991, for an individual CAE expert, it took about 60 hours to perform an analysis. By 1996, because of the types of software and hardware enhancements that have been made, that time was cut by 50% to a little over 30 hours. And based on our reviews of these technologies over the past year or so, we expect the time to reduce by 50% again by the year 2001, to an average time of 16 hours.

I want to emphasize that collaboration does require process practices, or else all of the software and hardware infrastructure means absolutely nothing. You really need to document your experiences so that the information can be reused. My recommendations for companies interested in collaboration across CAE experts and designers are:

- Establish mechanisms and practices to capture and reuse experiences;
- Evaluate and redefine role definitions and job performance measurements so that the experts working together have a common goal;
- Implement CAE effectiveness measures that can report back to senior management on how well you're doing, and;
- Audit and upgrade your software and hardware infrastructure.

Smith: Crane is a leading manufacturer of snack and drink vending machines. Typically, our machines each have over 400 parts. There are a lot of electronics that control these electromechanical devices. We faced design challenges with a new coffee machine that is a combination of sheet metal and molded plastic components.

We use an industrial design firm separated from us by distance. Communicating design concepts with outside firms typically involves travel, making mockups, and going through those iterations of the industrial part of the design. The other challenge was to make the design changes early in the process at the solid model level. You don't cut any tools, so you save the cost of tooling changes.

We were offered the opportunity from Co-Create to be a part of their Fast Track program, evaluating their software called OneSpace, a web-collaboration tool that allows you to work with many web clients at one time on one single model of data, and interact with that data. That opportunity coincided with the timing of the design of the new coffee machine.

We started in the first quarter of this year, so we're very early in the product development. The software was useful and cost-effective, enabling us to go into solid modeling. In the past, we had worked with solid models on similar design projects, and it was typical: we'd take the design process, whether it was internally or externally developed, take a sketch or rendering, develop that into mockups in our modeling area, and make evaluations. We'd then take that into the actual product design and transfer that to our toolmakers. Then, we'd go through the iterations of the most valid way to design this from the toolmaker's standpoint. We were looking at making this a more collaborative process, at least for the industrial design and engineering staff.

Our early collaborative sessions focused on training, and involved our design firm, the application engineer, and myself. Generally, we spent about two hours in training, and we covered the major topics of manipulating the geometry. After that, we gave a presentation to engineering management. Sketches and drawings were used initially to evaluate and create the concepts. The objectives for these first sessions were to review, refine, and narrow it down to the final two concepts that actually were modeled. Those two concept designs were selected with no prototypes and models. It was definitely a deviation from past methodology.

Our later sessions were more technical — more of the component-level form, location, and function of the parts. It was more of a true collaboration. Our engineers were impressed with the number and variety of design issues that could be covered in one session. We're too early in the project to come up with some hard, objective figures that validate how much faster this tool allows us to go through the process. In general, the engineers agree that it enhances the communication and decision-making process tremendously.

Roth: The trends in the product development process cover reducing time to design, develop, and prove out; to reduce costs, waste, and warranty returns; and improve quality. While these are trends we've seen before, what has changed are the motivation and the urgency to implement them. The main focus is to get the products out faster to meet the customer's needs. Traditionally, market research is done, and that goes into the product development process. It takes years for a product to be developed;

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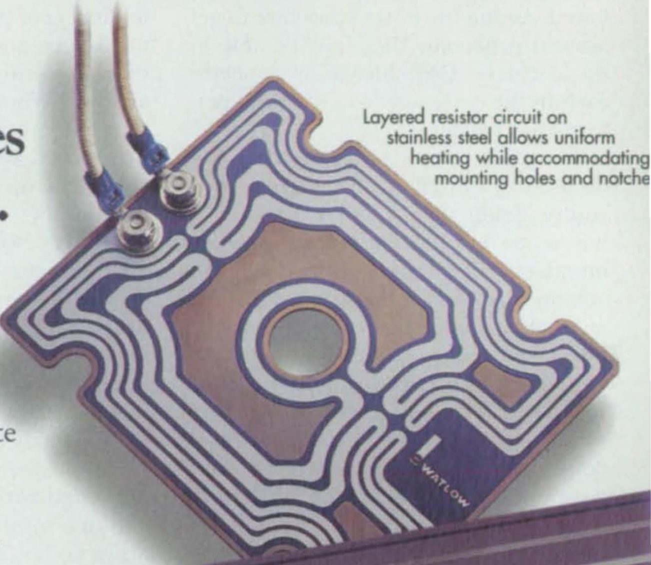

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often, by the time the product is developed, the needs have changed.

You have to have a very good structure to ensure that certain protocols are followed. As engineers, we know how to get around problems. You must be able to do basic-level CAE analysis of concepts early in the design cycle to filter out performance concerns.

You must have CAE codes that can be used by designers and engineers. If you're going to use this capability, it has to be easy to use, learn, and remember. The ultimate goal is to achieve first-pass success. What this entails is being able to prove the part, design it, have it go through its first testing, and pass all performance criteria. In the traditional product development timeline, most of the work is done just prior to release. That's when most of the problems are encountered. The trick now is to push that work up front.

In the early phases with the CAE design process up front, the design phase will take longer because models must be developed and changed, and information comes back that the feature is no longer good. Every time you do a design iteration, it requires failure analysis. When the part fails, it has to be redesigned and rebuilt with new prototypes, and then retested. All these steps add up to huge chunks of time and money.

The key issue is engineers or designers doing analysis work versus analysts. While I believe the best scenario would be to have an analysis core of thousands of people, all in engineering, I know this is not very likely. So what's needed to make the process flow work? First, an easy-to-use CAE type code that will allow for quick "what-if" studies at the engineering and designer levels, and that is intuitive and consistent with other codes. It must be easy to remember, not allow for serious pitfalls, and should provide robust solutions. It must be compatible with CAD solid modeling codes; it must fit in with the standard engineering/design processes and cultures; be portable to different hardware environments; and be documentable.

Johnson: The technology for collaboration continues to move forward in a variety of ways. One is network capacity. It's been a bottleneck for years. Today, algorithms are making the current wave of collaborative products and digital video products become practical for engineers to use. We see a revolution occurring in network capacity. We're also going to see networks become much easier to use.

The next interesting revolution will have to do with data. Ten years from now, you'll have a half-trillion bytes in

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your computer — maybe even in your laptop computer. You'll be able to save everything imaginable. This explosion of data will mean that we'll have more things on which to collaborate, lots more information associated in the enterprise, and more to talk to our partners about.

Bemis: There is a new class of user coming to the forefront of the analysis engineering simulation community, who is generally referred to as a periodic user. Up to this point, analysis has been something that's been done by very well-educated people who typically have a masters or a Ph.D. in engineering simulation studies.

The new class of user does not have that experience, nor does it have the time to get up that steep learning curve. This is someone who needs to be able to get to know a tool without really going through much training. They also need to be able to reintroduce the tool after a period of time and still be able to use it. It is not enough just to develop the tools for people; the collaboration must exist so these teams can work together over both organizational and geographic boundaries.

What we're trying to do is put collaborative processes in place so that the advanced analyst community can help the design community determine what tools they are using, and configure those tools. We do this to some extent today in DesignSpace, using the concept of wizards. With a wizard, you put in the floppy disk, hit the "go" button, and it steps you through a sequence of events. We see this in the future where the boundary conditions, the loads, and everything that is sensitive has been pre-set. The design person is able to work within the constraints of variability that the analysis community has laid in place for them.

These collaborative products cannot succeed without high-level management support, and they must be delivered in a staged fashion with training. The people who are implementing this have put their analysis community into some level of gradient: Level three is an advanced engineer; level two is a mid-range analysis engineer; and level one is a design engineer. As they train, they deliver more simulation technology to them.

Engineering simulation is moving out of research, where it has been, and into production. It is a direct result of the fact that hardware costs are dropping, and now you have the capacity to do things you couldn't do before. We have the opportunity to get out in front of that and become part of it, or deal with the consequences of playing with those tools without help.

For more information on collaborative engineering, and for the dates and places of upcoming interactive audioconferences, visit the HP Design Chain Engineering Website at: http://www.hp.com/go/design_chain. You can access the complete transcript of the audioconference at: www.nasatech.com

Commercialization Opportunities

Spectral Reflectometer for Quantifying Stress in Plants

A hand-held instrument quantitatively indicates the loss of chlorophyll and therefore the level of stress in plants. The instrument can find a wide range of applications in agriculture, environmental protection, and botanical research.
(See page 38.)

Portable Multispectral Telescope

This telescope produces multiple video images of the same scene in different spectral bands. The telescope could be readily configured for more, fewer, or different spectral bands.
(See page 40.)

Improved Ultrasonic Imaging of Microscopic Devices

A number of advances are proposed in time gating of ultrasonic signals in scanning acoustic microscopes to enable detailed nondestructive examination of bonds and other interfaces deep within integrated circuits and microelectromechanical systems.
(See page 45.)

Cheaper, Lighter Biplates for Methanol Fuel Cells

The reductions in weight and cost, relative to biplates now used in methanol fuel cells, would be achieved by modified geometry; cheaper, lighter materials; and cheaper manufacturing processes.
(See page 48.)

Transmissive Surface-Plasmon Light Valves

Colors in transmissive flat-panel display devices would be voltage tunable. These devices would be compatible with, and could be incorporated into, monolithic integrated circuits for use in display, addressing, and interface applications.
(See page 50.)

Improved Aerogel-Based Thermal Insulation Systems

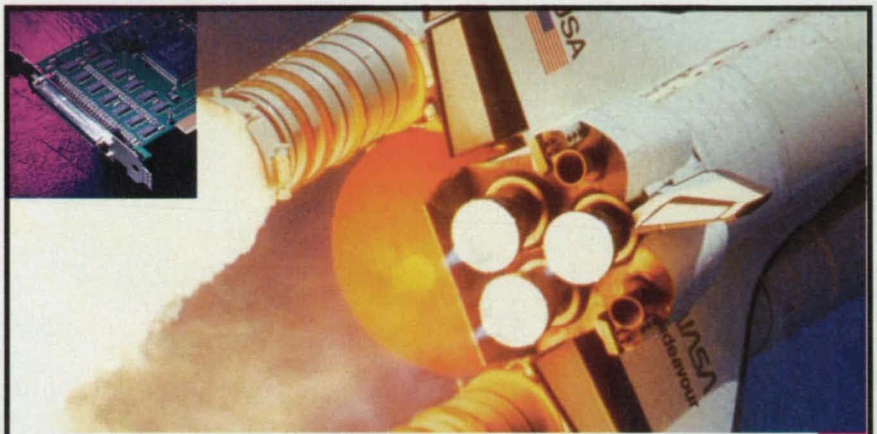
These insulation systems are composites which can be manufactured in blanket, sleeve, or clamshell forms to be used with or without evacuation. Advantage is taken of the low thermal conductivity of the ultra-low-density aerogels to minimize heat transfer.
(See page 56.)

Improved Inlets for T-38 Airplane

A change in the design of the engine inlets significantly reduces takeoff distances while increasing safety margins. This design is optimized for subsonic flight.
(See page 59.)

Kit for Sampling Nitrosamines From Aqueous Solutions

In comparison with the standard method, this kit is faster, cheaper and less labor intensive, and yields greater recoveries and more accurate test results. Nitrosamines are byproducts of dimethyl hydrazine, a rocket fuel that was used before it was linked to human cancers.
(See page 64.)



NASA Troubleshoots Deep Space Network With Portable Probe

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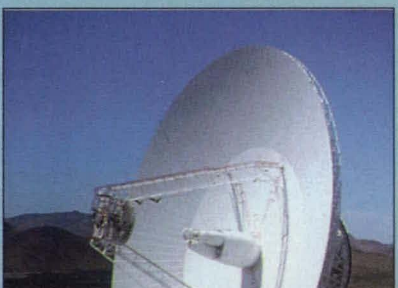
NASA's Jet Propulsion Laboratory (JPL) in Pasadena, CA, operates the Deep Space Network (DSN), which consists of more than 25 antennas arranged in three complexes spaced equidistantly around Earth. These complexes are about 120 degrees apart in longitude to provide nearly continuous coverage for deep-space missions. The Goldstone complex is located at the U.S. Army's Fort Irwin Military Reservation in California's Mojave Desert; the Australian complex is near Canberra; and the Spanish complex stands near Madrid. Scientists and researchers make use of these antennas to communicate with unmanned space probes launched by NASA, the European Space Agency (ESA), and the Japanese space agencies.

Each of the complexes has one each of the DSN's largest antennas, which are 70 meters in diameter. Of these antennas, only Goldstone's transmits high-power radar signals at approximately 500,000 watts, in addition to communication signals such as spacecraft commands, transmitted at 5,000 or 20,000 watts. This branch of DSN Science operations is known as the Goldstone Solar System Radar (GSSR). The GSSR has received radar echoes from objects as distant as the Saturn system of rings and moons.

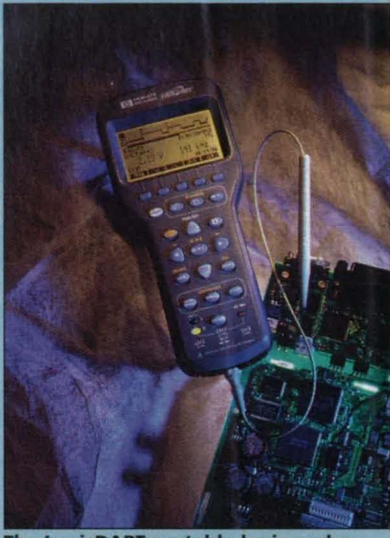


The Goldstone complex at the U.S. Army's Fort Irwin Military Reservation in California's Mojave Desert. (Image courtesy of NASA/JPL)

JPL recently built a new hardware data acquisition system to replace the GSSR's old system. JPL engineers used LogicDART, a portable logic probe from Hewlett-Packard, to troubleshoot the new system, which began operations in March 1998. To date, the new system has improved the functionality of the GSSR by enabling its use of the DSN's new all-digital receivers, providing increased resolution, and lowering the cost of operating the radar.

When the custom hardware system at Goldstone, controlled by a Digital Equipment Corp. VAX computer, was no longer cost-effective for GSSR, JPL engineers took steps to build a new system. "We were using a large set of custom hardware designed some 12 years ago, and we knew its mechanical parts wouldn't last," said Robert Frye, senior system designer at JPL. "Plus, we knew that we would soon no longer receive technical support and servicing on our VAX. Naturally, we decided to build a modern system using embedded CPUs and VME card cages to ensure the GSSR's continued operability and expand its capability."

Frye and Chad Nikoletich, a hardware design engineer for JPL, built the new system, comprised of 18 printed circuit, data acquisition, and correlator boards to replace the slower and more costly system. In operation, the new system processes radar signals received from a planet, asteroid, or comet via a set of low-noise receivers at the Cassegrain focus of the 70-meter antenna. These microwave signals are then converted down to lower frequencies and transferred first via waveguide and then fiber optics to a data acquisition board. Using correlator chips, the data is digitized and sent through custom hardware to a DSP chip. Next, software puts the data through a series of Fast Fourier Transforms (FFTs) to obtain the spectrum of the object's reflected radio waves.



The LogicDART portable logic probe. (Image courtesy of Hewlett-Packard)

While Nikoletich was building the system, he noticed that a chip in one of the boards was not resetting properly. The board's fine-pitch circuitry made it difficult to identify the source of the problem. He purchased LogicDART for its capability of measuring voltage and frequency of signals from a single probe tip.

"In the past, I'd used a bear of a solution that included large logic analyzers and integrated scopes that also required a lengthy set-up time," explained Nikoletich. "Now, I have a tool that I take right out of my toolbox and use immediately. I attach the LogicDART probe tip to a lead, and with a few keystrokes, I can compare waveforms of signals on the display within a few minutes."

Nikoletich tested the 0.5-mm fine-pitch circuitry on the boards by using a magnifying glass to attach the LogicDART probe tip to any lead. The LogicDART provides data visually with graphic timing displays and an LED feature. "Because I was looking for signal transitions during troubleshooting, the LogicDART's LED feature served me well," added Nikoletich. "It blinks whenever signals change, giving me instant knowledge of toggling signals. I immediately knew which chip needed repair."

The new system began operation early in 1998, and is currently in its acceptance phase, said Frye. "The new system certainly has renovated GSSR operations with an advanced electronic hardware system that takes up one-tenth of the space of our previous system. The whole system runs much faster, with greater reliability and at lower cost."

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Vol. 23, No. 6 June 1999 This form expires: November 30, 1999

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Motion Control Tech Briefs

Cover photo courtesy Thomson Micron LLC.

a tubular CHALLENGE to linear MOTORS

A versatile solution requires only one moving part.

The term "linear motor" is often used to describe "flat" linear motors, where essentially one flat plate is moved across the face of another. It is also used to describe motors that provide linear motion using some form of internal rotary-to-linear conversion. But now California Linear Devices has developed a tubular linear motor that provides the required axial force in a simple device with one moving part. This unit has many applications, ranging from motion control to welding, riveting, vibrating and driving compressors. With only one moving part the inherent reliability is high.

The motor is also suited to positioning applications. Through the use of a precision, high-resolution encoder, one can rely on detailed position information to a motion controller.

The basic principle on which this motor operates is as follows. The linear motor has a stator very similar to that of an induction motor. Windings are placed in slots throughout the periphery. Their purpose is to produce a moving magnetic field. The armature has a series of permanent magnets that attempt to align themselves with this moving magnetic field. The force level is set by the length and diameter of the stator, and the stroke is set by selecting the length of the armature.

Figure 1 is a simplified cross section of the motor showing the armature, the stator with the coils, the heat rejection fins, and the electrical connector.

Recently California Linear Devices undertook a program to show that, in relatively low-force material-testing applications, such a simple direct-drive linear motor can do a better, simpler, and cleaner job than a hydraulic system. It was considered that in the region under 2,000 lb. of force the use of a simple one-moving-part linear motor might be more controllable and easier to operate and maintain than a hydraulic control system. The program intended to demonstrate this with a goal of under 1% accuracy at 340 lb. force, with the ability to vary the load as demanded by an operator or through a PLC system input.

The motor is a DC brushless motor with three sinusoidally commutated phases. The DC supply for the motor driver which receives this commutation information and which in turn drives the motor was 300 V DC. The commutation

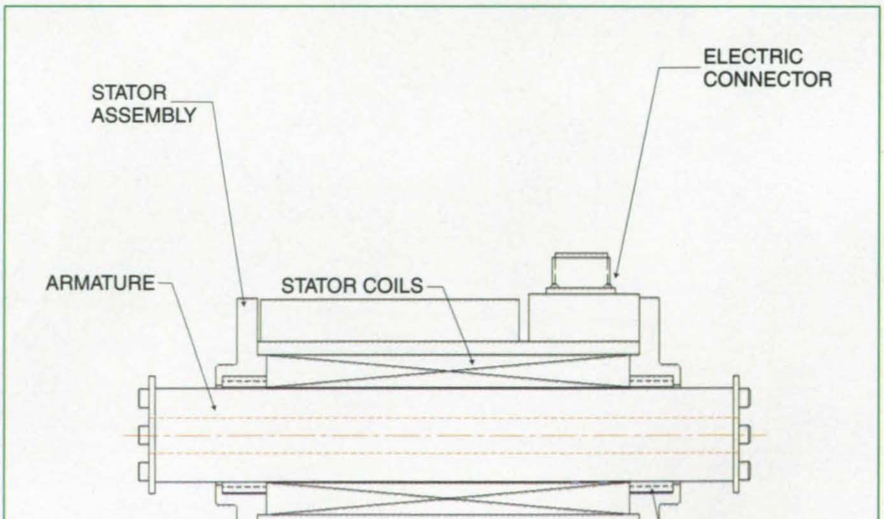

Figure 1. A simplified cross section of a tubular linear motor.

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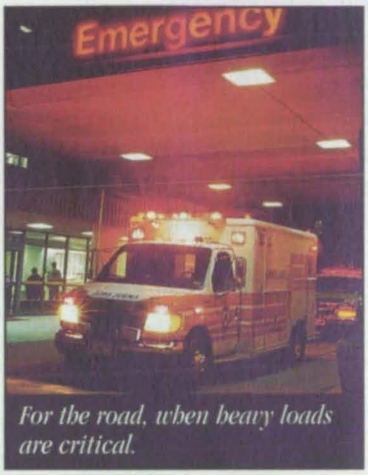

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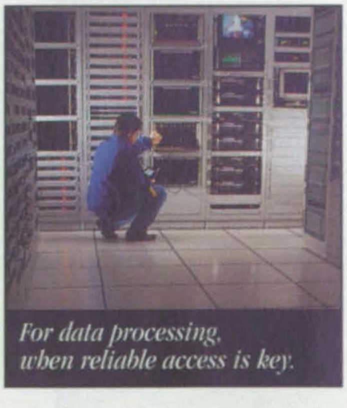

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Position and Force Control Diagram

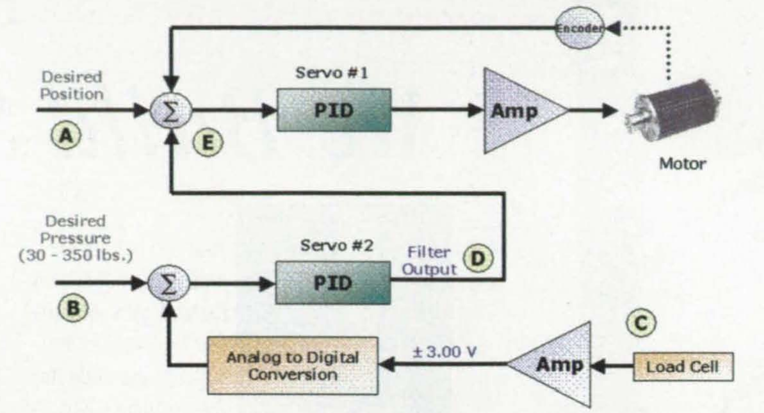

Figure 2. Motion controller set up.

requires knowledge of the motor position. In open-loop operation this is based on an assumption that the motor has reached the position requested by the controller. In closed-loop operation it is provided by the sensor position feedback.

The motion controller used was a Delta Tau PMAC2-Lite four-axis digital controller. The PMAC2 provides true digital control: commutated PWM (pulse width modulation) output and digital current-loop closure. One servo channel was used for PID position loop control and another was used for the force loop control. The servo amplifier used was a 3-kW Semipower Powerblok PWM servo amplifier.

To close the position loop, the required position information is provided by a 1-micron-resolution Renishaw optical encoder that reads the motor armature position directly. This position data was supplied to the motion controller in the form of a quadrature signal.

The diagram (Figure 2) illustrates how the motion controller was set up for this application. As can be seen, "Servo #1" provides the standard position loop control. At point (A) the desired motor position is summed with the actual position. "Servo #2" is set up to provide the force loop control. At point (B), the desired force is summed with the load signal. A load cell at point (C) is used to measure the exerted force and provides this as the feedback signal to "Servo #2". When a difference (error) exists between the desired force and the measured force, the servo loop output, at point (D), for "Servo #2" becomes non-zero. This signal is then combined with the command position of "Servo #1" at point (E), thus commanding the motor to change position until the load cell "sees" a force equivalent to the desired force.

Using two alternate ways of setting the position limit, one fed from the position control loop and one from the force control loop, the motor could be driven in the position control or the force control mode. This allowed the motor armature to be brought into contact with the work piece and then, switching to force control, the load to be adjusted up to the preset value. Now the load could be varied based on the input request signal. Finally, position control would be used to withdraw the unit. The analog force signal from the signal conditioning/amplifier unit was passed through an A/D converter and the resulting signal used as described above.

This unit proved very stable and was able to hold very tight limits on the force applied. At the test point of 340 lb. the load was held within 0.1%. The force could be varied as a function of time using a PC or a PLC system such as might be used in an integrated test machine.

The simple nature of this motor should make this a flexible and reliable approach to strength testing. The overall scheme, where a combination of positioning and force control is used in this type of motor, opens up a wide range of combined position- and force-control applications such as welding, riveting, various operations requiring controlled clamping, and possibly punching, extrusion and fluid dispensing, where a controlled force is important during part of the working cycle.

The engineer responsible for developing the control system was Harry Rivera, MSEE.

For more information, please contact Graham Jones, vice president of sales and marketing, at California Linear Devices Inc., 2236 Rutherford Rd., #119, Carlsbad, CA 92008; (760) 603-8026; fax: (760) 603-0049; http://www.calinear.com.

Miniature DC Servo Actuators Mini RH Series

HD Systems offers a line of miniature DC servo actuators for use in applications such as robotics, instrumentation, and factory automation where precise motion control is required. The actuators combine zero backlash harmonic drive gearing with rare-earth magnet DC servo motors to provide both high torque and positional accuracy better than 2 arc-minutes. Rated torques of 2.6 thru 56 in-lb and rated speed of 15 thru 60 rpm are available depending on frame size and gear ratio. The smallest actuator measures just 20 mm in diameter. Encoders and/or tachometers are available as an integral part of the actuator.

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

Circle No. 605

New, Hollow Shaft Gearing SHF Series

Featuring a through-bore up to 70 mm in diameter, the SHF Series component sets and gearheads enable the design engineer to pass shafting, wire bundles, or other components directly through the center of the gear. The new SHF Series provides high accuracy in a compact design. This unit design is both axially shorter and lower in weight, as compared to conventional harmonic drive gearing. This is accomplished by using HD Systems patented "S" tooth profile. Rated torques up to 6590 in-lb and positional accuracy better than 2 arc-min can be achieved. Gear reduction ratios of 50:1 through 160:1 are available in a single stage.

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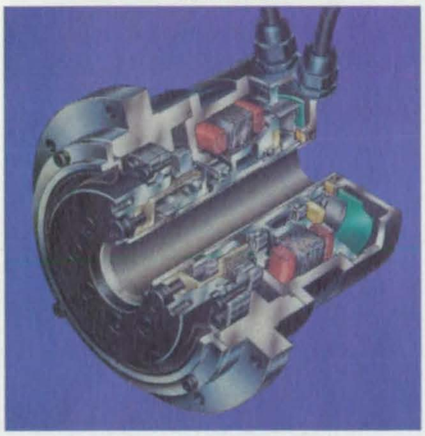
Circle No. 604



Hollow Shaft DC Brushless Actuators

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

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Circle No. 603

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We Have the Solution

For More Information Circle No. 602

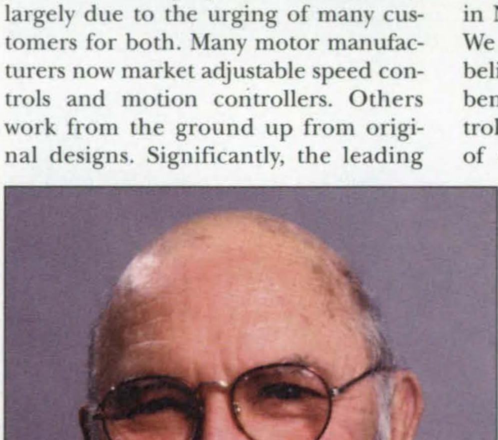
Converging into One Industry:

Motors & Controls

Electric motors and electronic motor controls are coming together, to the benefit of the end user.

by Roland S. Boreham, Jr., Chairman, Baldor Electric Co.

Industrial electric motors and electronic industrial controls are in the process of merging into one industry, largely due to the urging of many customers for both. Many motor manufacturers now market adjustable speed controls and motion controllers. Others work from the ground up from original designs. Significantly, the leading controls manufacturer has entered the motor field.



Roland S. Boreham, Jr.
Chairman
Baldor Electric Company

The consolidation continues rapidly in North America, and globally as well. We at Baldor Electric and many others believe this is a healthy trend, because it benefits users of both motors and controls. Also, it is definitely to the benefit of designers of systems incorporating motors and controls. One important reason is compatibility: though using components from one manufacturer does not guarantee compatibility, it certainly improves the odds for success.

There is also the important subject of responsibility. A look at the history of these industries will illustrate this.

Electric motors have been important to industry for more than one hundred years, and have become a medium-sized industry of approximately $10 billion dollars per year in North America, and two or three times this large globally.

A second industry, known by many names but which we'll refer to as industrial controls, was born soon after. A large percentage of these controls were designed and used originally to start and stop motors. Then later, in some cases, there were many different ways to adjust the speed of motors, usually direct-current motors. In fact, one of Thomas Edison's reasons for supporting the use of DC motors rather than AC motors was their controllability.

These old controls were mostly electromechanical. Power electronics, including the old thyratrons and other devices, gradually took over some of these applications, sometimes improved their performance, and often lowered costs.

Until 1960, most industrial-motor speed controls were large, heavy, and expensive. An exception was the military use of servos. With the invention of the silicon-controlled rectifier (SCR) in the late 1950s at Bell Labs, the ability to control industrial motors rapidly increased (Figure 1).

The SCR opened up much better ways to adjust output DC voltage to the motor armature and control the speed of shunt-wound or compound-wound DC motors. More than 100 manufacturers of SCR controls sprang up around the world. These controls were gradually adopted by most industrial establishments as well as some commercial enterprises.

Many were not satisfied, however. Many users would have preferred controlling AC motors rather than DC motors. This preference often resulted from the belief—sometimes true, sometimes not—that DC motors required much more maintenance.

Then, referring again to Figure 1, along came the inverter in the mid-1970s. Early models had many disadvantages. They were much heavier, larger, and more costly—at least double and more often triple—than an SCR control of a similar size. They also had less speed range and lacked torque controllability.

In any event, this situation gave designers and users of these components a choice they had not previously experienced. Some liked DC and some liked AC. Gradually the costs came to be quite similar, with the DC motor costing more but the DC control less, and the AC control costing more but the AC motor less.

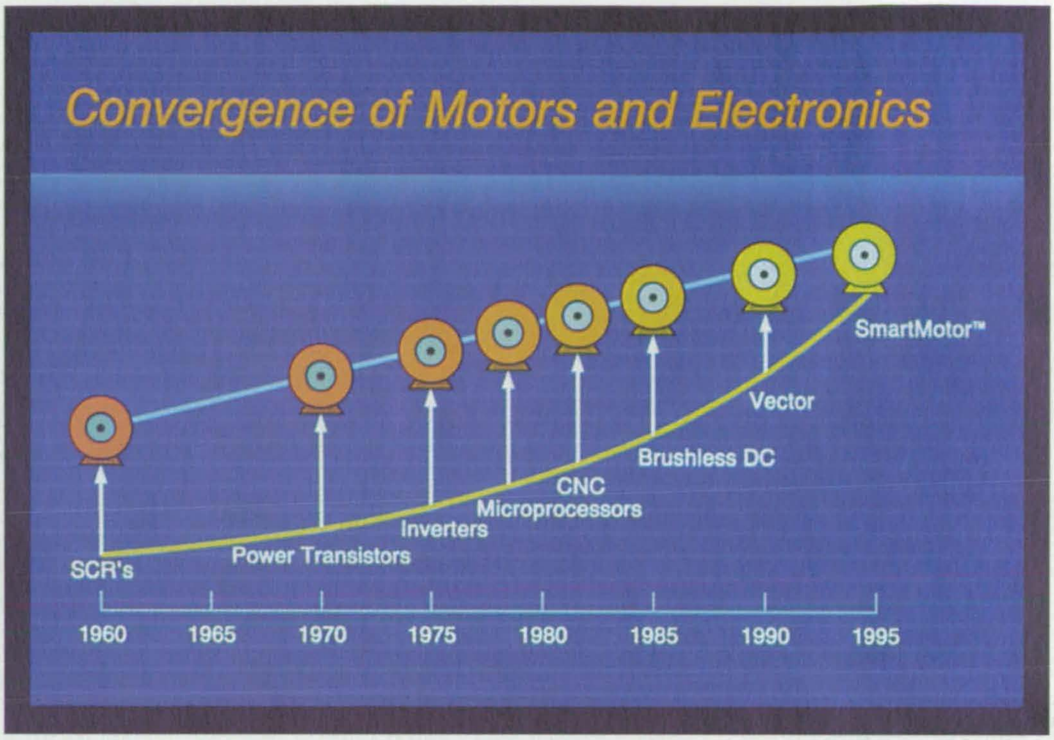


Figure 1.

Improved performance led to brushless DC motors in the 1980s. "Brushless DC" is really a misnomer, for these are really AC motors. They were dubbed brushless DC because they perform like DC motors, but usually with a wider speed range, better speed regulation, and some advantages not always available with AC controls. In Europe they are referred to as AC servo motors. The controls are much more complex than SCR controls, and the motors are more expensive than conventional AC induction motors by a factor of two or three.

The closed-loop flux vector controls, developed experimentally in the 1980s and coming into more widespread use in the 1990s, solved many problems. The flux vector control is referred to by laymen as "the first AC control that performs as well as DC." It yields the wide speed range of a DC/SCR, and can also produce full torque at zero speed. The motor response is also very good, and wide speed ranges, from zero with full torque up to two, three, or four times the design speed of the connected AC motor, are available.

While these design improvements were well accepted by system designers and users, there were still some problems to be solved. One was "ringing" of voltage buildup in long lines between the control and the motor. The longer the cable between the two, the larger the problem. Also, compatibility continued to be a problem, although not to the extent it had been in the 1970s and 1980s.

This led inevitably to the invention of Baldor's "SmartMotor."™ As the name implies, this is a motor with the electronics and magnetics built as one unit. Compatibility problems disappeared, and of course, ringing was no longer a factor. Also, SmartMotors allow the machinery designer to design a truly self-contained and self-sufficient piece of equipment.

Continued

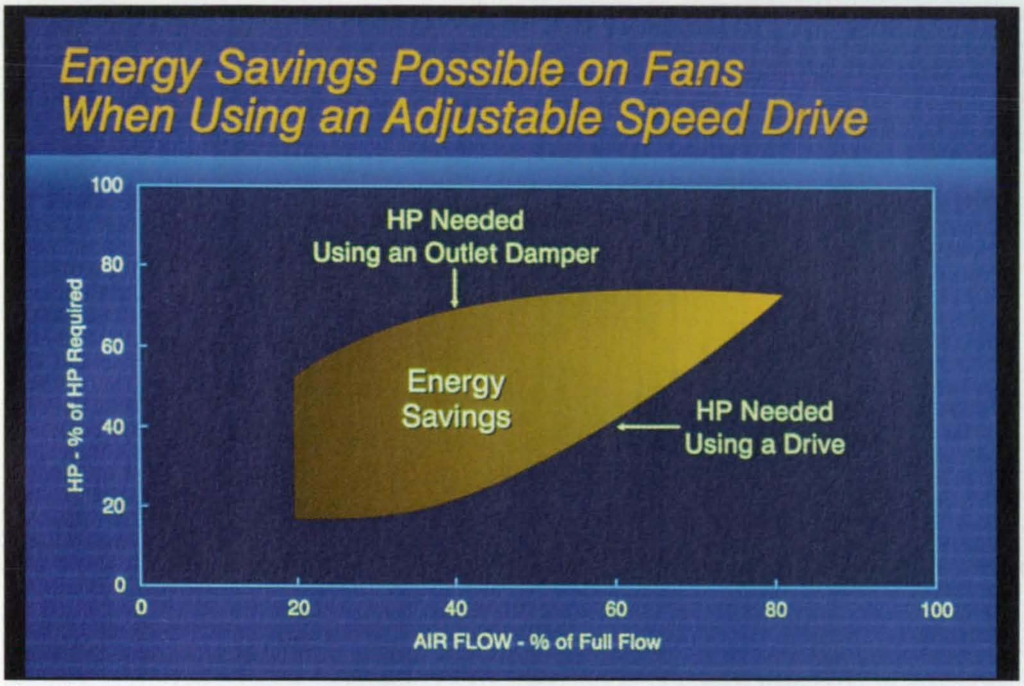


Figure 2.

While SmartMotors are not yet widely used, their advantages are being gradually recognized. Also, the reliability of all these industrial electronics has greatly improved over the past ten years. Lack of reliability ten to 20 years ago was the reason many designers looked for different ways to do the job.

One reason for the greatly increased use of adjustable speed controls is the potential saving of large amounts of energy. Figure 2 shows the difference in energy requirements between running a pump at reduced flow using a standard motor as opposed to using an adjustable-speed drive. At 50 percent flow requirement the energy saving is approximately 50 percent. Considering that a very large proportion of industrial motors—some say as high as 30 or 40 percent—are used to run pumps, and that motors in total use 58 percent of all electricity generated in the United States, it is apparent that the potential energy saving using adjustable-speed drives is tremendous.

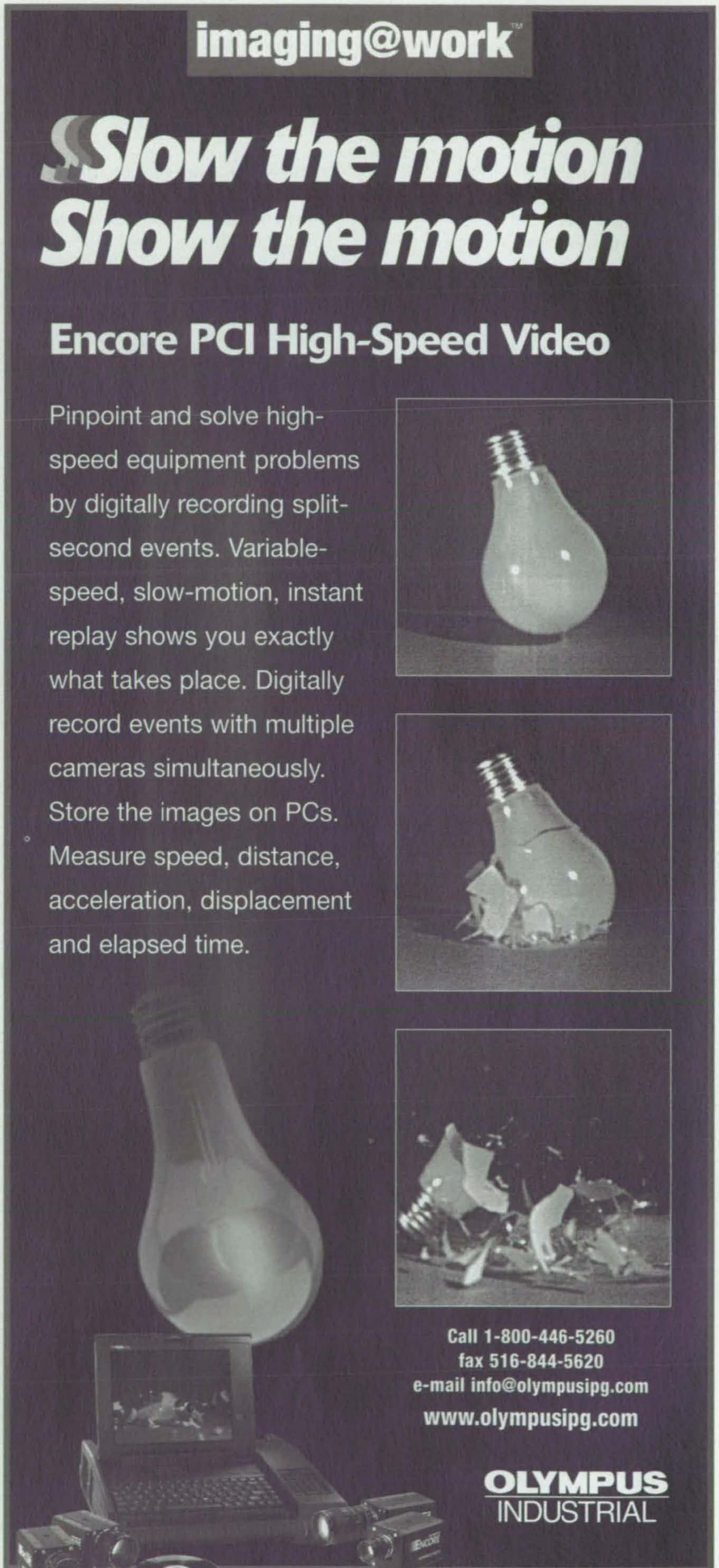
Another common use of motors is to move air with blowers, fans, and so forth, and the same cube rule, of course, applies here just as it does to centrifugal pumps. Therefore the energy saving is quite similar to that of Figure 2. Considering that motors often use ten times their cost in electricity per year, it is apparent that even minor improvements from the use of more efficient motors and adjustable-speed controls yield absolutely tremendous savings in energy and dollars.

Baldor SmartMotors

For example, a 100-horsepower motor, of which there are many thousands in use, has an original cost of $3000 or $4000, depending on the type. If used continuously at a dollar per day per horsepower, such a motor would incur energy costs of $36,500 per year.

Therefore the convergence of these two industries is a very healthy sign for improvements in productivity and competitiveness for American industry. It also gives the design engineer, whether designing a military system, a commercial system, or a brick plant, much more freedom to design built-in productivity advances.

For more information on Baldor, contact Baldor Electric Co., 5711 R. S. Boreham, Jr. Street, Fort Smith, AR 72902; (501) 646-4711; fax: (501) 648-5792; or visit their web site at: www.baldor.com.



For More Information Circle No. 608

Linear Motors Offer New Motion Capabilities

The LinMot® P family represents an innovation in linear motor design.

LinMot Division of Sulzer Electronics, Zurich, Switzerland

The linear motor was invented in the mid-nineteenth century, at much the same time as its brother, the rotating electric motor. Because the linear motor always has to effect a reversing movement—from one end of the motor to the other and back again—it has physical drawbacks as a source of energy as compared with the rotating version, and is therefore less frequently used.

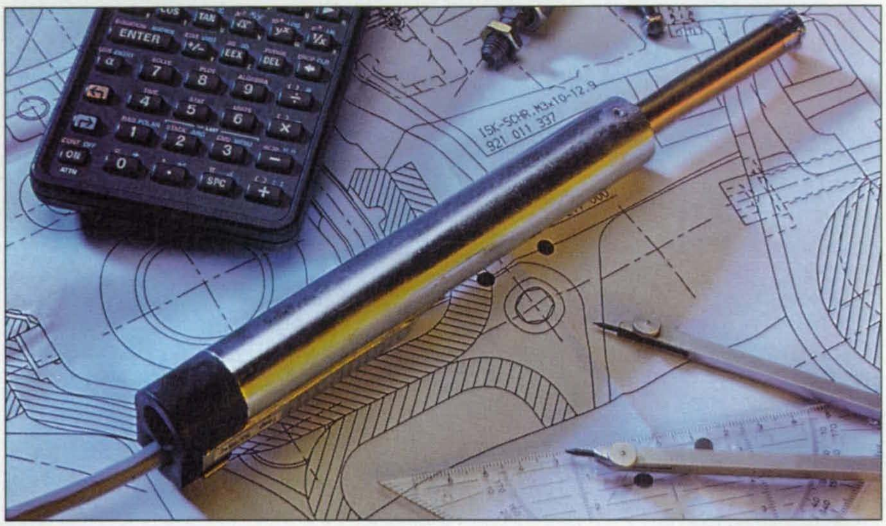


Figure 1. **Technical Properties of LinMot P Linear Motors** include free positioning, electronic cam disc function, extreme acceleration, cyclical movement frequencies, and high dependability and life expectancy, even in harsh industrial environments.

If, however, short-stroke linear motions are needed, as is often the case for applications in the construction of textile and packaging machinery or for handling purposes, the linear motor becomes an ideal form of drive. Gears, levers, and belts can be dispensed with, thus also reducing the space required as well as wear. The linear motion is generated directly by the electromagnetic force.

The decisive innovation in the LinMot P family of linear motors (see Figure 1) resides in the rational implementation of the basic concept of a modern design element. Figure 2 shows that, from the motor components as such via the bearing to position-determination and electronic-sensor systems, all the components are integrated into a strong metal cylinder. The whole structure is based on shaped and pressed components; the sole purpose of the two screws is to satisfy the directives for electromagnetic compatibility when the cable is fixed in position. This

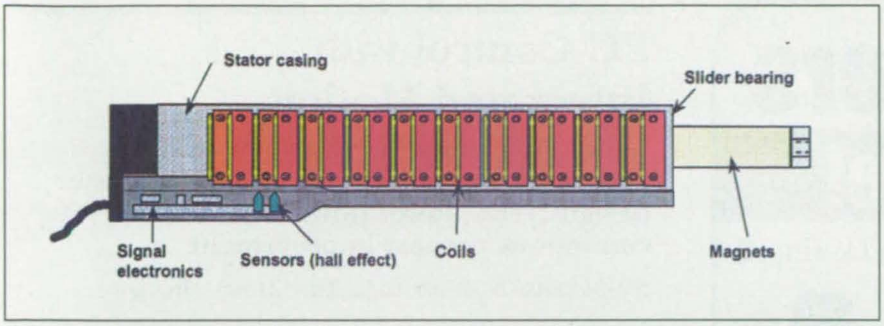


Figure 2. In the innovative **Design of LinMot P Linear Motors**, all the components are integrated into a robust metal cylinder, and the entire structure is based on pressed and shaped components.

innovative design for linear motors is the first to satisfy the tough requirements placed on a component used in industrial machine construction.

LinMot P motors are a suitable replacement or supplement to conventional linear motor technologies such as stepper motors, servo motors, mechanical cams, pneumatic cylinders, and mechanical levers. These motors are suitable for numerous precision linear motion applications, including robotics and laboratory automation.

The special technical qualities of these linear motors can be summarized as follows: they can be freely positioned; they have an electronic cam disc function; extreme accelerations are possible (>200 m/sec^2); cyclical movement frequencies can be greater than 10 Hz; they are dependable, even in harsh industrial environments; and they have high life expectancy.

In comparison, pneumatic solutions cannot be freely positioned, and their dynamics do not offer comparable values. The free programmability of LinMot P is a particular advantage over purely mechanical components such as levers or cam discs.

With LinMot P, the speed of movement can be freely chosen, and other positions, movement profiles, or modes of operation preset by clicking a mouse. LinMot P movement profiles and movement sequences are defined by software and performed immediately. The process-led programming assisted by LinMot permits decentralized functional units.

The design of a machine is determined essentially by two forces: the task which the machine is to perform, and the technical possibilities available to the designer. The previous need to perform fast linear motions by means of centrally driven cam discs and levers determined the structure of many machines. LinMot P represents a real breakthrough in this regard, because the engineering designer now only needs to concentrate on the implementation of the target function: if he needs a linear motion he uses the LinMot component that performs this movement on the site. This enables decentralized functional units to be produced easily. Synchronization, starting characteristics, and the emergency stop situation are defined by software. The decentralized functional units become modules that can be coupled together. A machine can therefore be made up from functional modules and does not have to be redesigned on each occasion.

For more information, contact Dr. Ronald Rohner, manager of **LinMot**, *Zurich, Switzerland, and the author of this brief, at PO Box 521, Rogers, MN 55374-0521; toll free: 1-877-LINEAR-0; fax: 612-274-0224; E-mail: rohner@linmot.com; www.linmot.com.*

PC Control with Integrated Motion

Using PC-based control and flowchart programming, engineers can achieve faster design cycles, lower downtime, and continuous process improvement.

Steeplechase Software Inc., Ann Arbor, Michigan

PC-based control has become one of the fastest-growing automation solutions for the factory floor. Control engineers are quickly dropping their proprietary PLC boxes and replacing them with PC-based control systems to gain the benefits of open-systems architecture. Similar to the shift away from proprietary Wang and Sperry-Univac mainframe systems to PCs in the office, the shift on the factory floor is equally dramatic. The drivers of this migration are pure business benefits: cost-effective integration of off-the-shelf hardware and software solutions; lower overall system costs; control system design cycles cut in half; enterprise-wide connectivity; and easier-to-use systems.

PC-based control combines the functions of several separate platforms into a single PC. This includes the runtime control engine, the programming and monitoring tools, the graphical operator interface, the data collection, alarming, and storage traditionally performed by the SCADA node, real-time simulation, and Windows DDE, DLL, or COM/DCOM data servers.

Beyond the obvious cost savings that result from eliminating an expensive proprietary PLC and several PCs, there are a number of technical factors that should be evaluated when moving to a PC-based control system:

- Hard real-time control;
- Eliminating the multiple database trap;
- Mix & match, commodity I/O;
- Off-the-shelf hardware and software components; and
- Advanced, easier-to-use Windows-based programming tools.

There are five fundamental rules of PC-based control that must be met to replace a PLC:

1. Must provide deterministic operation. Control must be treated as the highest priority and ensure a predictable, repeatable response.
2. Must survive a Windows crash. A machine control program must survive a General Protection Fault in Windows, or the "Blue Screen of Death" in Windows NT, and continue to operate in a safe manner.
3. Must be isolated from poorly behaved Windows applications and drivers. The control system cannot be adversely affected by unstable Windows NT applications or drivers.
4. Must survive a hard disk crash. It is essential that deterministic control not be interrupted in the event that a hard disk crashes or is removed. If the hard drive in the PC fails, the real-time control must continue to execute.
5. Must be based on a proven real-time engine. The control engine must have a proven track record in mission-critical applications.

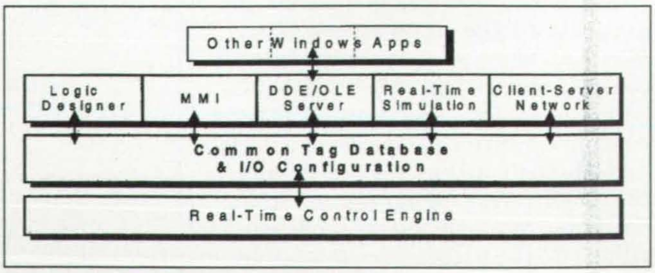


Figure 1. **PC-based Control Architecture** with common database.

Hard real-time control is the technology that is required to meet these rules. As opposed to "Soft Logic," which runs a PLC emulator under Windows NT, hard real-time control couples the core of a PLC—a real-time operating system—with Windows NT on the same PC. Because Windows NT is completely isolated from the PLC core, Windows NT can "blue screen" or the hard drive can fail, and the control system keeps running.

One of the key benefits of Windows PC-based control software is the elimination of the multiple databases required to support a PLC system. Because the software incorporates the functions of the PLC, the programming PC, and the operator interface and provides real-time data access to other software applications running in Windows, a single common database can be used across all of the tools (see Figure 1).

Each element of the software can access the same database with a single set of tag names. I/O points are configured and given tag names once, and the same tag name is used throughout all of the software applications. The most important benefit of using the single tag in PC-based control systems is the elimination of human error.

Another key advantage of PC-based control is its ability to support multiple PLC I/O types. With an I/O scanner card, the PC can connect to and scan most industrial I/O. Examples of typical I/O families include Allen-Bradley's Remote I/O, Genius I/O, and Modicon Remote I/O. Open device-level buses include Interbus-S, DeviceNet, Smart Distributed System, and Profibus. A PC-based controller can mix several different I/O families in the same PC by simply installing scanner cards for each I/O family.

An even more powerful feature of PC-based control is the ability to switch I/O families, comparable to changing printers in Windows. A system designed for a particular I/O family can be changed to use a different I/O family through a simple drop-down box.

Manufacturers make a significant investment in developing their applications and processes, and recognize that this investment must be protected. To "future-proof" their investment, they are interested in using platforms that will support their investment into the future. The research and development dollars alone spent in the $200-billion PC industry exceed the total revenue of the $4-billion PLC industry.

One of the most significant advances introduced with PC-based control is graphical flowchart programming. Flowcharts offer a simple, intuitive graphical description of a process that is used and understood by nearly everyone on the factory floor. A common language allows engineers, operators, and electricians to easily interpret flowcharts that describe the step-by-step process to program, operate, or troubleshoot a machine.

Flowchart blocks describe the motions as simple function calls. These can be placed inside the flowchart logic (Figure 2) and can describe in written English how the motion is programmed. Commands such as "Jog," "Axis Symmetrical Move," and "Axis Relative Move" can be dropped in place. Configuring the motion blocks becomes as simple as filling out parameters in a dialog box such as axis, position, acceleration/deceleration rate, and velocity. With Steeplechase Software's patent-pending flowchart-enhanced ladder logic, the same motion blocks defined for flowchart programming can also be dropped directly into ladder-logic rungs.

Control system design time can be reduced by 50 to 70 percent using PC-based control and flowchart programming, compared with traditional PLC design using relay ladder logic. Flowchart programming also reduces machine downtime in two ways: by displaying the

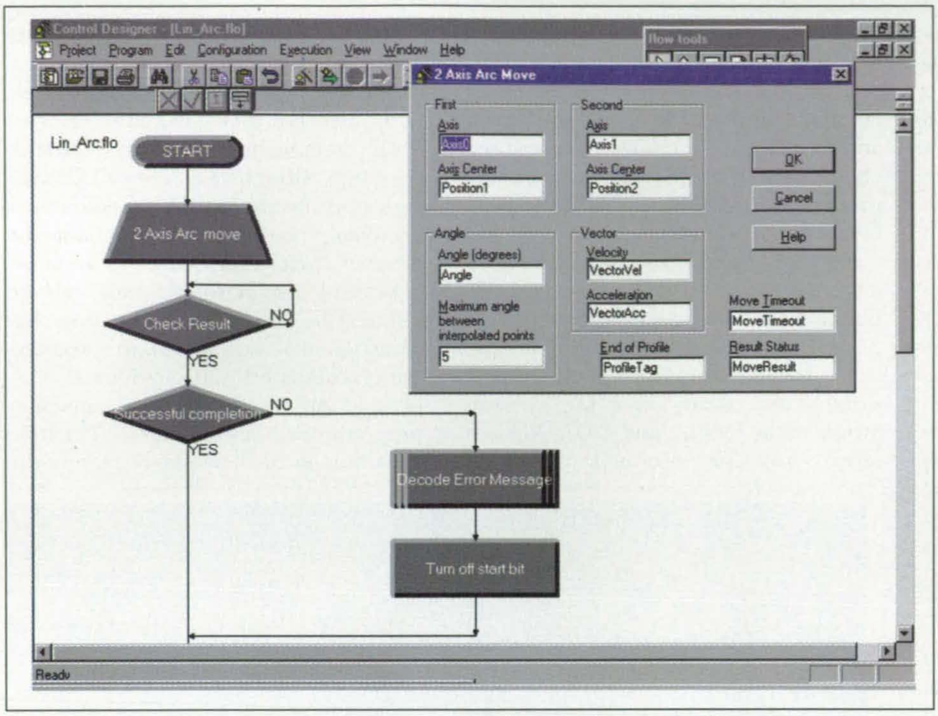


Figure 2. **Flowchart Programming** incorporating motion blocks and motion configurations.

machine status on the PC screen and prompting the operator through repair steps, and by displaying the underlying machine steps with graphical troubleshooting flowcharts.

PC-based control with flowchart programming also provides the ideal tools for continuous process improvement. With a graphical, step-by-step sequencing of the machine's operation, it becomes easier to read, understand, and improve the operation of the machine.

As PCs have become more widely accepted in the manufacturing environment, a number of advances have taken place to add motion control capabilities to the PC. Smart servo systems using high-speed PID algorithms are built right into PC interface cards. These cards enable onboard digital signal processing chips to provide servo loop closures and path planning in the microsecond range. This capability makes servo systems an excellent fit for high-precision motion applications.

The benefits of hard real-time PC-based control can be extended to the motion control solution. Execution of the motion programs run under the hard real-time core is isolated from Windows NT. All five rules of PC-based control cited above can be extended to motion control.

The common tag database can be expanded to include the motion control parameters. By integrating the motion database with the rest of the PC-based control database, the motion parameters and data are directly accessible from the common programming environment, MMI, and other Windows applications either through DDE/DLL/COM/DCOM interfaces or over the network to remote PC applications. All of the benefits of a common tag database can now be expanded to include motion control on the PC.

There are a number of applications where PC control can be applied for simple single-axis and multiaxis motion control. These include gantry material handling, X-Y-Z overhead crane control, electronic component pick-and-place controls, and single-axis feed to length applications where material is fed from a roll into a press to be formed and cut. Other applications include transfer lines, material position, test stands, articulating profile motion, stepper applications, and point-to-point positioning applications.

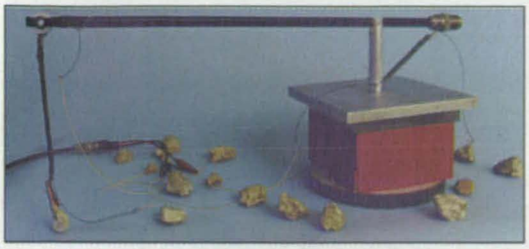
This work was done at **Steeplechase Software Inc.,** *1330 Eisenhower Place, Ann Arbor, MI 48108; (734) 975-8100; fax: (734) 975-8123. For more information contact Mike Messick, the author of this article, which was adapted from the 1999 Proceedings of the National Manufacturing Week Conference. Copyright © 1999 Reed Exhibition Companies.*

Robot Arm Actuated by Electroactive Polymers

The actuators function similarly to components of human arms and hands.

NASA's Jet Propulsion Laboratory, Pasadena, California

The figure shows a robot arm that is essentially a miniature crane actuated by electroactive polymers. This mechanism has been constructed as part of a continuing effort to develop lightweight, compact, low-power-consumption telerobots.



This **Miniature Crane** has been used to demonstrate the feasibility of small, lightweight, low-power-consumption robot arms containing electroactive-polymer actuators. In an experiment, the crane lifted a rock by 3/4 in. (19 mm). It should be possible to increase the lifting distance by optimizing the design of the ropelike LEAs.

Electroactive polymers have been chosen as the actuator materials for this development because they offer advantages over such competing actuator materials as electroactive ceramics (both piezoelectric and electrostrictive). For example, whereas the maximum actuation strains of electroactive ceramics range between 0.1 and 0.3 percent, those of electroactive polymers exceed 10 percent; and whereas the densities of electroactive ceramics range from is 4 to 6 g/cm^3, those of electroactive polymers range from 1 to 2.5 g/cm^3. Electroactive polymers can be formed into almost any shape, are flexible and tough, and damp vibrations. Like other polymers, electroactive polymers can be mass-produced at relatively low cost. Unlike piezoceramics, electroactive polymers need not be poled during manufacturing; this helps keep production costs low.

The lever arm of the miniature crane is a hollow graphite/epoxy rod 15 in. (38.1 cm) long, with an inner diameter of 1/4 in. (6.4 mm) and an outer diameter of 1/3 in. (8.5 mm). The pivot point divides the rod into two parts with length ratio of 5:1. The electroactive-polymer actuators are of two types:

- There are two linear electrostatic actuators (LEAs). These are ropelike objects made from an electrostatically activated polymer (a silicone) with carbon surface coats as electrodes. LEAs function analogously to muscles in that they act by shortening or lengthening. One of the LEAs lies along the top and over the outer end of the longer part of the lever arm, where it hangs down and holds a gripper. The other LEA is fastened between a fixed point and the outer end of the shorter part of the lever arm. The two LEAs are electrically activated in synchronism so that their actuation effects add to maximize the stroke in lifting or lowering an object held by the gripper.
- The gripper contains four fingers that are not jointed but nevertheless bend and thus function similarly to human fingers. The fingers are perfluorinated-ion-exchange-membrane/platinum composites. When a voltage is applied across the thickness of such a finger, electrostriction in the ion-exchange polymer in the membrane causes the finger to bend; the direction of bending depends on the polarity of the voltage. Hooks on the ends of the fingers help to secure the grip on the object, which can be picked up and carried once the fingers close around it. [The gripper was described previously in more detail in "Robot Hands With Electroactive-Polymer Fingers" (NPO-20103) *NASA Tech Briefs*, Vol. 22, No. 10 (October 1998), page 78.]

This work was done by Yoseph Bar-Cohen and Tianji Xue of Caltech, and Brian Lucky, Cinkiat Abidin, Marlene Turner, and Harry Mashhoudy of UCLA for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Machinery/Automation category.* NPO-20393

New Products

Automated Machinery Analysis Software

Predict/DLI, Bainbridge Island, WA, offers the ExpertALERT™ Enterprise™ vibration analysis and automated diagnostic software system. It includes a new feature called the In-Tray, a "folder" that contains the machines most important to the user. In-Tray settings allow ExpertALERT to immediately notify the user when the condition status of any selected machine changes. The NetCasting feature is a network-based dynamic web site that automatically generates HTML pages and machine status summaries accessible by a common web browser.

For More Information Circle No. 762

Laser Through-Beam Sensor

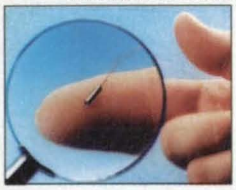
Balluff Inc., Florence, KY, makes available the BOS-18M laser through-beam sensor for a wide variety of industry detection needs, from tiny objects at close range to large-area motion and event monitoring over a 50-m range. The BOS-18M can detect objects as small as 0.03 mm from 10-80 cm. Its long sensing range removes criticality in mounting by allowing greater "stand-off" on minute objects, the company says, and the distance-sensing capability can permit area coverage with fewer sensors. With a standard M12 connector, it is available in both straight and right-angle formats for greater mounting flexibility.

For More Information Circle No. 763

Servo-Class Coupling Line

Helical Products Co., Santa Maria, CA, says that its new line of torsionally stiff couplings was designed to meet the exacting positioning requirements of servo-motor applications. The company says the X Series has the excellent performance characteristics of the metal bellows concept at a competitive price. Other features are low radial loads, one-piece integrity, and zero backlash. The X Series' substantial parallel misalignment capability reduces the need for high-precision alignment during assembly operations.

For More Information Circle No. 764



Tiny Gearmotor

Micro Mo Electronics, Clearwater, FL, calls the BL 1900 Series brushless motor and planetary gearhead the world's smallest commercially available gearmotor at 1.9 mm (0.007 in.) in diameter. Key to its size, the company says, was the use of LIGA micromachining to produce molded plastic microgears only 80 μm in diameter. Based on System Faulhaber® ironless coil technology, the tiny system uses a bipolar neodymium permanent magnet for the motor's rotor, and a sensorless electronic commutation system. Continuous output torque is 150 μN-m (0.02 oz-in.) and an intermittent output torque of up to 300 μN-m (0.042 oz-in.).

For More Information Circle No. 765

Single-Coil Clutch/Brakes

The CSB Series from Electroid Co., Springfield, NJ, offers five clutch/brake models that use a single coil to accomplish both clutching and braking for rotary motion control. Varying in size from 1.75 in. to 5.865 in. in diameter, the devices range from 15 to 600 in.-lbs torque for clutches and 6 to 150 in.-lbs. for brakes. The series features a zero-backlash clutch armature with spring release and a stationary field coil eliminating slip rings and brushes. Precision sealed ball bearings are available.

For More Information Circle No. 766

Stepper Motor Driver

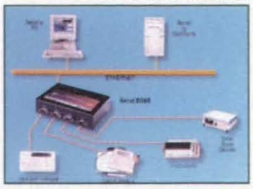
CyberPak Co., Downers Grove, IL, says that its CY-42C AC supply stepper motor driver may be powered with any low-cost 24-28-V AC secondary transformer. No other power-supply components are required, since they are already built into the CY-42 module, which the company says substantially reduces system cost. The control interface supports step, direction, enable, full/half-step mode, and recirculate controls. CyberPak says that the CY-42C incorporates power-saving strategies that make the module run 20 °C or more cooler than other similar motors.

For More Information Circle No. 767

Bellows-Type Shaft Couplings

Servometer Corp., Cedar Grove, NJ, introduces a new metric line of bellows-type flexible shaft couplings that it says are ideal for critical precision positioning applications. According to the company, the couplings have zero backlash and extremely low windup, as low as 4.4 arc-sec/N-cm. Servometer says the coupling can absorb parallel shaft misalignments up to 1.73 mm, angular misalignments to 31°, and axial movements of 5.84 mm, or a combination of all three, while precisely transmitting torque loads. Stock couplings have a torque range from 1.4 N-cm to 198 N-cm; custom torque capacities are available.

For More Information Circle No. 768



Serial-to-Ethernet Converter

A new model has been added to the Serial EDAS™ line by Intelligent Instrumentation Inc., Tucson, AZ, providing what the company calls a complete and cost-effective solution for connecting serial devices to Ethernet networks. The Ethernet/serial converter can connect RS-232 to devices such as terminals, scales, bar code scanners, machines, instruments, PLCs, controllers, gauges, smart sensors, and others. Additionally, device and machine manufacturers may embed these systems to provide products with Ethernet connectivity.

For More Information Circle No. 772

Hollow-Shaft Incremental Encoders

Stegmann Inc., Dayton, OH, offers the HG660 Series of hollow-shaft incremental encoders that have resolution capability up to 10,000 ppr. Their 60-mm external diameter and integral flexible stator coupling allow large axial (±2 mm) and radial (±0.1 mm) drive-shaft movements. The HG660 AKR and HG660 DKR encoders each feature quadrature output signals and a reference marker, as well as a range of 5-30 V. Each has push-pull, differential line driver, and operating speed to 6000 rpm. The HG660 AKR features interchangeable collets for 6-15-mm shaft diameters.

For More Information Circle No. 771

Precision Stages

Nutec Components, Deer Park, NY, announces that it has incorporated a precision, fine-resolution roller leadscrew as the drive mechanism in its compact Trimline™ series of stages. The company says that, with its continuous-contact rolling motion, the low-hysteresis leadscrew maintains 0.5-micron repeatability and 1.5-micron/25-mm accuracy up to a drive speed of 3500 rpm. Measuring 76 × 156 mm, the Trimline can be used in single-axis, X-Y table, or custom configurations in semiconductor assembly, metrology and inspection, laser work, vision systems, and robotics.

For More Information Circle No. 773

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How to Develop a Successful Business or Product

Engineers and other technical professionals are becoming increasingly important as business drivers. Most, however, know few of the skills required to turn a good idea into a successful business. This course will focus on the knowledge, skills, and behaviors needed to "Make it Happen." It will deal primarily with nontechnical issues, as most projects fail due to "people issues."

BENEFITS

You will learn:

- how to recognize an opportunity
- how to sell and market an idea
- how to effectively manage enterprise projects
- how to assemble, motivate, and manage a team
- how to prepare a business plan
- fatal flaws that kill projects
- a roadmap for a successful project.

Most importantly, you will get an understanding of how people really work together, what motivates them, and how the use of simple people skills can make you more efficient and effective.

WHO SHOULD ATTEND

The course will address the needs of both those who run major development projects within an organization (intrepreneurs) and those who want to do it on their own (entrepreneurs).

INSTRUCTOR

Leslie M. Gray, an entrepreneur and engineer, started Airflow Research and Manufacturing Corp. in 1980 to market quiet cooling fans for automobiles; ten years later, when he and his partners sold Airflow to the Robert Bosch Corp., it had grown to $55 million in annual sales. He continues to consult to Bosch while teaching entrepreneurship and serving on the boards of several startup firms.

SC100 $150 prereg/$195 on-site
Mon., Sept. 20: 9:00 am to 12:30 pm

Introduction to Rapid Prototyping and Tooling Technologies

As product design and manufacturing cycles have become more and more compressed, new timesaving tools have emerged to help engineers meet their production challenges. This course will provide an overview of the latest technologies in the areas of rapid prototyping, rapid tooling, and high-speed machining; illustrate practical examples of how these technologies can save time and increase productivity; and discuss which of the technologies make sense for various product design and tooling applications. Topics will include:

- 3D CAD — the starting point
- traditional prototyping vs. rapid prototyping:
- reverse engineering
- rapid prototyping methodologies (Stereolithography, Solid Ground Curing, Laminated Object Manufacturing, Selective Laser Sintering, Fused Deposition Modeling, etc.)
- 3D printing
- rapid desktop and office modelers
- introduction to rapid prototyping applications
- plastic and metal rapid prototyping
- sheet metal fabrication
- high-speed machining vs. rapid prototyping
- RP service bureaus

BENEFITS

In this course you will learn:

- how to slash time and drive down product development costs
- the range of rapid prototyping and tooling technologies available today, how they work, and their cost
- the advantages and limitations of each technology
- which technologies are appropriate for your applications
- new advances on the horizon.

WHO SHOULD ATTEND

Engineers and managers involved in product design, prototyping, and development; individuals involved in making decisions on incorporating rapid prototyping technology into existing design and manufacturing processes; anyone interested in gaining comprehensive knowledge of these emerging technologies.

INSTRUCTOR

A pioneer in the rapid prototyping industry, **Merlin C. Warner** has more than 15 years experience in engineering and manufacturing, and has worked for companies involved in tooling design, rapid prototyping, and rapid manufacturing. He is president of Warner Technologies, Waterford, MI, and is an internationally renowned expert, consultant, and speaker in the field of rapid prototyping, high-speed machining, and their applications.

SC101 $175 prereg/$225 on-site
Mon. Sept. 20: 9:00 am to 1:00 pm

Technology Commercialization Strategies/Finding Niche Markets

Whether your product or service is just an idea, recently patented, emerging or mature, this workshop will help you evaluate the potential opportunities and risks and find the most profitable niche commercial markets.

BENEFITS

You will learn through discussion and brief exercises:

- how to evaluate new product ideas and minimize your risk
- what key factor has the most influence in the acceptance of technology in the commercial marketplace
- the "new" metrics in commercialization success
- specific techniques for targeting your best opportunities

Continued next page

- cost-effective ways to find the commercial value of your product
- how to launch products on tight budgets
- how to prepare a commercialization plan that gets attention.

WHO SHOULD ATTEND

Engineers and other technical professionals, business managers/owners, entrepreneurs and others involved in marketing and selling technologies, products and services.

INSTRUCTOR

William J. Dorman is President of Dorman Associates Inc., Lambertville, NJ. Dorman Associates Inc. is a marketing strategies, management engineering, consulting and research company established in 1976.

SC102 $150 prereg/$195 on-site
Mon., Sept. 20: 1:30 pm to 5:00 pm

Speeding the Innovation Process: How to Improve the Performance of Engineering Systems

This course will review product and process analysis to correctly define and solve product concept design problems. Attendees will examine the resource limitations that impede innovation, how the world's patent collection can be applied to improve product development, and how to predict novel solutions.

BENEFITS

During this course, you will learn:

- how to avoid design mistakes made by other companies
- how to apply the laws and trends that govern engineering systems to your own projects
- how evolutionary practices can predict innovation to be used to improve current systems
- how to use these trends to guarantee success in product design initiatives.

WHO SHOULD ATTEND

Design and R&D engineers, product development managers, leaders of major development projects within organizations

INSTRUCTOR

Dr. Sergei Ikovenko, Director of Training and Services for Boston-based Invention Machine Corp., has conducted more than 300 courses on design innovation and technology optimization. In addition to working with Fortune 500 companies worldwide, Dr. Ikovenko has taught seminars at MIT, Harvard, Carnegie-Mellon, and other leading engineering schools. Dr. Ikovenko has received 76 patents in various field of engineering and authored more than 30 scientific papers.

SC104 $150 prereg/$195 on-site
Tues., Sept. 21: 9:00 am to 12:30 pm

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Registration includes course materials, complimentary tickets for coffee and dessert breaks, and entry to all exhibits. For information on group discount rates, call Melissa Hinnen at (212) 490-3999; melissa@abptuf.org

***NASA Tech Briefs* also will be hosting courses and exhibits (including "Technology 2009") in Miami Nov. 1-3. Visit www.techeast.net for the latest details.**

SBIR as a Business Development Resource: A workshop for SBIR-active and interested firms

With over $1.2 billion in annual funding from TEN federal agencies, the Small Business Innovation Research Program is the largest U.S. source of early-stage technology development financing. Over 9,500 firms have been funded for almost 50,000 projects in every field of endeavor, and some 4,500 new projects are selected each year involving several hundred new firms as well as previous winners.

With strong emphasis on bringing technology to full use-condition, SBIR must now be understood as involving far more than simply having a good idea and getting an award. The scale and scope of federal participation itself has changed in important ways, as has the expectation of what awardees must subsequently address to be judged "successful."

For SBIR awardees and newcomers alike, this all-day, highly interactive, workshop will provide information, analysis, tools and insight into effective SBIR participation and long-term business achievement.

BENEFITS

Featuring leading federal procurement and business development experts, the workshop will cover:

- SBIR's changing dynamics (and the opportunities therein!)
- how the program REALLY works…and making it work for YOU
- effective project design and proposal development
- understanding the government as a customer
- factoring to current (changed) business circumstances
- identifying and valuing technology assets
- critical issues in bringing technology to market-use condition
- tools and strategies for exploiting your technologies

WHO SHOULD ATTEND

Those with a well-established SBIR presence as well as those just getting started will profit from this workshop, as will ANY company seeking to bring technology from lab to market.

- The morning session will address issues highly relevant to both SBIR veterans and newcomers;
- Two afternoon tracks will target, respectively: the practical needs of SBIR involvement, and appropriate and profitable market penetration.

IMPORTANT BONUS

An online interactive roundtable will support post-conference continuing discussion and materials exchange (access included in the workshop fee).

INSTRUCTORS

Ann Eskesen will lead a team of respected, experienced experts from industry, business and government. Since 1983, Ms. Eskesen has been President of Inknowvation Development Institute. She is a dynamic public speaker with a substantial reputation as an SBIR advocate.

SC103 $195 prereg/$245 onsite
Tues., Sept. 21: 8:30 am - 5:00 pm

Marketing For Survival: Creating Opportunities and Solving Problems through the POWER of Marketing

Marketing isn't a choice. We all do it every day. To survive in today's fast-paced world, we need to convince management to support, investors to risk, and customers to buy. As professionals in other disciplines with little time to spare, we need practical, proven marketing tools that get the job done right.

BENEFITS

- **Clarity:** About who our "customers" are and why they buy, fund, and invest
- **Value:** The ability to define the value of our products and services to each customer segment
- **Discipline:** Mental tools that help maintain a focus on satisfying customers in a competitive environment
- **Confidence:** When interacting with our customers, management, and investors
- **Power:** Abilities to use the disciplines and processes of marketing to reach goals and manage change
- **The Book:** "Marketing for Survival"

WHO SHOULD ATTEND

Anyone serving "customers" with technologies, products, services, projects, investment opportunities, or time as employees in professional disciplines

INSTRUCTOR

Dr. Gary Lundquist transitioned from scientist to marketer while converting a service company into an INC 500 software company. He helps high-tech companies and R&D labs nationwide to manage change with marketing. He has marketed technologies, products, and services ranging in price from one hundred to half a billion dollars.

SC105 $150 prereg/$195 on-site
Wed., Sept. 22: 9:00 am to 12:30 pm

Intellectual Property: Protection, Licensing, and Government Technology Transfer Issues

This course will provide an overview of three critical areas of concern when bringing technology to the marketplace: protecting intellectual property; dealing with the government in technology transfer matters; and licensing technology.

BENEFITS

This easy-to-understand course will bring you up to speed on:

- trade secret, patent, copyright, and trademark protection and their relevance to commercializing technology
- the Federal Technology Transfer Act and Cooperative Research & Development Agreements (CRADAs), one of the primary mechanisms for government-industry partnerships and tech transfers
- intellectual property issues when dealing with the government — pitfalls to avoid and proven paths to success
- licensing agreements, in particular the key differences between licensing from the government and from the private sector
- how to determine royalties.

WHO SHOULD ATTEND

Industry, government, and university technology managers; engineers; scientists; and entrepreneurs who want to learn how to effectively protect and license their ideas.

INSTRUCTOR

Jacob N. (Jesse) Erlich, a partner with Perkins, Smith, & Cohen, LLP, specializes in intellectual property matters. Previously, attorney Erlich served as Chief Patent Advisor for the U.S. Air Force. He holds a BS in Mechanical Engineering from Worcester Polytechnic Institute and a Juris Doctor degree from Georgetown Law School. A Past-President of the Boston Patent Law Association, Erlich recently coauthored a book entitled "Technology Development and Transfer — the Transactional and Legal Environment."

SC106 $150 prereg/$195 on-site
Wed: 9:00 am to 12:30 pm

Vision and Manufacturing

Ease of use, low cost, and flexibility make vision sensors an attractive choice for basic quality inspections.

When machine vision was introduced to the manufacturing marketplace in the early 1980s, many users and potential users had high expectations that this exciting new technology would serve as a quick-fix cure-all for their quality control issues. When this did not happen in many cases, vision came to be perceived as a mysterious solution that had promised to improve manufacturing quality, but often could not deliver on this promise.

Why did the initial vision product offerings fail to deliver on their promise in the manufacturing arena? Why, during the past couple of years, has machine vision suddenly caught hold and spread rapidly in the manufacturing environment? After suggesting a few answers to these questions, we'll look at new low-end vision technologies that are making machine vision an attractive option for every type of manufacturer, from OEM to end user, from large companies to small, for those people with previous vision experience, to those who have none.

Why Did Vision Fail to Take Hold?

One of the primary reasons that machine vision failed in many manufacturing environments was due not to the technology itself; rather, it was due to lack of user understanding of machine vision concepts, setup, and programming terminology. Most machine vision systems were complex and required extensive programming time. In addition, many users did not realize that machine vision as it then existed was as much an art form as a technology, one that relied on unique solutions methodology combined with custom lighting and optics. Users who expected vision to be a quick cure-all were disappointed, and those who realized that extensive training and experimentation were required to set up a reliable system for their application, sometimes steered away from it as a result.

Another reason that manufacturers were reluctant to implement vision was due to its high price. With vision systems typically ranging from $15,000 to $100,000, users were unwilling, and unable, to invest large amounts of money in a technology they did not understand.

Other factors affecting manufacturers' decisions not to use vision in the past included the proprietary nature of the systems, which offered limited or no ability to communicate with other automation products. Another factor was the lack of flexibility of the systems, which required extensive re-programming whenever a different part was being inspected.

Why is Vision Gaining Acceptance?

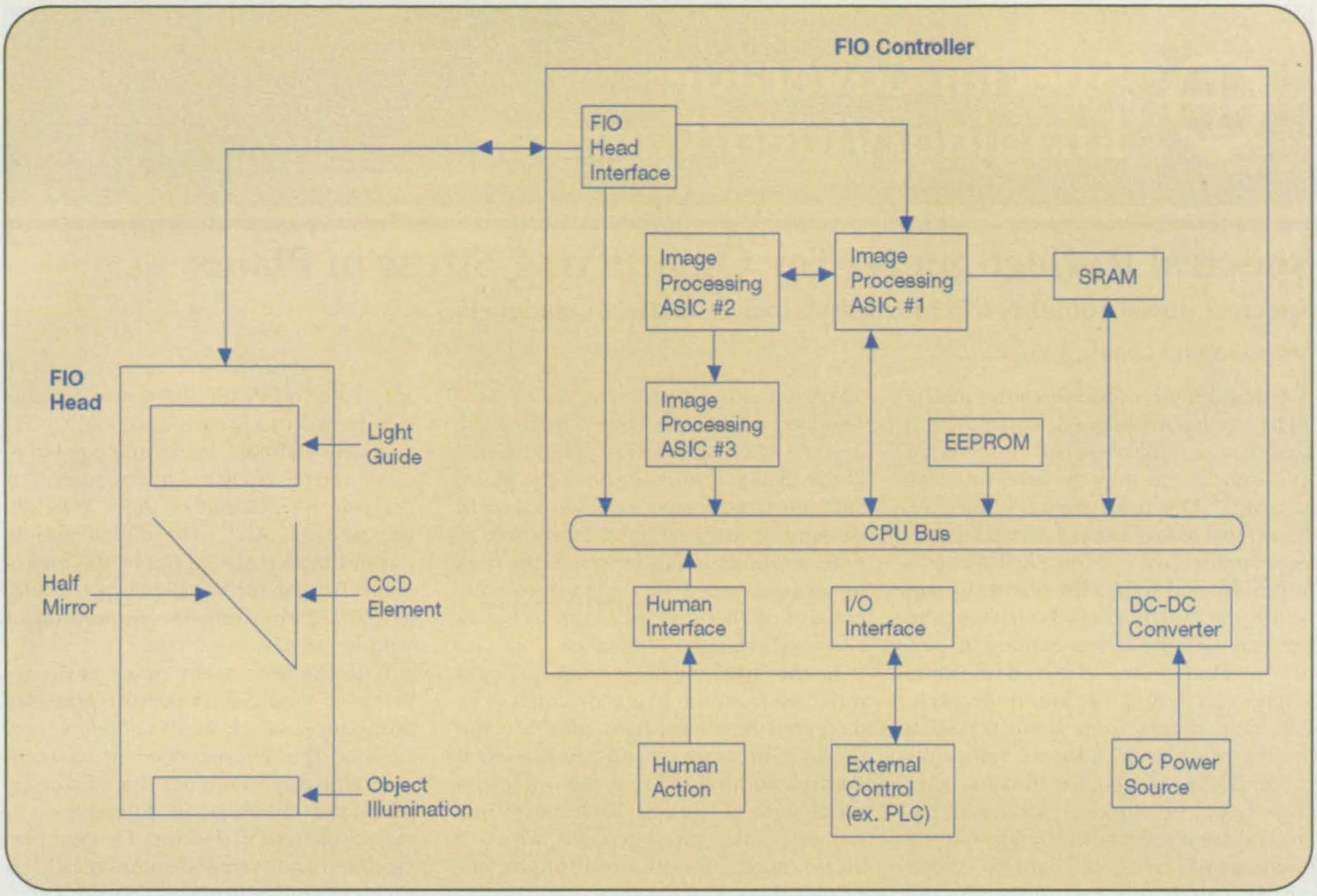
A combination of factors is causing both manufacturers and users of vision solutions to realize that there is a great need for low-cost, easy-to-use vision solutions. As employers are cutting back their work forces and increasing the duties of their remaining personnel, technical staffs are demanding solutions that are easier to understand and use. Because their staffs are spread so thin, companies can no longer afford to have their employees spend days, or even weeks, learning how to use complex vision systems, and they are less willing to pay big money for these systems. They also are not willing to pay for the vision expertise necessary for programming, lighting, and lensing. And, as customers continue to demand higher-quality products, manufacturers are looking for low-cost, easy-to-use, flexible inspection solutions that they can incorporate throughout the various stages of their manufacturing processes.

PC-based vision has addressed some of these user needs. The same PC that is used for word processing and sending e-mail has become fast enough to solve vision applications. Relative to most proprietary systems, PC-based vision offers ease of use through its colorful, graphical user interfaces and its common program development languages such as Visual Basic and C++. PC-based vision is also lower in cost than many traditional proprietary vision systems, which can cost in excess of $100,000. And PC-based vision offers great functionality in terms of simple connection to standard communications like Ethernet, and in terms of the reporting and analysis functionality it provides.

Like traditional proprietary vision systems, PC-based vision typically addresses high-end user needs. These high-end systems provide a range of solutions, from simple to complex, from general to application-specific. Typical prices for PC-based systems (excluding any integration fees) range from $13,000 to $50,000.

But what about the many users who do not need a highly functional vision system that integrates easily with other automation systems? Many vision applications are very basic; for example, is the label facing the right way on a carton? Is the correct printing positioned properly on a business card? Are the instructions included

The F10 consists of an amplifier and a sensor head that look very similar to those of a photoelectric sensor.



in a bottle of medicine? Is the part oriented properly?

Omron has pioneered a new breed of machine vision sensors to address the niche between photoelectric sensors, which cannot see two dimensions, and traditional vision systems, which are often overkill for basic inspection applications. These vision sensors require no user programming; applications are easily configured and re-configured via a handheld console or selection buttons like those found on many photoelectric sensors. Lighting, which is often the most difficult aspect of configuring an application, is built into the system, simplifying setup so that even inexperienced vision users can have an application up and running within minutes.

The Technology Inside

How was a highly complex technology simplified and incorporated into such an easy-to-use interface? We basically re-engineered the technology found in our high-end vision systems, reducing the complexity and functionality of certain components to produce a smaller, faster, easier-to-use and much less costly quality assurance system. Looking at our F10 vision sensor as an example, the vision sensor incorporates both a true grayscale camera and a high-technology grayscale algorithm known as normalized correlation that was adapted from a more complex processing system found in our high-end systems. This normalized correlation algorithm compares an image being inspected against what it has stored in memory to see if the patterns match.

The F10 consists of an amplifier and a sensor head that look very similar to those of a photoelectric sensor. What is it that happens inside that makes a vision sensor different from a photoelectric sensor? (See figure above.) The sensor head contains a camera, lens, and ring light all in one 70 x 33 x 33mm package. A visible green or blue LED generates the search area for the user to see what he or she is inspecting. A half-mirror between the light source and the lens allows light to shine through the lens to project the search area so the user can see what is being inspected. The image is reflected up through the lens to the half-mirror, then reflected 90 degrees to the CCD element. The visible LED light guide enables users to simply teach the F10 to recognize certain patterns (a logo, for example). The user then presses a teach button to register the pattern in the sensor, runs a sample test, and adjusts threshold levels if needed via an up or down select button. The system is then ready to run an application.

Since it detects patterns (rather than spots, as photoelectric sensors do), it enables a wider range of applications. For example, rather than merely detecting label presence or absence, the F10 can detect whether a label is upside down, if it is skewed, or if more than one label is present. Other applications include printing verification and conformity checks.

While machine vision sensors provide limited functionality when compared with PC-based vision systems or traditional proprietary vision systems, a substantial number of applications at the low end of the vision spectrum can be solved quickly, easily, and inexpensively (for about the price of a high-end photoelectric sensor and less than many measuring photoelectric sensors) with machine vision sensors. Because low-end vision sensors respond to the needs of users in the manufacturing environment, vision is starting to become widespread in manufacturing, living up to the promise of its technology, and ultimately benefiting vision users and their customers with the increased level of quality built into parts and products.

For more information, contact the author of this article, Peter McHugh, Marketing Manager of Machine Vision, at Omron Electronics, One Commerce Drive, Schaumburg, IL 60173-5302; Tel: 847-843-7900; Fax: 847-843-7787; or visit the web site at: www.omron.com.

Spectral Reflectometer for Quantifying Stress in Plants

Spectral measurements of chlorophyll loss indicate stress levels.

Stennis Space Center, Mississippi

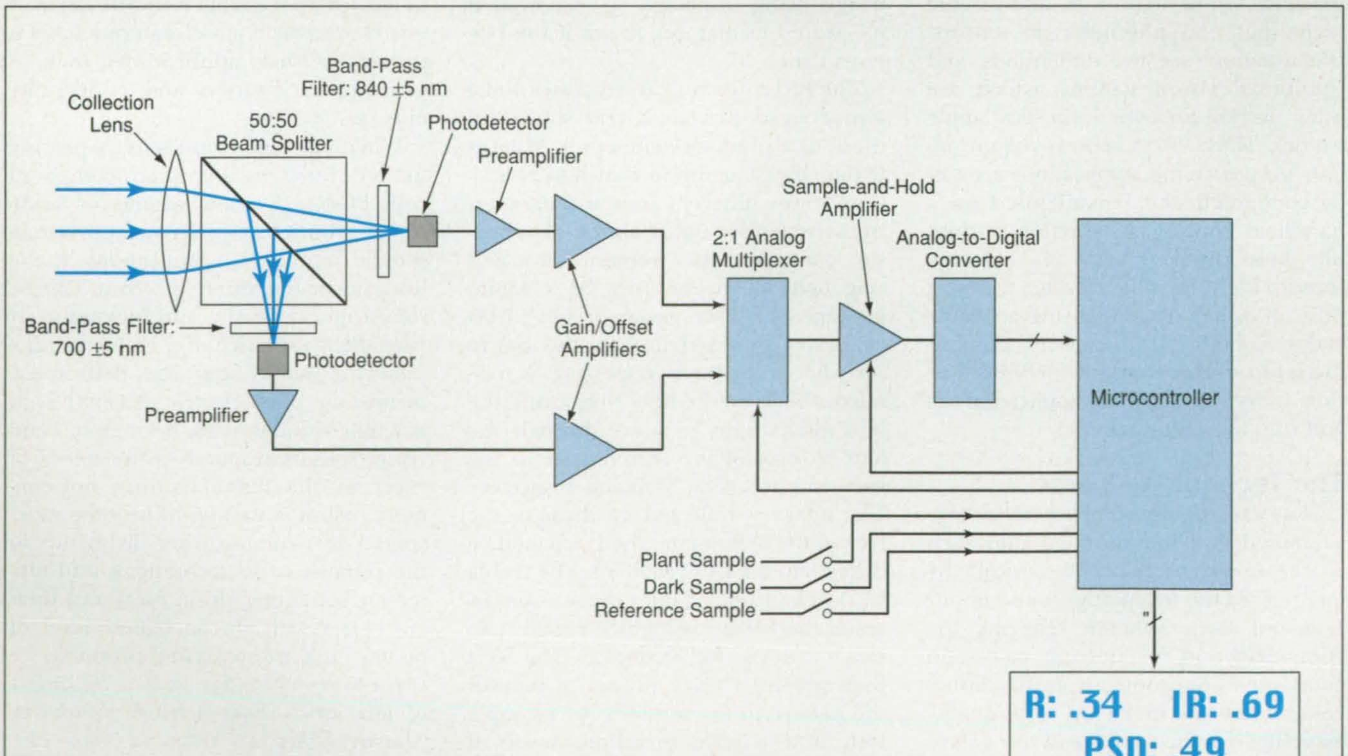
A hand-held optoelectronic instrument has been designed to generate a quantitative indication of the loss of chlorophyll, and thus the level of stress, in plants. The instrument exploits the known spectral-reflectance characteristics associated with the chlorophyll contents of healthy and unhealthy plants. In particular, the instrument indicates the ratio between the reflectances of plants in narrow spectral bands centered at wavelengths of 700 and 840 nm, respectively. This ratio ranges from about 0.1 for a healthy plant to ≥0.4 for an unhealthy plant. [Other similar instruments have been based on fluorescence (as distinguished from reflectance) ratios, but the intensity of reflected light is much greater than fluorescence intensity at the wavelengths used in this instrument.]

The instrument is operated in the following procedure: Readings are first taken with the instrument aimed at a standard reflectance target. Next, readings are taken with the instrument aimed at the plants of interest. Both the plants and the target could be illuminated by sunlight or artificial light. From time to time, readings are also taken in the dark to obtain corrections for nonzero components of photodetector outputs ("dark currents") at zero illumination.

In the instrument (see figure), light reflected from the plants or target is intercepted by a lens, then split into two beams. One beam is band-pass filtered at a wavelength of 700 nm, the other at a wavelength of 840 nm. Each beam then impinges on a photodetector, which is located with the center of its input face at a focal point of the lens.

The outputs of the photodetectors are amplified and offset as needed. A 2:1 multiplexer selects whichever of the two amplified, offset photodetector outputs is to be fed to a sample-and-hold (S/H) amplifier followed by an analog-to-digital converter (ADC). A microcontroller controls the multiplexer, the S/H amplifier, and the ADC. The digital sample put out by the ADC is fed to the microcontroller for further digital processing in coordination with the acquisition of samples, as described next.

With the instrument aimed at the reflectance target, the operator presses a pushbutton switch marked "reference," causing the microprocessor to command the acquisition of a digital sample, first at the wavelength of 700 nm, then at the wavelength of 840 nm. Five samples are taken and averaged automatically on each channel with the single push of a button, then the sample from the dark reading at that wavelength is subtracted to obtain a corrected reading, which is



This **Instrument Measures** the ratio between the reflectances of a plant sample at two wavelengths; one red, the other infrared. The ratio indicates the level of stress in the plant sample.

stored. The instrument is then aimed at the plants of interest, and the operator presses a pushbutton switch marked "plant sample," causing the microprocessor to command the acquisition and processing of readings from the plants in the same manner as from the reflectance target.

At any time before or after acquiring the reflectance-target or plant readings, the operator could place an opaque cover over the lens and press a pushbutton switch marked "dark sample" to acquire the dark readings. In the same manner as for the reflectance-target and plant readings, five dark readings would be acquired at each wavelength and averaged. The average values would then be stored and used to correct the reflectance-target and plant readings as described above.

The microprocessor divides the corrected plant reading for the wavelength of 700 nm by the corrected reflectance-target reading for that wavelength to obtain the reflectance of the plants at that wavelength $[r(700)]$. The microprocessor also divides the corrected plant reading for the wavelength of 840 nm by the corrected reflectance-target reading for that wavelength to obtain the reflectance of the plants at that wavelength $[r(840)]$. Finally, the microprocessor calculates $[r(700)/r(840)]$, which is the desired ratio indicative of stress in the plants.

This work was done by Bruce A. Spiering and Gregory A. Carter of **Stennis Space Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Stennis Space Center; (228) 688-1929. Refer to SSC-00050.

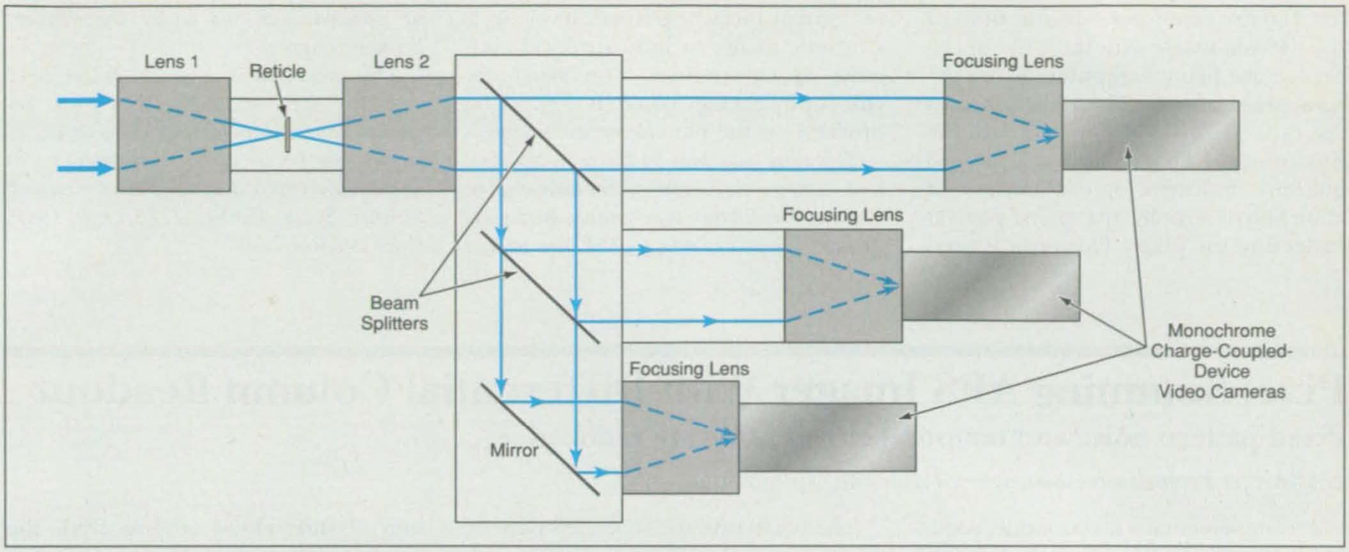
Portable Multispectral Telescope

Optics can be reconfigured relatively easily, and off-the-shelf components can be used.

Stennis Space Center, Mississippi

A telescope produces multiple video outputs representing coregistered images in multiple spectral bands that can range from ultraviolet through far infrared. Although the overall function of the telescope is partly equivalent to that of a color television camera equipped with telescopic lenses, its basic optical configuration differs from that of a color television camera, and it is designed for different applications. In the original intended application, the telescope will be used in research on remote optical detection of stress in plants. By suitable choice and placement of optical components, as described below, the telescope can readily be configured for other special applications.

Light from the scene under observation enters the telescope along an input telescopic optical path that is common to the multiple output paths (see figure). The input telescopic optical path includes lenses 1 and 2. (As used here, "lenses" is shorthand for optical subsystems that could, optionally, comprise single- or multiple-element lenses or multiple-lens subsystems.) Lens 1 focuses the light to a real image on a reticle, which serves as a common alignment reference for the multiple spectral images. Lens 2 then expands and collimates the light. The collimated beam then enters an assembly of beam splitters, filters, and a mirror. The portion of the collimated beam emerging through each filter in



The **Portable Multispectral Telescope** produces multiple video images of the same scene in different spectral bands. The telescope could readily be configured for more, fewer, or different spectral bands.

this assembly contains only light in one of the desired spectral bands. A lens on the optical path for each spectral band focuses the collimated light onto the array of photodetectors in a video camera that is dedicated to producing the video image for that band.

Although the configuration shown in the figure is for three spectral bands, other configurations with fewer or more spectral bands could be chosen. The input beam could be split and filtered as many times as needed, subject only to the practical limitation imposed by finitude of the available luminous flux. Lenses, beam splitters, filters, and video cameras can be off-the-shelf or custom-designed, as needed, for imaging in specified spectral bands.

This work was done by Bruce A. Spiering of **Stennis Space Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Stennis Space Center; (228) 688-1929. Refer to SSC-00048.

Portable Video Imager for Detecting Stress in Plants

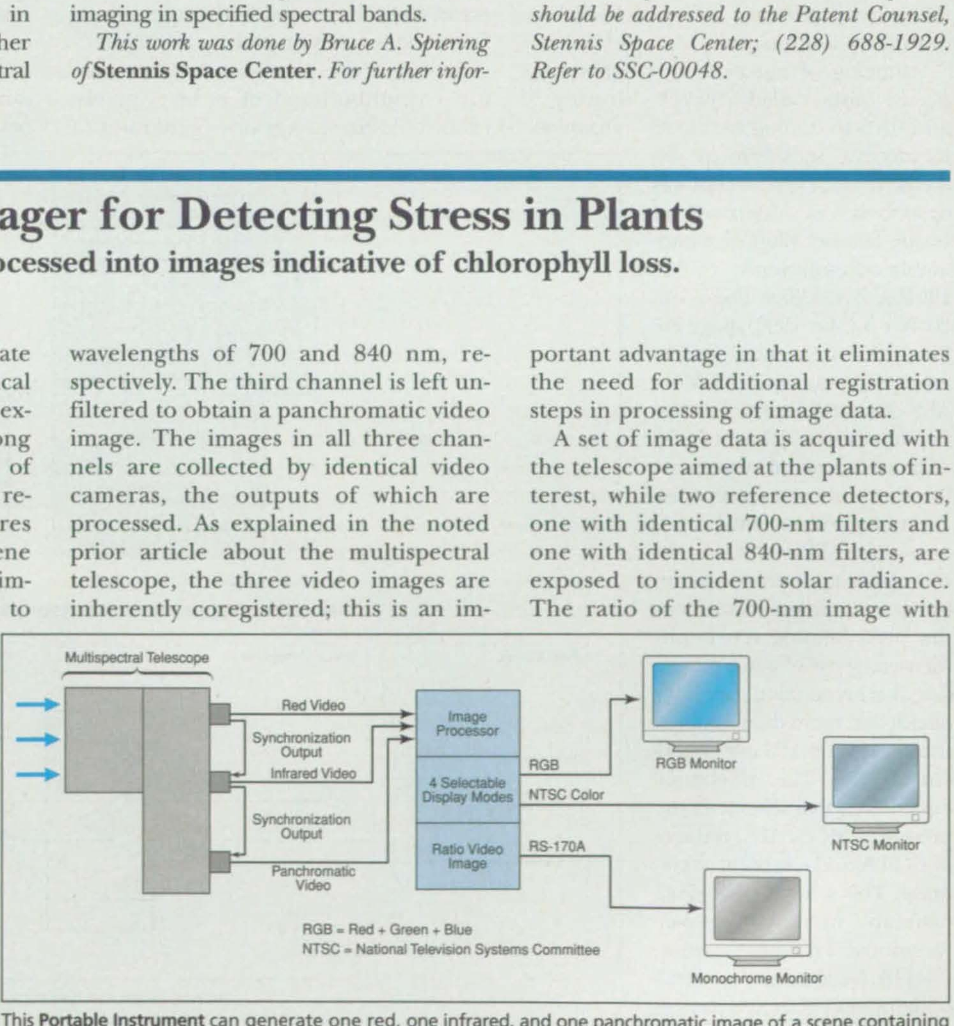
Multispectral images are processed into images indicative of chlorophyll loss.

Stennis Space Center, Mississippi

A portable instrument can generate video images indicative of physiological stress in plants. The instrument exploits the known relationships among physiological stress in plants, loss of chlorophyll, and changes in spectral reflectance. The instrument acquires multispectral video images of a scene that contains plants, digitizes the images, and processes the image data to generate a new image that maps chlorophyll loss in the scene.

The instrument (see figure) is based partly on the instruments described in the two preceding articles, "Spectral Reflectometer for Quantifying Stress in Plants" (SSC-00050) and "Portable Multispectral Telescope" (SSC-00048). It includes a multispectral telescope similar to the one described in the second-mentioned preceding article, with three spectral channels. Two of the channels would contain narrow-band optical filters centered at wavelengths of 700 and 840 nm, respectively. The third channel is left unfiltered to obtain a panchromatic video image. The images in all three channels are collected by identical video cameras, the outputs of which are processed. As explained in the noted prior article about the multispectral telescope, the three video images are inherently coregistered; this is an important advantage in that it eliminates the need for additional registration steps in processing of image data.

A set of image data is acquired with the telescope aimed at the plants of interest, while two reference detectors, one with identical 700-nm filters and one with identical 840-nm filters, are exposed to incident solar radiance. The ratio of the 700-nm image with



This **Portable Instrument** can generate one red, one infrared, and one panchromatic image of a scene containing plants. It processes the red and infrared images to obtain ratios between red and infrared reflectances. These ratios are used to control brightness levels in a synthetic video image to indicate levels of stress in the plants.

the 700-nm reference and the ratio of the 840-nm image with the 840-nm reference are being computed as the images are scanned. Then the outputs are ratioed 700–840 nm to create the final output. This ratio is the desired quantity indicative of the amount of chlorophyll lost by the plant part(s) imaged in the pixel. This ratio is used to control local brightness levels in a synthetic image to indicate local contents of chlorophyll. The synthetic chlorophyll image could, if desired, be overlaid on the panchromatic image.

This work was done by Bruce A. Spiering and Gregory A. Carter of **Stennis Space Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*

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Pixel-Summing APS Imager With Differential Column Readout

Fixed pattern noise and temporal circuit noise are reduced.

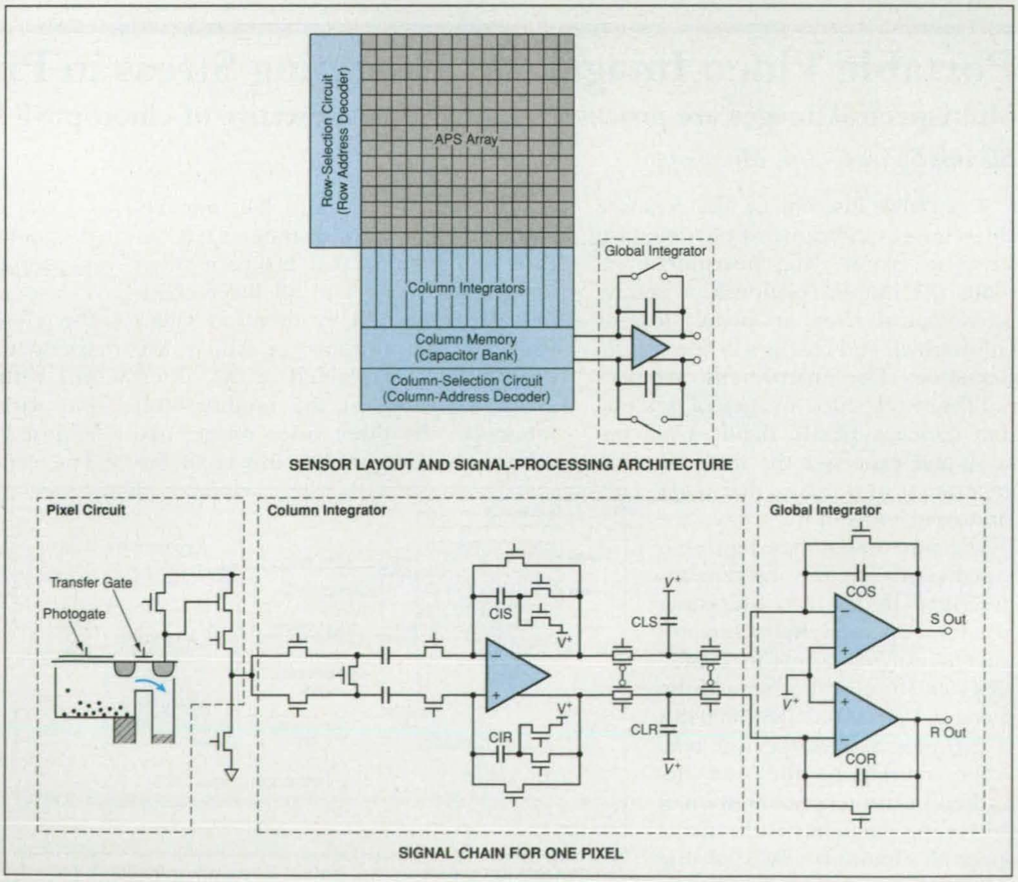
NASA's Jet Propulsion Laboratory, Pasadena, California

A complementary metal oxide/semiconductor (CMOS) integrated-circuit video image detector of the active-pixel-sensor (APS) type has been designed to implement programmable multiresolution output (through summing of outputs from selected groups of neighboring pixels) in a low-power, high-speed, low-noise differential column-readout scheme. This scheme increases (relative to CMOS APS devices of older designs) the signal-to-noise ratios achievable under low illumination.

Summing of signals from neighboring pixels, also called "pixel binning," amounts to trading away spatial resolution to increase sensitivity or decrease noise. This concept was described in "Active-Pixel Image Sensors With Programmable Resolution" (NPO-19510), *NASA Tech Briefs*, Vol. 20, No. 5 (May 1996), page 26. Pixel binning was implemented previously in a CMOS APS designed for frame-transfer operation. That CMOS APS proved to be susceptible to pickup of extraneous noise and to high residual fixed pattern noise (FPN) due to the use of a single-ended column integrator circuit. Moreover, the pixel binning was implemented by use of a two-dimensional-array analog memory circuit that more than doubled the area of the APS integrated-circuit chip. The differential column-readout scheme of the present CMOS APS reduces both FPN and temporal circuit noise. This scheme also eliminates the need for a two-dimensional memory array, thereby facilitating the development of CMOS APS devices with greater numbers of pixels and higher speed of operation.

Like other typical CMOS APS devices, the present one comprises a two-dimensional array of photogates with active pixel and peripheral readout circuits. The selection of rows and columns for programming the dimensions and sequence of summation kernels is effected by use of externally generated control signals fed to row- and column-address decoders. The figure illustrates both the overall unique signal-processing architecture and the portion of the circuitry in the signal chain from one pixel to the output terminals.

To begin the pixel-summing process for a neighborhood of *m* by *n* pixels, each column integrator generates a sum of differential outputs from the pixels in the *m* selected contiguous rows in that column, in the following procedure: The signal (S) and reset (R) levels of each row are first sampled on the sample-and-hold capacitors CMS and CMR, respectively, as the column integrators are reset. Then the S and R levels are then differentially integrated on integrating capacitors CIS and CIR, respectively. The foregoing steps are repeated until the signals from all *m* rows in the neighborhood have been summed. The integrated levels are then sampled and held on the column memory capacitors CLS and CLR. A global



The **Combination of Unique Design Features**, namely, pixel binning, differential column readout, and the use of a single output buffer (global integrator) reduces output noise.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For More Information Circle No. 513

integrator generates a differential output signal, one neighborhood at a time, by summing the signals from the memory capacitors of the *n* selected columns. The imager chip dissipates only 24 mW of power while running at 125 frames per second.

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

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A 640 × 486 Long-Wavelength Infrared Camera

Televisionlike imaging in the long-wavelength infrared is now feasible.

NASA's Jet Propulsion Laboratory, Pasadena, California

Figure 1. A **QWIP Camera** here is held by hand.

A rectangular integrated-circuit focal-plane array of 640 × 486 GaAs/$Al_xGa_{1-x}As$ quantum-well infrared photodetectors (QWIPs) constitutes the image sensor in an experimental long-wavelength infrared camera. This is the first long-wavelength infrared camera containing photodetectors in a focal-plane array that enables imaging in a format similar to that of standard television. The camera, which is sensitive to wavelengths between 8 and 9 μm, can be operated in a staring, snapshot, or video mode.

Until now, state-of-the-art long-wavelength infrared photodetectors have been made from HgCdTe. Difficulties associated with the HgCdTe material system — especially, nonuniformity of devices in arrays — have prevented the fabrication of HgCdTe photodetectors in 640 × 486 arrays with sufficient pixel-to-pixel uniformity to obtain images of acceptable quality in the 8-to-12-μm region of the infrared spectrum. The development of the present camera was guided by the conjecture that by using large-band-gap materials like GaAs and $Al_xGa_{1-x}As$, which can be grown and processed easily, one should be able to fabricate large, relatively uniform arrays of QWIPs to detect light at wavelengths between 6 and 25 μm.

The QWIPs in the present camera are of the bound-to-quasi-bound type, for which the thermionic component of dark current is less than for other types. [This topic was discussed in more detail in "Bound-to-Quasi-Bound Quantum-Well Infrared Photodetectors" (NPO-19633), *NASA Tech Briefs*, Vol. 22, No. 9 (September 1998), page 54. The basic multiple-quantum-well (MQW) structure of the QWIP array is a stack of 50 identical quantum-well bilayers. Each bilayer comprises (1) a 45-Å-thick well layer of GaAs n-doped at a density ≈5 × 10^{17} cm^{-3} and (2) a 500-Å-thick barrier layer of $Al_{0.3}Ga_{0.7}As$. The MQW structure is sandwiched between 0.5-μm-thick top and bottom contact layers of GaAs doped similarly to the well layers.

All of the aforementioned layers were grown on a semi-insulating GaAs substrate by molecular-beam epitaxy. A 300-Å-thick $Al_{0.3}Ga_{0.7}As$ stop-etch layer was grown on top of the top contact layer for use in fabricating a cross-grating structure to couple light into the array. [The cross-grating-coupler concept was described in "Cross-Grating Coupling for Focal-Plane Arrays of QWIPs" (NPO-19657), *NASA Tech Briefs*, Vol. 22, No. 1 (January 1998), page 6a.] A 0.7-μm-thick GaAs cap layer was grown on top of the stop-etch layer. The cross-grating structure was fabricated by photolithography and dry chemical etching.

The array of 640 × 486 photodetectors, with a pitch of 25 μm and a pixel size of 18 × 18 $μm^2$, was then formed by wet chemical etching through the MQW layers into the bottom contact layer. The cross gratings on the tops of the detectors thus formed were covered with Au/Ge and Au for ohmic contact and reflection (reflection at the top surface increases photoresponse, inasmuch as the device is operated in a back-illuminated configuration —

(a) (b)

Figure 2. These **Infrared Images** were acquired when the camera was cooled to about 70 K and operated at a video frame rate of 30 Hz. The left image taken around midnight shows where the automobiles were parked during the daytime. The right image shows a man's face with a warm mustache, which was heated by a hot-air blower. It also shows hot air emanating from the air blower.

that is, with illumination through the substrate). Indium bumps were evaporated onto the (Au/Ge)/Au layers, then the bumps were used to bond (hybridize) the array to a silicon-based complementary metal oxide/semiconductor (CMOS) integrated-circuit 640 × 486 readout multiplexer. The QWIP-array/readout-circuit hybrid was then mounted along with an antireflection-coated, 100-mm-focal-length germanium lens to form the camera (see Figure 1).

In tests, the camera produced excellent images that demonstrated high sensitivity (see Figure 2). The performance of the QWIP operating in a photoconductive (as distinguished from photovoltaic) mode at a reverse bias of 2 V, temperature of 70 K, and background temperature of 300 K was characterized by, among other things, a noise-equivalent differential temperature of 36 mK. The uncorrected nonuniformity (which includes a 1-percent nonuniformity of the readout circuit and a 1.4-percent nonuniformity of a cold stop in front of the array) was found to be only 5.6 percent.

This work was done by Sarath Gunapala, Sumith Bandara, John Liu, and Winn Hong of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*

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Refer to NPO-20312, volume and number of this NASA Tech Briefs *issue, and the page number.*

Improved Ultrasonic Imaging of Microscopic Devices

Critical interior bonds could be inspected.

Goddard Space Flight Center, Greenbelt, Maryland

Advances in time gating of ultrasonic signals in scanning acoustic microscopes have been proposed to enable detailed nondestructive examination of bonds and other interfaces deep within the interiors of such micromachined objects as high-density integrated electronic circuits and microelectromechanical systems. The capability to perform such examinations could contribute significantly to ensuring ruggedness and long operational lifetimes for electronic circuits, sensors, and actuators that must withstand harsh environments.

A scanning acoustic microscope is usually operated in a C-scan mode, using a pulse-gated acoustic signal with carrier frequency between 50 and 100 MHz. The scan can reveal features at depths up to several millimeters. However, the bonds, interfaces, and other features that are of interest in an assessment of the structural integrity of a micromachined object typically have dimensions of the order of microns, and acoustic signals (pulse echoes) that could be used to analyze these features often appear with similar signals from other features superimposed on them. As a result, it is difficult to assess structural integrity of a feature of interest.

In C-scan acoustic microscopy as it has been practiced until now, the pulse echo from an area of interest is gate-peak-detected to produce the ultrasonic image of that area. When the detection gate interval is set to encompass the entire pulse envelope, the depth resolution of the image is compromised because of the superposition of pulse echoes mentioned above.

The proposed advances in time gating would increase the isolation of the echo signal of interest from the other superimposed signals. One of the proposed advances would exploit the observation that by limiting the duration of the detection gate to a single cycle of the carrier signal, the sharpness of the acoustic image can be increased greatly. If the gate interval contains the echo from a feature of interest, the structural integrity of the feature can be analyzed.

Other advances could include improved sensors and shaping of pulses to increase signal-to-noise ratios. Yet another advance would be the use of a phase-lock loop to track the peak of the pulse echo corresponding to a feature of interest; this would greatly increase the capability for examining complex structures.

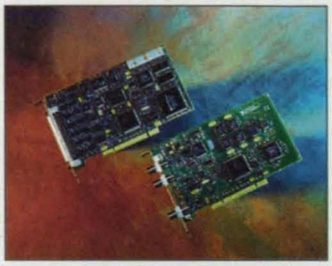
This work was done by E. James Chern of **Goddard Space Flight Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*
GSC-14092

Special Coverage: Imaging/Video/Cameras

The Industrial Video Systems division of Hitachi Denshi America, Woodbury, NY, has introduced the KP-M2R and KP-F2 black-and-white **near-infrared cameras** for the machine vision market. The KP-M2R, designed for microscopy and image processing, features a 768 x 494 pixel, 1/2" image-sized CCD with sensitivity in the near-infrared spectrum. It also features eight-step electronic shutter, HD/VD external drive, and non-interlaced scanning.

The KP-F2 is a progressive scan shutter camera using a 1/3" microlens IT CCD. It features 7.4 micron-square pixels and has 658 x 496 effective pixels. Two simultaneous video signals can be obtained from either the rear panel multi-pin connector or two BNC lines.

For More Information Circle No. 706



Two **image acquisition boards** from National Instruments, Austin, TX, provide hardware solutions for building machine vision and imaging applications. The PCI-1407 single-channel, monochrome image frame grabber acquires RS-170 and CCIR monochrome images from cameras and VCRs. It is designed to speed image processing software and enhance computer-based vision applications such as onboard image scaling and partial image scanning.

The PCI-1422 is a flexible image acquisition board that acquires large images from digital area and line scan cameras at rates up to 80 MB/s. It features 16 MB of memory and can buffer large image captures for sustained real-time throughput to PC memory. Both feature high-speed scatter-gather DMA transfers and external triggering capabilities.

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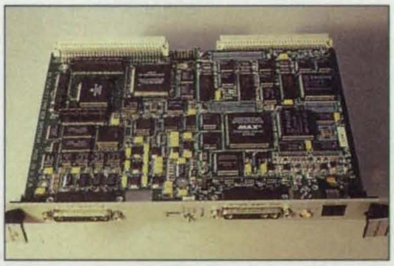
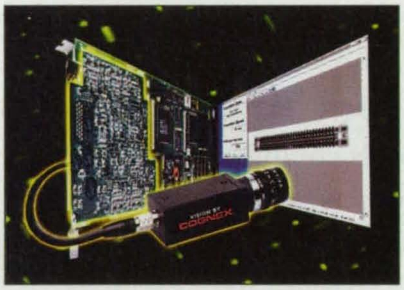


RGB Spectrum, Alameda, CA, has introduced the RGB/View 6000 **video display input board** in 6U VME format that combines up to 10 computer screens and/or video signals on a single monitor or projector. Installed in a 6U VME workstation, the board is compatible with any monitor or data display projector up to 1600 x 1200 resolution. Input signals can be NTSC, PAL, S-Video, FLIR, or any computer signal up to 1280 x1024 pixels.

Video and computer inputs are shown as windows on the main screen. All windows can be positioned, scaled from icon size to full screen, overlaid with computer graphics, or overlapped with other windows. Each input also can be panned and zoomed. Applications include wherever multiple video and computer sources must be displayed simultaneously.

For More Information Circle No. 711



The CVC-1000 **progressive scan video camera** from Cognex, Natick, MA, is designed for industrial machine vision applications and combines image acquisition, enhanced image quality, compact size, and flexible control options. The camera acquires full-frame (640 x 480) images at a rate of 60 frames per second over a single channel. The camera digitizes image data synchronously, without filtering or sampling operations.

For multiple-camera applications, images can be stored on the camera for up to 100 ms, and then sequentially transmitted to the vision system for analysis. Users also can configure the camera to capture a small area of interest within a larger field of view.

For More Information Circle No. 708

PC Video Conversion, Morgan Hill, CA, offers the HyperConverter Gold **scan converter**, a genlockable, broadcast-quality converter accepting inputs up to 1024 x 768 from all platforms. It enables genlock to a black burst signal with separately adjustable delay and subcarrier phase. All models output composite NTSC/PAL and Y/C VHS video signals.

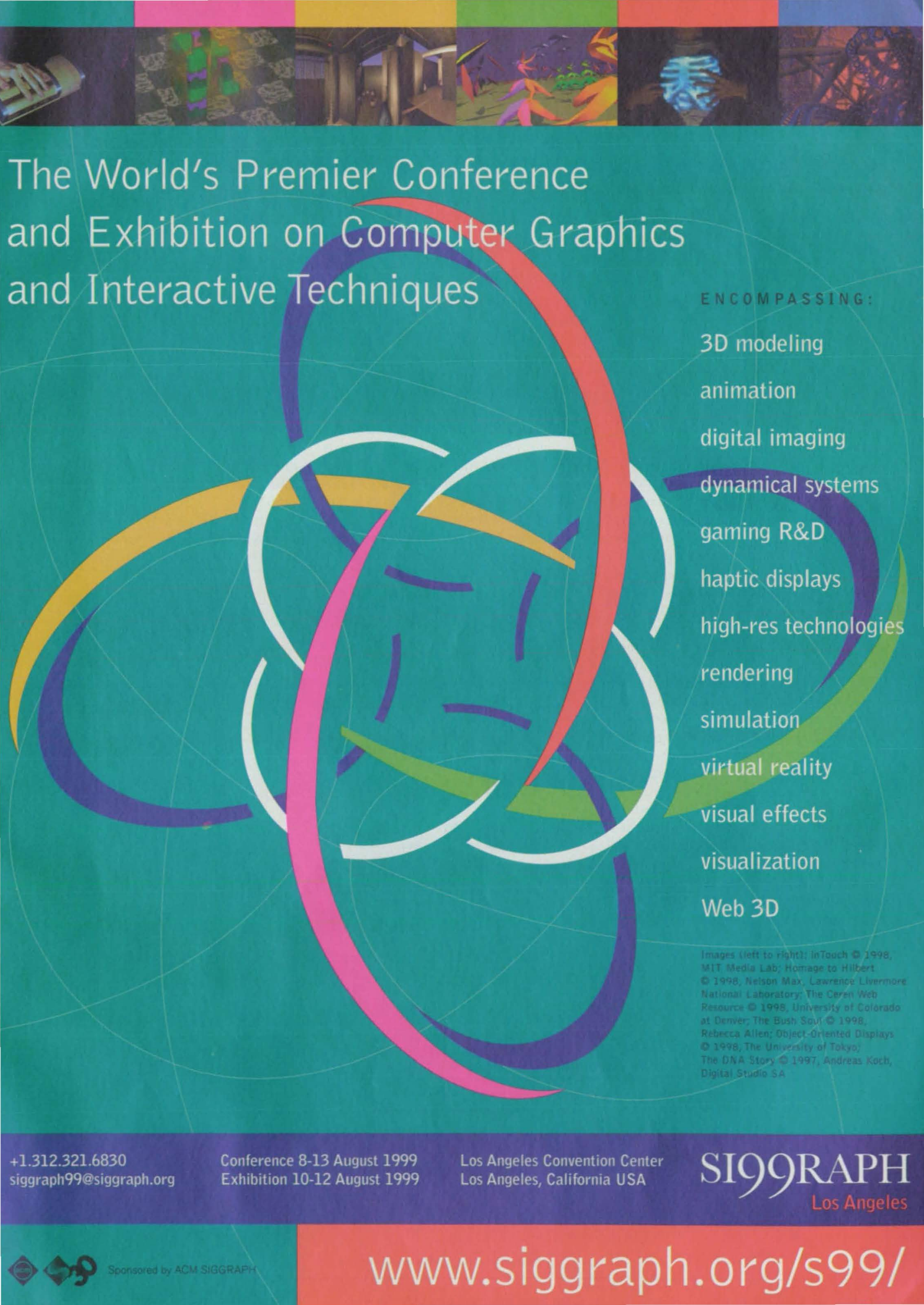
Features include 2X zoom and pan, digital flicker filtering, and adjustable picture positioning and sizing. Adjustments can be simultaneously accessed via IR remote and front panel keypad controls. It also features RS-232 control. The converter is available as PCI board and desktop versions.

For More Information Circle No. 709

The DSL6000 high-speed **digital camera** from PPT Vision, Minneapolis, MN, is designed for machine vision applications and features an integrated 10-bit A/D converter for internal image capture and digitization. The camera yields a complete scale of 256 gray levels, resulting in accurate edge finding, pattern matching, and other inspection algorithms.

The camera can acquire more than 70 full-resolution images per second; with partial scanning, image acquisition speeds exceed 10,000 parts per minute. The progressive scan camera is capable of asynchronous image capture in either strobed or shuttered modes. It is configured and controlled entirely by software via the DSL network through a single DSL cable.

For More Information Circle No. 710



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Electronic Components and Systems

Cheaper, Lighter Biplates for Methanol Fuel Cells

The main bodies of the plates would be molded from polymers.

NASA's Jet Propulsion Laboratory, Pasadena, California

Relatively inexpensive, lightweight biplates for methanol fuel cells have been proposed. The reductions in weight and cost, relative to biplates now used in methanol fuel cells, would be achieved by use of a combination of modified geometry, cheaper and lighter materials, and cheaper manufacturing processes.

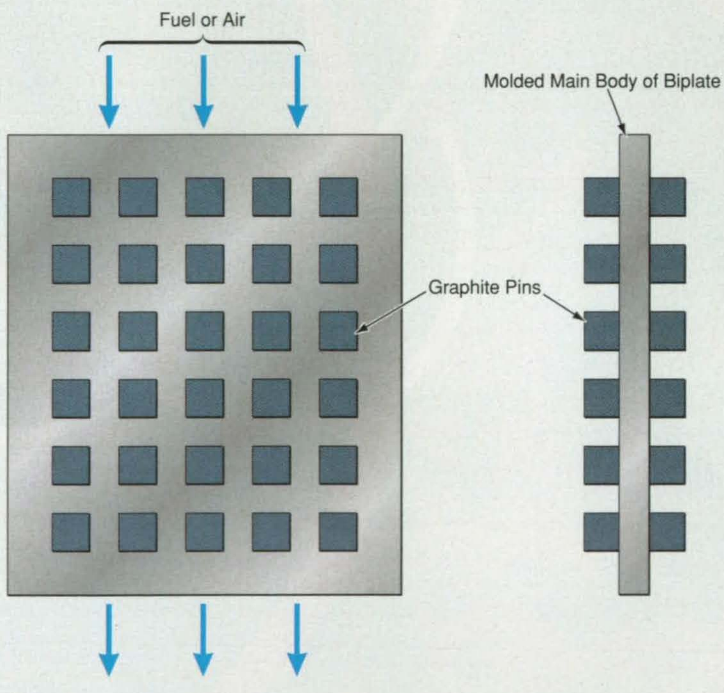
A typical methanol fuel cell includes a number of membrane/electrode assemblies (MEAs) stacked in alternation with biplates. Each biplate serves (1) partly as an electrical contact between the cathode of the MEA on one side and the anode of the MEA on the other side, (2) partly as a fuel-and-oxidizer-delivery manifold, (3) partly as an exhaust manifold, and (4) partly as a heat exchanger to remove waste heat. The biplate contains channels for circulating air past the cathode, plus other channels for circulating the fuel solution (methanol dissolved in water) past the anode. The flowing aqueous methanol solution, which is 97 weight percent water, can be used to remove the waste heat.

Heretofore, biplates in methanol fuel cells have been fabricated by machining them out of graphite. About one-third of the cost of a typical methanol cell is incurred in conjunction with the machined graphite biplate(s). In addition, graphite has a density of about 2.0, whereas some other materials that could be used in biplates have lower densities. Thus, if one could reduce the costs of biplates and make them of less-dense materials (plastics), one could effect significant reductions in the costs and weights of methanol fuel cells.

One reason for using graphite until now is that graphite has the required electrical conductivity. A plastic biplate by itself would not be electrically conductive, but the design could be modified to use electrically conductive pins inserted through the thickness of the biplate to provide electrical contact between the anode on one side and the cathode on the other side. The modified design would feature a "pincushion" flow-field configuration; the channels on the cathode and anode sides would be defined by the pins, which would disperse the flows of fuel and air over the electrodes (see figure).

The main body of the biplate, with its channels and holes, could be molded. To obtain the required fluid seals around the pins, the main body could be molded around the pins. A suitable material for the main body of the plate might be mineral-filled phenolic, (better known by the trade name "Bakelite"), which has a density of 1.3. While the graphite pins would increase the average density a bit, the average density would still be considerably less than that of a biplate made solely of graphite.

This work was done by Andrew Kindler of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Tech-*



A Biplate Could Be Made of a plastic main body molded around graphite pins, instead of machined from a solid block of graphite. The molded plate with pins would cost and weigh less.

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Transmissive Surface-Plasmon Light Valves

Colors in transmissive flat-panel display devices would be voltage-tunable.

NASA's Jet Propulsion Laboratory, Pasadena, California

Transmissive light valves based on voltage-tunable color-selective absorption of light in surface plasmons are undergoing development. Like other surface-plasmon-based devices reported in a number of recent articles in *NASA Tech Briefs*, these light valves could be constructed in many different configurations and concatenated with other optical and electronic components to produce a variety of display and color-filtering devices. These devices would be compatible with, and could be incorporated into, monolithic integrated circuits for use in display, addressing, and interface applications.

As shown in Figure 1, a basic transmissive surface-plasmon light valve would include a substrate made of glass or other suitable transparent material, a metal film (e.g., a thin layer of metal or of indium tin oxide), a layer of electro-optical material (typically a liquid crystal), and another metal film as top electrode. White light would be introduced from the bottom; some of this light would pass through the bottom electrode and impinge on the top electrode, where it would excite surface plasmons at the interface between the metal films and the liquid crystal.

The surface plasmons would absorb some light in a resonance wavelength band determined partly by the index of refraction of the electro-optical mate-

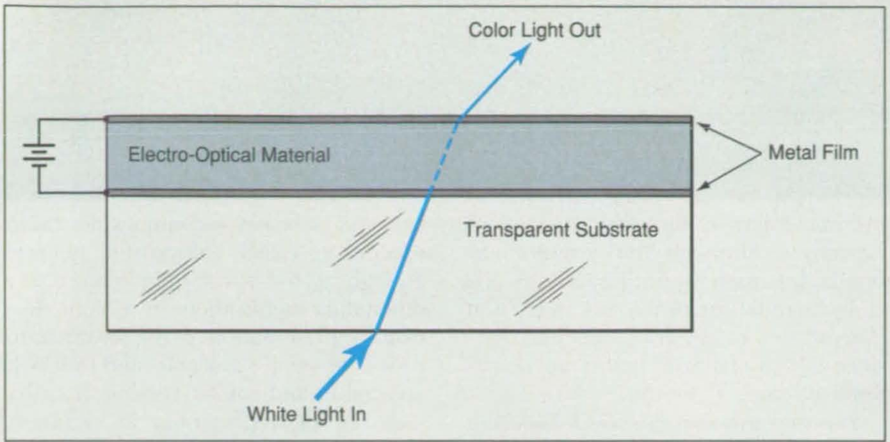

Figure 1. This **Light Valve** would exploit voltage-tunable color-selective absorption of light in surface plasmons. Light of the color complementary to that of the surface-plasmon absorption resonance would be transmitted.

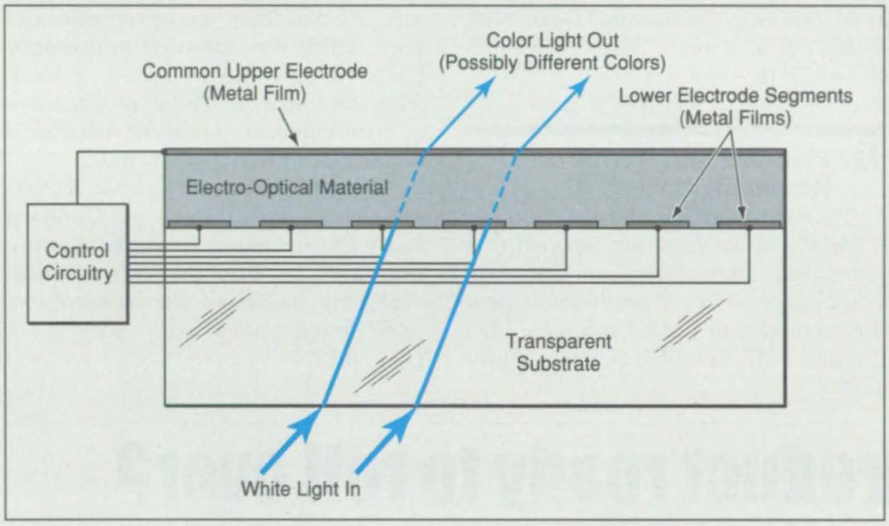

Figure 2. **Multiple Light Valves** could be arrayed by fabricating a common upper electrode plus multiple side-by-side lower electrode segments. The voltage applied between the common upper electrode and each lower electrode segment would control the color of light transmitted through that segment.

rial. The light not absorbed in the surface plasmons would pass through the top metal film. The color of this transmitted light would be complementary to that of the reflected light. As in the previously reported surface-plasmon devices, the index of refraction of the electro-optical material, and thus the absorption wavelength band, would depend on the electric field imposed by applying an electric potential between the electrodes. Therefore, one could control the transmitted complementary color by controlling the applied voltage.

Figure 2 illustrates part of a flat-panel display device comprising one of the many different possible combinations of surface-plasmon light valves. This device would be similar to that of Figure 1, except that the lower electrode would be divided into segments that could, for example, correspond to pixels of a display. The colors in each segment could be controlled, independently of the other segments, by applying a distinct voltage between the common upper electrode and the lower electrode for that segment. The electronic circuitry for controlling the voltages on the lower electrode segments could be fabricated on the transparent substrate.

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

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Software

Automated Scheduling and Reporting of Fire Inspections

A computer-based automated system for scheduling, reporting, and tracking fire inspections at Kennedy Space Center has supplanted a manual system based on paper fire-inspection reports transmitted by mail. The automated system not only minimizes the consumption of paper and other resources but also significantly reduces the time spent in responding to potentially hazardous conditions. The software in the automated system generates a multiscreen interactive display containing standard fire-inspection report forms. Inspectors check off predefined items, fill in blanks, and/or enter text, as needed, to complete the forms. The information thus entered is stored in a data base. Automated mail-merge documents are created and transmitted to responsible site managers by electronic mail. Inspections are tracked by a report section that identifies overdue corrective actions and prompts follow-up by a fire inspector or supervisor. Although this software was originally written for fire inspections, it is easily adapted for nearly any inspection process, i.e., safety, environmental, etc., since all "predefined" items can be defined at setup.

This work was done by Hans J. Siepmann formerly of EG&G Florida, Inc., for **Kennedy Space Center.**

Inquiries concerning rights for the commercial use of this invention should be addressed to the Technology Programs and Commercialization Office, Kennedy Space Center, (407) 867-6373. Refer to KSC-12050.

Planning and Resource Reasoning Software

"Planning and Resource Reasoning" ("PARR") is the name now applied to a scheduling methodology and to computer programs developed to implement the methodology during the years 1985 through 1987. In PARR, one uses heuristics and reactive techniques to build schedules. PARR software is generic enough to be useable in almost any scheduling application in which electronic representations of the resources to be scheduled are available, and in which constraints and conflict-resolution strategies can be represented in terms of heuristics. PARR software takes much less time to produce schedules than do programs that produce optimized schedules. Although PARR-generated schedules are suboptimum, they are acceptable and they satisfy the specified constraints. PARR software can be run in a batch mode for initial generation of schedules, or in an interactive mode for refinement of previously generated schedules.

This work was done by David Richard McLean of Allied Signal for **Goddard Space Flight Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Information Sciences category.*
GSC-14097

PSSA/PVDF Polymer Electrolyte Membranes for CH_3OH Fuel Cells

Methanol crossover is reduced, with consequent increases in fuel efficiency and electrical performance.

NASA's Jet Propulsion Laboratory, Pasadena, California

Improved polymer electrolyte membranes for direct methanol fuel cells can be made by any of a variety of processes in which cross-linked polystyrene sulfonic acid (PSSA) is mobilized within electrochemically inert matrices of poly(vinylidene fluoride) (PVDF). Alternatively, other matrix materials can be substituted for, or blended or copolymerized with, PVDF. The principal advantage of these membranes over polymer electrolyte membranes made of other materials is that they are less permeable to methanol; this translates to less crossover of methanol in molecular form (denoted "methanol crossover" for short). Methanol crossover is undesired because it wastes fuel and degrades fuel-cell performance, as explained below.

Figure 1 schematically illustrates a typical direct liquid-feed methanol fuel cell in operation. The polymer electrolyte membrane is part of a membrane/electrode composite-material laminate known in the industry as a membrane/electrode assembly. The anode is preferably made from a carbon-supported Pt/Ru catalyst; the cathode is preferably made from a carbon-supported Pt catalyst. An aqueous solution of methanol is circulated past the anode, while air or oxygen is circulated past the cathode.

Oxidation of methanol at the anode generates carbon dioxide, electrons, and protons. The electrons travel through an external electrical load, to which they deliver the electrical energy generated by the chemical reactions in the fuel cell. The polymer electrolyte membrane serves as a medium for transport of the protons to the cathode, where the protons combine with electrons and oxygen, producing water. To the degree to which the polymer electrolyte membrane allows conduction of electrons, electrical energy is diverted from the external load; and to the degree to which the membrane allows methanol crossover, the methanol fuel is consumed unproductively at the cathode.

It would not be possible, within the limits of this article, to present a com-

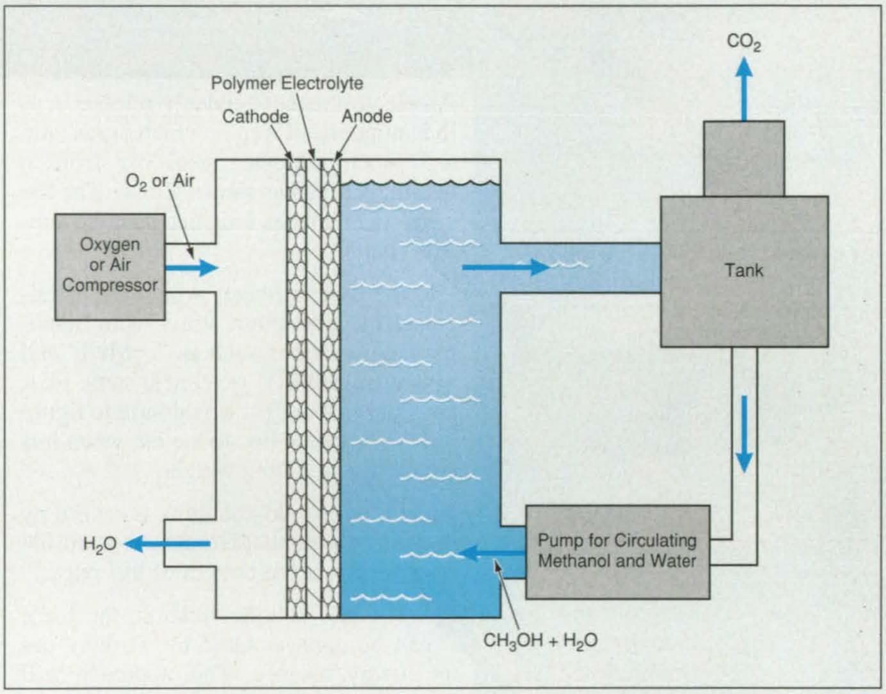


Figure 1. **A Direct Liquid-Feed Methanol Fuel Cell** depends on a polymer electrolyte membrane for proper operation.

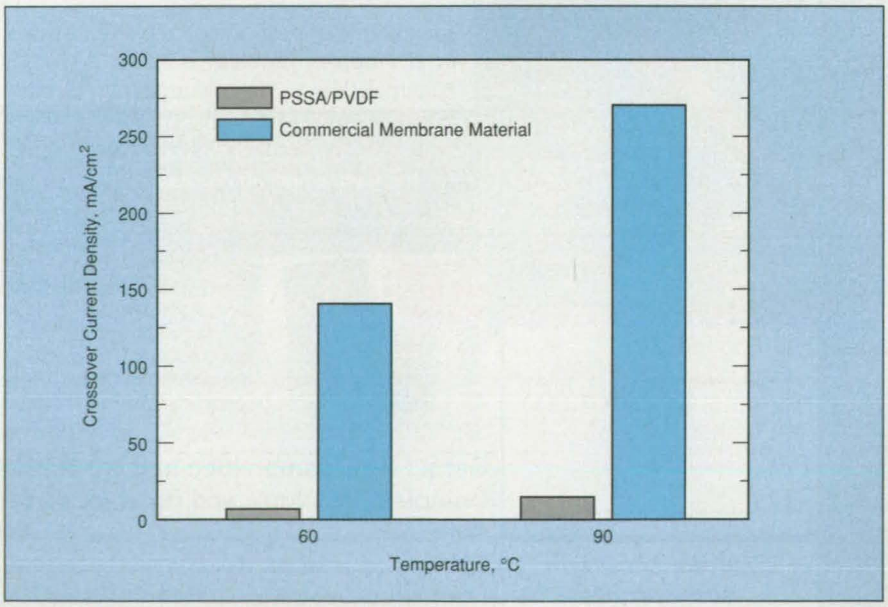


Figure 2. **Methanol-Crossover Current Densities** were measured in two fuel cells operating with 1.0 M methanol solution circulated past the anodes and oxygen at a pressure of 20 psig (gauge pressure of 138 kPa) circulated past the cathode.

prehensive description of the many alternative materials, techniques, and processes that could be used in fabricating PSSA/PVDF membranes and membrane/electrode assemblies that contain them. The best that can be done here is to present an example of a preferred approach in which (1) a PVDF membrane matrix is prepared; (2) the membrane matrix is impregnated with a solution of styrene, divinylbenzene, and a small amount of a polymerization initiator; (3) the styrene and divinylbenzene are copolymerized within the membrane matrix; (4) the membrane is sulfonated; and (5) the membrane is sandwiched between electrode films.

The PVDF membrane matrix can be prepared by hot pressing of PVDF powder or of a PVDF membrane cast from solution. Alternatively, one can start with a commercial film made of PVDF or a copolymer of PVDF and hexafluoropropylene. The membrane matrix is impregnated by immersion in a bath of styrene, divinylbenzene, and azobis(isobutyronitrile) (AIBN) or another suitable polymerization initiator. The proportion of AIBN is typically between 0.3 and 0.4 weight percent. The proportions of styrene and divinylbenzene govern the amount of cross-linking.

After removal from the bath, the membrane is heated to a temperature between 150 and 170 °C and pressed at 500 to 2,000 psi (3.4 to 14 kPa) for as long as it takes to increase the density of the membrane by 15 to 25 percent. The membrane is then sulfonated by immersion in a solution comprising 15 percent of chlorosulfonic acid in chloroform for 24 hours. The sulfonated membrane is washed in distilled water, then hydrolyzed in distilled water at a temperature of 65 °C. At the end of this process, there is a sulfonic acid group attached to almost every aromatic ring in the membrane. A membrane/electrode assembly is then fabricated by hot-pressing the membrane, while it is still in its hydrated state, between catalyzed, polytetrafluoroethylene-impregnated porous carbon electrode layers.

Figure 2 presents an example of experimental data that show that the methanol-crossover rate of a membrane/electrode assembly made with PSSA/PVDF was less than that of one made with an expensive commercial perfluorocarbon proton-exchange membrane that has been the membrane of choice for methanol fuel cells in recent years. Another advantage of a PSSA/PVDF membrane over the commercial membrane arises in connection with oxygen-flow rates. The necessary circulation of oxygen past the cathode undesirably tends to dry the membrane, thereby increasing its electrical resistivity. Therefore, to minimize the drying effect, it is preferable to operate a fuel cell at the smallest feasible oxygen flow. A fuel cell containing a PSSA/PVDF can function well at a small oxygen flow, whereas one containing a membrane of the commercial material performs poorly at a small oxygen flow.

This work was done by G. K. Surya Prakash, George A. Olah, Marshall C. Smart, and Qungie J. Wang of the University of Southern California and Sekharipuram Narayanan 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
JPL
Mail Stop 122-116
4800 Oak Grove Drive
Pasadena, CA 91109
(818) 354-2240

Refer to NPO-20378, volume and number of this NASA Tech Briefs *issue, and the page number.*

Improved Aerogel-Based Thermal Insulation Systems

Thermal conductivities are generally lower than those achieved previously.

John F. Kennedy Space Center, Florida

Improved aerogel-based thermal insulation systems have been developed to provide cost-effective and easier-to-handle alternatives to various types of multilayer insulation (MLI) and evacuated powder insulation now used on cryogenic equipment. The apparent thermal conductivities of the aerogel-based systems are comparable to MLI systems and are well below the thermal conductivities of the other systems.

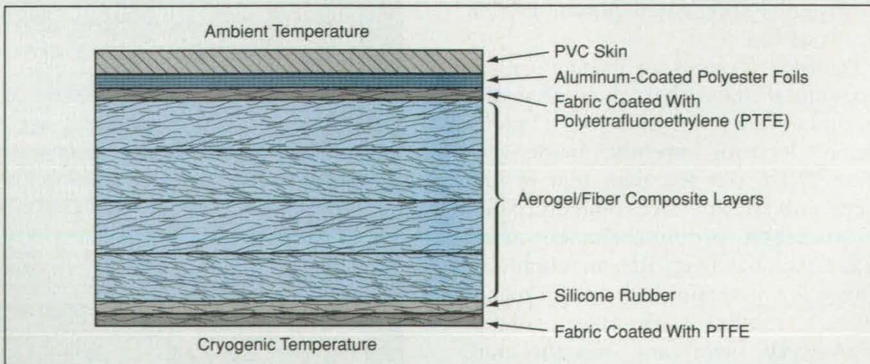
MLI systems are expensive, structurally complex, and bulky; the insulating properties are anisotropic; and maintaining a high vacuum [10^{-4} to 10^{-5} torr (about 10^{-2} to 10^{-3} Pa)] is required in MLI for full insulating effectiveness. Evacuated powder insulation is about one order of magnitude less effective than is MLI, but its insulating properties are isotropic, it is generally easier to install, and it requires only a moderate vacuum [10^{-2} to 10^{-3} torr (about 1 to 10^{-1} Pa)] to realize its full insulation potential. Unfortunately, the powder in evacuated powder insulation tends to settle in response to vibration and thermal cycling, forming voids that act as heat leaks.

The improved aerogel-based insulation systems are composites which can be manufactured in blanket, sleeve, or clamshell forms to be used with or without evacuation. These composite systems take advantage of the low thermal conductivity of the ultra-low-density aerogels to minimize heat transfer and incorporate a flexible, durable matrix to maximize applicability. The core of the system is aerogels formed at the fiber-fiber contacts of the matrix, forcing solid heat-transfer to occur through the aerogels. This composite configuration improves both the ease of handling aerogels and the overall thermal resistance. The closed-packed structure of the aerogels eliminates the open spaces in the fiber matrix and thereby minimizes convection heat transfer. Excellent thermal resistance has been achieved for both evacuated and nonevacuated insulation systems while maintaining good flexibility. The aerogels can also be produced in an opacified fiber matrix to inhibit radiation heat transfer in the infrared range.

A typical insulating system for use on cryogenic equipment is an integrated, layered structure that includes a backing layer on the cold side and protective layers on the warm side (see figure). One of the protective layers is a tightly woven fabric coated with polytetrafluoroethylene (PTFE), which serves as a vapor barrier to prevent condensation of moisture. Multiple layers of polyester foil coated with aluminum serve as radiation shields and give additional protection from the environment. An outer layer of polyvinyl chloride (PVC) in the form of pipe or a foil jacket provides secondary protection from the environment and protection against mechanical impacts. This system can be designed as a fully flexible blanket type configuration or a pre-formed molded type configuration for installation on a variety of cryogenic storage and transfer equipment.

This work was done by James E. Fesmire of **Kennedy Space Center** *and Jaesoek Ryu of Aspen Systems, Inc. For further information, please contact Kang P. Lee, President, Aspen Systems, Inc., 184 Cedar Hill Street, Marlborough, MA 01752.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Technology Programs and Commercialization Office, Kennedy Space Center, (407) 867-6373. Refer to KSC-11903.



Aerogel-Based Superinsulation contains layers of highly engineered materials, each performing a function that contributes to the overall reduction of heat transfer, to safety, and/or to protection against the environment.

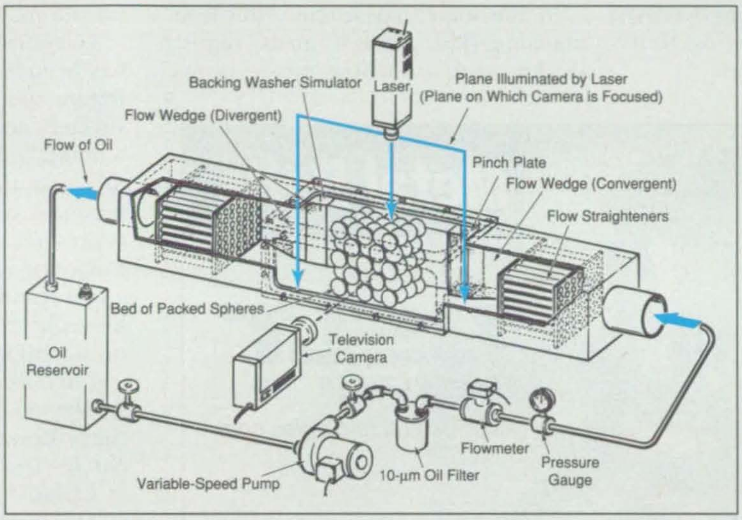
Mechanics

Visualization of Flows in Beds Packed With Spheres

Flows were made visible by seeding and illumination with a sheet of laser light.

John H. Glenn Research Center, Cleveland, Ohio

The figure shows an oil tunnel and associated equipment used in experiments, using the full-flow-field tracking (FFFT) technique, to characterize flows in beds packed with poly (methyl methacrylate) spheres. The indices of refraction of the oil and the spheres were matched to make the spheres invisible to the eye and cameras. The oil was seeded with magnesium oxide particles as flow tracers. The packed bed and the seeded oil in its interstices were illuminated with laser light in a plane aligned along the direction of bulk flow, thereby making visible some aspects of the flow dynamics. The image of the illuminated plane was recorded by a television camera aimed perpendicularly to the flow. The light sheet was traversed from one side of the tunnel to the other to acquire image data in different planes for use in synthesizing a three-dimensional image of the entire flow field.



Oil Flowing In the Interstices of a bed of spheres was seeded with small particles and illuminated with a sheet of laser light to make the flow visible.

The optical nature of the boundary interface between the working fluid and the spheres rendered the spheres black, permitting visualization of the exact locations of the circular oil/sphere interfaces in both the axial and transverse directions, with direct visualization of the complex interstitial spaces between the spheres within the bed. Strobing the laser provided a means to estimate the velocities of the flows within the bed of spheres and facilitated tracking the flow. Flows were observed near the planar tunnel walls and sets of spheres as well as near minor circles that appeared with great circles at various transverse positions and were not always uniformly ordered. The recorded images revealed very complex flow fields, and it was observed that flow channeling in the direction of bulk flow occurs between sets of adjacent spheres.

The flow was found to be fully three-dimensional and complex to describe. The most prominent finding involved conclusive experimental demonstration of flow threads as computed for hyper-cluster spheres in NASA Technical Memorandum 107361, "Numerical Flow Visualization in Basic- and Hyper-Cluster Spheres." More specifically, it was found that the bulk of the flow field has a natural tendency to establish the flow paths of least resistance (the above-mentioned threads) through the packed bed that are parallel and distinct, and that for a regular array of spheres, the number of threads is related to the number of open areas in a cross section in a plane perpendicular to the direction of bulk flow.

Beds of spheres used in the experiments were constructed, variously, with regularly or randomly packed spheres of 12.7-mm or 19.05-mm diameter and were used to obtain various flow patterns. The effects of bed voids were also characterized and tended to disrupt flow threads and create vortices. Still photographs and video recordings that illustrate the flow phenomena are available.

This work was done by R. C. Hendricks of **John H. Glenn Research Center**, *S. Lattime of B & C Engineering, M. J. Braun of the University of Akron, and M. M. Athavale of CFD Research Corp. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Mechanics category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA John H. Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16562.

Smoother Wing Leading-Edge Joints Would Favor Laminar Flow

Appreciable reductions of drag should be achievable.

Ames Research Center, Moffett Field, California

Some changes in the design and construction of the leading edges of metal airplane wings have shown promise as means to suppress laminar-to-turbulent flow transitions. The significance of this development is that it creates an opportunity to take advantage of laminar-flow boundary layers to reduce aerodynamic drag.

During the early 1950s, the aeronautical community reached a consensus to abandon laminar-flow drag-reduction techniques, in part because of a belief that practical metal airplane surfaces could not be made smooth enough to support laminar flow. The present development addresses an important aspect of the smoothness issue; namely, the interruption of the smooth wing surface at the joint between a leading edge and the rest of a wing. On a typical commercial jet airplane, each wing is constructed with a single-piece wraparound leading-edge skin piece attached to the rest of the wing by screws (see figure). The locus of attachment is a spanwise joint 4 to 6 in. (10 to 15 cm) downstream of the leading edge. The gaps and steps in the wing surface at the joint (including the exposed heads of the attaching screws) have been blamed for triggering laminar-to-turbulent flow transitions.

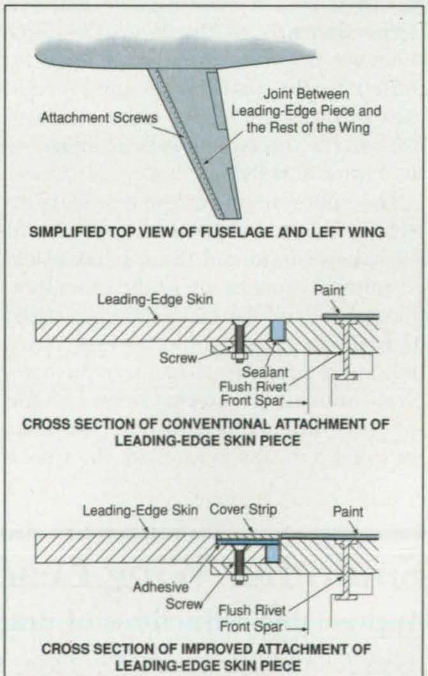
The present improved attachment scheme yields a joint smooth enough to support laminar flow. The improved scheme does not differ radically from the conventional scheme described above, does not require manufacturing accuracy significantly beyond that of conventional practice, and does not require expensive materials or expensive fabrication techniques. In the improved scheme as in the conventional scheme, the leading-edge skin piece is removable for infrequent inspection.

In the improved scheme, the leading-edge skin piece is made slightly thicker and a shallow recess is machined along the attachment region to allow for subsequent flush mounting of an aluminum or plastic cover strip. The cover strip is attached by use of a modern, easy-to-handle, commercially available high-strength adhesive; indeed, it is only the advent of such adhesives that has made it practical to implement the present scheme. The edges of the strip can be trimmed carefully so that the remaining gaps are smaller than a critical dimension for triggering the laminar-to-turbulent transition.

The efficacy of the improved scheme, has been verified in flight tests: A test fixture designed to reproduce a wing surface according to the improved scheme, with various simulated degrees of manufacturing precision, was mounted on an airplane and flown at representative mach and Reynolds numbers. Laminar flow was observed, and a readily available foam-backed adhesive held the cover strip in place with no sign of failure.

This work was done by Robert A. Kennelly, Jr., Dennis J. Koga, and Fanny A. Zuniga of **Ames Research Center***; Aaron Drake of San Jose University State; Michael L. Hinson of Learjet, Inc; and Russell V. Westphal of Washington State University. No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center; (650) 604-5104. Refer to ARC-14088.



The **Surface in the Joint Region** is smoother when the leading-edge skin is attached according to the improved scheme. A smooth surface can support laminar flow, making it possible to obtain less drag than would be possible if surface discontinuities were allowed to trigger the transition to turbulent flow.

Improved Inlets for T-38 Airplane

The change in inlet design reduces takeoff distances and increases safety margins.

Lyndon B. Johnson Space Center, Houston, Texas

A change in the design of the engine inlets of the T-38 airplane significantly reduces takeoff distances while increasing safety margins. Although the newer inlet design (see Figure 1) is based on well-known engineering principles, it is unique and will prove invaluable to the NASA fleet and to other T-38 fleets; e.g., the fleets flown by the United States Air Force (USAF) and by foreign governments. The change in design was needed because in an inlet of the older design, separation of flow in the lower third of the inlet degraded efficiency, even under normal takeoff conditions. Johnson Space Center (JSC) engineers compensated for this deficiency in formulating the newer design by adopting an inlet shaped according to aerodynamical considerations; the shape was chosen to minimize separation of flow to produce greater engine thrust as the T-38 accelerates to takeoff speed.

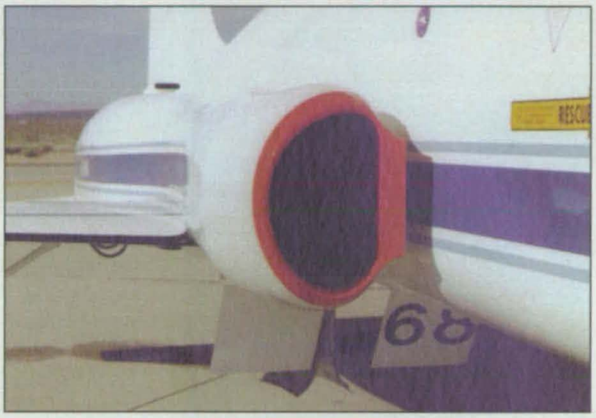


Figure 1. **The Improved T-38 Engine Inlet** design affords enhanced performance and safety. NASA's T-38 fleet will be modified to incorporate this design. The USAF T-38 fleet and the fleets of foreign countries can be similarly modified.

Figure 2 depicts an aspect of the older and newer inlet shapes. The older design, developed in the late 1950s, was optimized for supersonic flight. However, both the NASA and USAF missions for the T-38 now emphasize subsonic flight, in which the older inlet design causes internal separation from incoming air. This separation starves the engines of air, thereby reducing engine efficiency. The consequences of reduced engine efficiency include increases in takeoff distances, decreases in safety margins, and engine failures that result in higher-risk, single-engine takeoffs.

At such hot, high-altitude airports as the one at El Paso, Texas, the risk is even greater. Because of climatic conditions and the relative thinness of the atmosphere there, especially in summer, T-38s cannot take off at full weight. Fuel must be burned off, or flight crews must wait until surface temperatures fall sufficiently to permit takeoff. Such extremes produce a Category III condition; that is, a condition in which critical field length exceeds runway length, reducing the accepted measure of takeoff performance. JSC engineers addressed this condition in changing the inlet design.

The JSC design was not the only alternative considered. The older inlet might have been modified with auxiliary, moveable doors that could open for takeoff to allow more air to enter the engines. However, this modification would have (1) increased aircraft weight by 120 lb (54 kg), posing a sizeable risk at El Paso and other locations where weight is already of concern; and (2) increased the T-38 life-cycle cost, owing to required maintenance on the modified inlet.

By enlarging the area of the inlet and significantly thickening the inlet, JSC engineers developed an inlet design that promotes laminar flow of incoming air, increasing aircraft efficiency and thrust. The exterior profile was customized for maximum aerodynamic performance and to maintain continuity with existing aircraft structures. Because there are no moving parts, the increase in weight associated with the modification is negligible [approximately 10 lb (≈4.5 kg)]. Clearly, the JSC inlet for T-38 aircraft offers a superior alternative to both the older design and to the auxiliary-door proposal.

NASA's T-38 fleet will be modified to incorporate the newer design. The USAF T-38 fleet and the fleets of foreign countries can be similarly modified.

This work was done by Robert Ess and David Eichblatt of **Johnson Space Center.** *No further documentation is available.*
MSC-22785

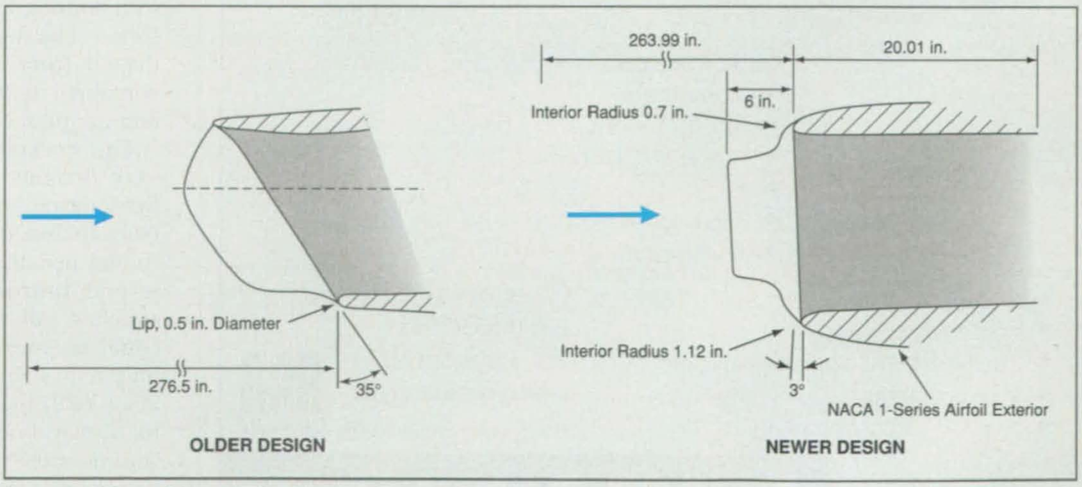


Figure 2. **Older and Newer Inlet Cross Sections** in a longitudinal plane differ in ways that translate to better subsonic performance for the newer design.

The X-36 Program: A Test Pilot's Perspective on UAV Development Testing

A test pilot shares his experience with this unique aircraft.

Dryden Flight Research Center, Edwards, California

The Dryden Flight Research Center (DFRC) has been a partner in many uninhabited-aerial-vehicle (UAV) test programs. Our participation has largely been in the areas of technical oversight and range safety, but the X-36 program provided an opportunity to get some "stick and throttle" experience in this very unique type of flying. It was also an excellent opportunity to evaluate first hand the elements which make a successful UAV test program. I participated in the program as part of an independent review team, a chase pilot, and as a project pilot. In November 1997, I piloted two parameter-identification and flight-envelope-expansion sorties — they proved to be some of the most intense flight testing of my career.

The X-36 is a 28-percent scale, remotely piloted research aircraft (see figure) designed to develop tailless, high angle of attack fighter agility with a stealth design. It uses a control system consisting of canards, split ailerons, leading and trailing edge flaps, and thrust vectoring. The aircraft length is nearly 18 ft (5.5 m), the wingspan is about 11 ft (3.4 m) and the takeoff weight is approximately 1,250 lb (567 kg). It is powered by a Williams International F-112 turbojet engine with approximately 700 lb (318 kgf) of thrust. The flight operations were conducted from a control trailer, which contained both control-room stations and the pilot cockpit.

The cockpit controls and displays were designed to emulate a standard fighter type aircraft cockpit. The controls included a displacement stick, rudder pedals, a throttle quadrant, and several instrument-panel pushbutton switches. All normal flight functions could be controlled from the buttons on the stick and throttle (HOTAS). Two 20-in. (0.51-m) color displays were used to display information. One had the "out-the-nose" picture from the onboard video camera, with heads-up display (HUD) symbology overlaid to obtain a true 1:1 correlation with the video imagery. The second screen had a map indicating the location of the aircraft in the test area and numerous system-status and warning indicators. Finally, a microphone located inside the aircraft provided some valuable audio information on aircraft systems and engine performance.

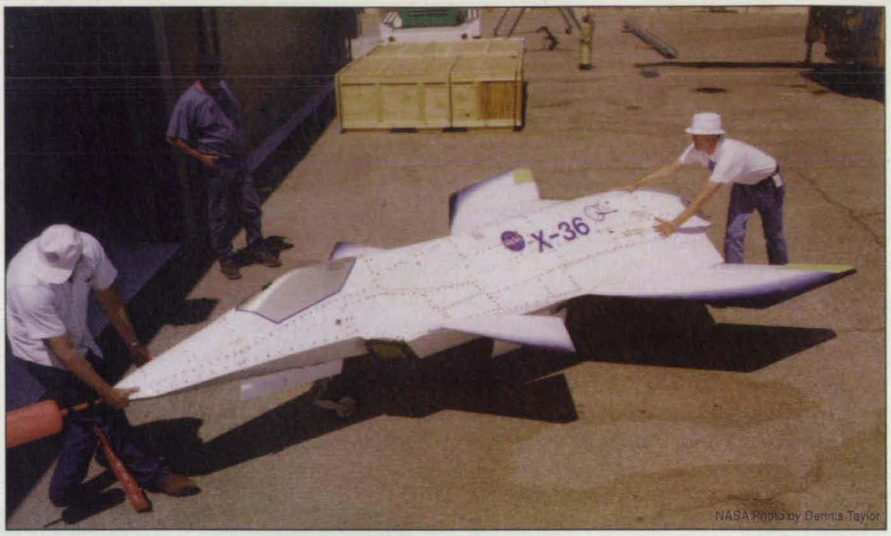
Piloting the X-36 is an intensely visual task. Gone are the large field of regard, the subtle "seat-of-the-pants" inputs and numerous audio clues which normally allow the test pilot to have better situational awareness than anyone else on the test team. Instead, the pilot must rely on a rapid and focused cross check of his/her displays and precise communications with the test conductor. To aid concentration, the pilot was isolated from the rest of the control room area by a curtain and his communications were restricted to the flight director and radio traffic using a separate "flight loop" intercom setup. Behind the pilot was a position which allowed another pilot/engineer to view the displays. This position proved useful for both pilot training and for providing "copilot type" assistance to the flying pilot.

The display symbology needed to meet two conflicting requirements. First, it had to provide enough information to the pilot, in an intuitive format, to compensate for the lack of audio and physical cues discussed previously. Second, the symbology needed to be uncluttered enough to allow the pilot to find and assess quickly key flight parameters. During rapid maneuvering, it was often desired to track airspeed, angle of attack, bank angle, and normal acceleration precisely, while looking for any indication of sideslip or angle-of-attack excursions, engine-compressor stalls, and the like. The X-36 symbology was developed primarily by the chief contractor pilot and reflected his experience with F-15 and F-18 aircraft. I found the symbology very complete, but often too cluttered and a large portion of my training was devoted to finding the correct cross check for each maneuver block. The tailoring of symbology is an issue in all types of aircraft, but for an RPA, the correct symbology set is often critical to flight safety and mission success.

The key to my success with these sorties was the 10 hours of high-fidelity simulation training I obtained prior to an actual takeoff. I "piloted" the aircraft from the actual RPA cockpit with the most current aircraft model and a simulated out-the-nose visual presentation. Both normal and emergency operations were practiced until I was proficient. The simulator training culminated in a full test mission practice prior to the actual flight. Additional training included an actual engine start and a high-speed taxi test to 70 kn on the lakebed runway.

The test flights closely followed the simulator training. The takeoff was accomplished from lakebed runway 15 and the aircraft quickly climbed into the test airspace. Basic aircraft control was easily accomplished using the HUD symbology and the video image. The test maneuvers included a series of control-stick and rudder-pedal rolling maneuvers at various airspeeds and angles of attack. Several level accelerations were accomplished to expand the speed envelope of the aircraft. The aircraft exhibited excellent flying qualities throughout the flight. All the rolls were rapid and the bank-angle/angle-of-attack targets were precisely tracked. The aircraft was able to change speed rapidly, and the lack of any audio or physical speed cues required the pilot to spend extra attention to this display.

Perhaps the most challenging part of the flight was the landing pattern. Airspace restrictions forced us to use a continuous turn to final which meant that the runway was not in sight until very late in the approach. The turn was



The **X-36 UAV** is being rolled out of a hangar for a flight test.

made using the moving map display to insure the correct offset. This maneuver required the use of almost all the information presented to the pilot. The landing was accomplished by simply establishing an on-speed descent at about 1 degree. The aircraft would smoothly touch down, and ground control and braking were very easy.

My experience with this program confirmed my belief that successful development and flight testing of a UAV requires the same discipline and expertise as any other aircraft. Years of flight test experience have defined a set of "flight test best practices." Simply stated, these embody the attitude and the processes which have proven to be critical to mission success. A few of the key points are:

1. Robust Designs and Quality Construction – A major "benefit" of going with a UAV is the ability to simplify the systems of the vehicle. However, simple, nonredundant systems demand careful design to reduce the effect of failures. A "graceful degradation" of system performance is desired. Critical "single string" systems (such as flight controls) are only successful when supported by high-quality parts and construction. "Off-the-shelf" technologies which are integrated into a new vehicle do not insure low-risk flight operations.
2. Hazard Analysis – The failure of the UAV prior to meeting its mission objectives is unacceptable. The hazard analysis must properly identify the probability and the severity of the hazards the vehicle may encounter. Once identified, steps must be taken to mitigate each of the hazards to the lowest level possible. Only then can the program present to management the true level of risk that must be accepted during flight test.

   Also, the program must avoid the "expendability mind-set," which accepts that UAVs fail at a higher rate than other aircraft. This attitude may result in accepting a substandard system or procedure. Today's UAVs are not often cheap, throw-away aircraft. They are sophisticated, expensive, and often one-of-a-kind aircraft, the damage or loss of which has a major impact on the mission success of the program.
3. Configuration Control – The hardware and software of the system will always change during the course of development. A well designed and built vehicle cannot maintain its high standard without a process for identifying and controlling changes to the baseline.
4. Test Planning and Test Mission Conduct – Programs need to recognize that flight test personnel can make valuable inputs to the design of the entire system. Often, the best engineering choice is the one which satisfies the operational requirements for the vehicle, and the flight tester usually has the most experience in this area. Also, it is important to recognize that it is normally unacceptable to take "short cuts" in the flight test process. Flight safety and mission success are seriously impacted by the omission of any of the "best practices" discussed.

Overall, the X-36 program was both challenging and educational. In my opinion, it is an excellent example of how to conduct UAV developmental flight test.

This work was done by Dana D. Purifoy of **Dryden Flight Research Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Machinery/Automation category.*
DRC-97-55

Improved HSPES-Based MEAs for Methanol Fuel Cells

Cathode structures and the process used to make them have been modified.

NASA's Jet Propulsion Laboratory, Pasadena, California

Improved membrane/electrode assemblies (MEAs) made partly from hydrogen form of sulfonated polyether sulfone (HSPES) have been developed for use in methanol fuel cells. In comparison with traditional fuel-cell MEAs made partly from a commercial perfluorosulfonic acid-based polymer, these MEAs perform similarly, but cost much less.

Prior to the development reported here, MEAs made partly from HSPES did not perform as well as did the traditional ones. Analysis of polarization data for an HSPES-based MEA revealed that losses in the cathode accounted for the loss in performance. Further analysis guided by previous experience led to the conclusion that the loss in performance was caused by poor utilization of the cathode catalyst. This conclusion, in turn, led to the conjecture that performance might be improved by use of a modified fabrication process that would yield a modified cathode structure, wherein the cathode catalyst would be bonded in an improved way and distributed in different structures, such that a greater proportion of the catalyst loading would participate in electrochemical reactions.

It was conjectured, further, that the best way to improve bonding and reduce migration was to immobilize some of the catalyst prior to a hot-pressing step that is part of the MEA-fabrication process. In a previous version of the process, a paint containing polytetrafluoroethylene, water, and triton was applied to carbon paper and sintered at a temperature of 350 °C under a nitrogen blanket; this immobilized the catalyst. A solution of the perfluorosulfonic acid-based polymer was then applied to the catalyst-covered electrode before hot pressing. One of the goals pursued in the development of this previous version was of the process to obtain adequate performance with a catalyst loading reduced from the value (4 mg/cm^2) of the traditional MEAs. The catalyst loading achieved was 1 mg/cm^2, but, as stated above, performance was below that of traditional MEAs.

In the modified process, the catalyst loading is not reduced from that of traditional MEAs. However, the catalyst is applied in two layers, each containing half (2 mg/cm^2) of the total catalyst loading. The first half of the catalyst is applied as in the previous version of the process and sintered at 350 °C, but unlike in the previous version of the process, the perfluorosulfonic acid-based polymer is not applied after sintering. The second half of the catalyst loading is applied as part of a paint that also contains water and the perfluorosulfonic acid-based polymer. Unlike the first layer, the second layer is not sintered. Instead, the MEA is hot-pressed after application of the second layer.

The two-layer cathode catalytic structure offers advantages over the previous single-sintered-layer cathode catalytic structure:

- The high sintering temperature can reduce the activity of the catalyst. As a result of the placement of the unsintered layer over the sintered one, highly active catalyst is in direct contact with the membrane after hot pressing.
- Quasi-sintering of polytetrafluoroethylene can reduce catalyst activity by covering otherwise active catalytic sites. However, the unsintered layer contains no polytetrafluoroethylene. Because the unsintered layer becomes bonded to the membrane, the lower catalytic activity of the sintered layer becomes less important. For this reason, it might be possible to increase the polytetrafluoroethylene content of the sintered layer to improve the barrier to migration.

The performances of an HSPES-based MEA made by the modified process (improved MEA) and of one made by the previous version of the process were measured in a comparative test. At a current density of 300 mA/cm^2, the MEA made by the previous version of the process exhibited a potential of 212 mV, whereas the improved MEA exhibited a potential of 387 mV.

This work was done by Andrew Kindler and Shiao-Ping Yen 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.*

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-20306, volume and number of this NASA Tech Briefs *issue, and the page number.*

Kit for Sampling Nitrosamines From Aqueous Solutions

Carcinogens to be analyzed can be extracted from groundwater or soil relatively quickly and cheaply.

Lyndon B. Johnson Space Center, Houston, Texas

Scientists at White Sands Test Facility (WSTF) have devised a kit for extracting nitrosamines from aqueous solutions. In comparison with extractions according to the method recommended by the Environmental Protection Agency (EPA), extractions by use of the kit are faster, cheaper and less labor-intensive, and they yield greater recoveries as well as test results that are more accurate. No other nitrosamine test kit performs at the level of this kit while satisfying requirements unique to WSTF.

The nitrosamines found at WSTF are organic compounds. They are powerful carcinogens that are by-products of dimethyl hydrazine, a rocket fuel used at WSTF before the fuel was linked to human cancers. Because the EPA requires suspected groundwater and soil be tested for carcinogens by use of gas chromatography (GC) and because the EPA's method of extraction and preparation of samples for analysis by GC is a labor-intensive method that involves the use of dichloromethane, WSTF scientists developed their own extraction method, which involves the use of the present kit for sampling nitrosamines from aqueous solutions.

In developing the kit, the WSTF scientists improved on sampling kits that were already extant to provide for extraction and concentration of nitrosamines from groundwater or soil analysis into a nitrogen/phosphorous detector prior to GC. Their technique involves passing a sample with a volume of 250-mL through a solid-phase extraction tube that contains 0.5 g of activated charcoal. Experiments have shown that two nitrosamines found at WSTF — N-nitrosodimethylamine (NDMA) and N-nitrosodi-n-propylamine (NDPrA) — collected by this technique and stored in the dark at a temperature of 4 °C are stable for up to 28 days — sufficient time to ship samples for analysis. Once a sample has arrived in a laboratory, NDMA and NDPrA are eluted with 2 mL of acetone and analyzed under conditions detailed in EPA Method 607 and SW-846 Method 8070.

Nitrosamines in groundwater and/or soil can exert adverse effects on human health in production facilities where they are found, and contribute to overall pollution. Because some nitrosamines are powerful human carcinogens, their presence in any place where humans live or work must be of continuing concern to public and private industries. The WSTF sampling kit is expected to be most useful at WSTF, where its sensitivity and accuracy have significantly improved the ability of scientists to detect NDMA and NDPrA, which are two of the three on-site nitrosamines linked to dimethyl hydrazine. The kit could also be used in measuring the effects of production and/or pollution-abatement activities elsewhere, in connection with industrial activities that involve handling of the analytes of rocket fuels.

This work was done by Gary Moffett and Benjamin Greene of Allied Signal for **Johnson Space Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*

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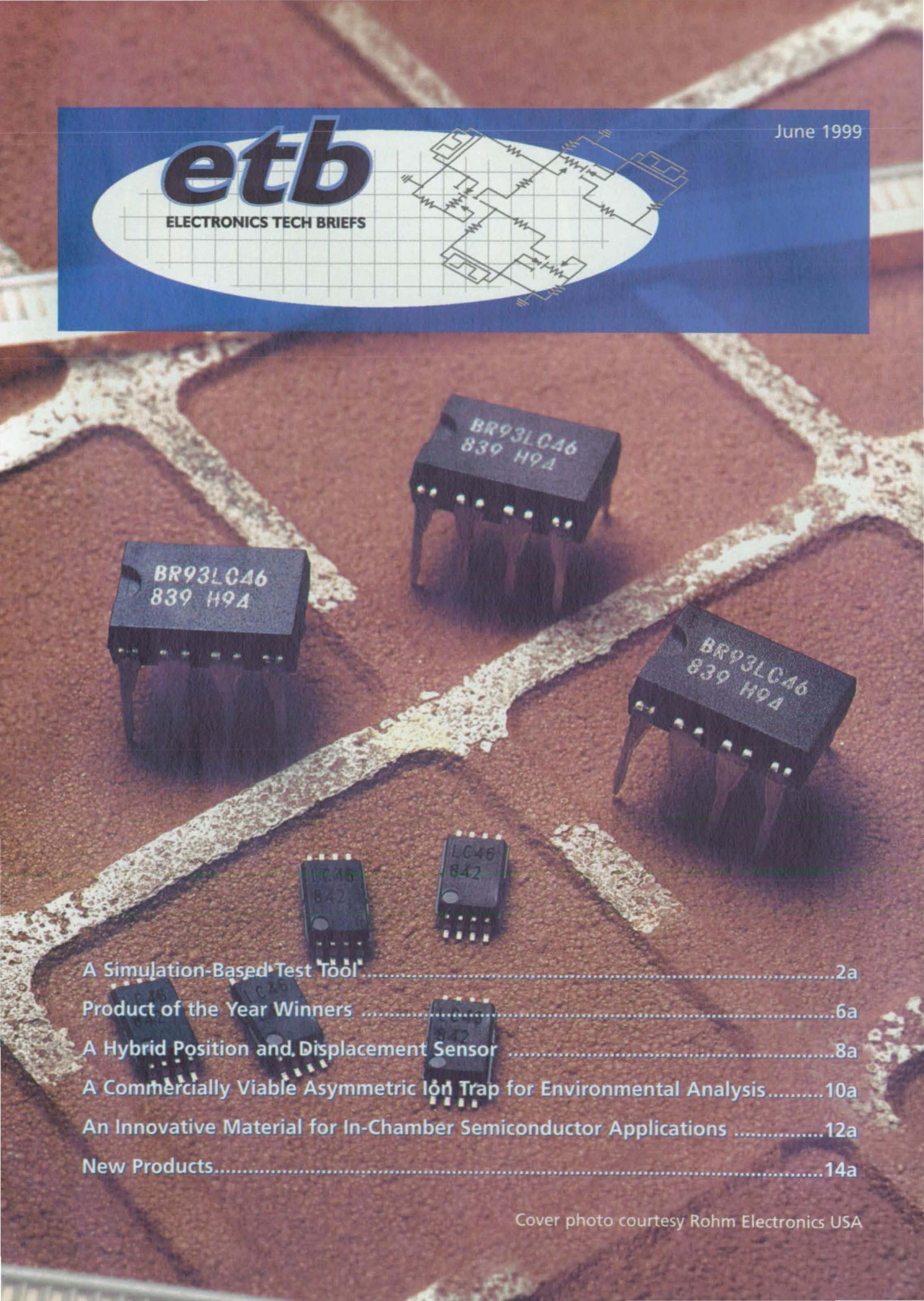
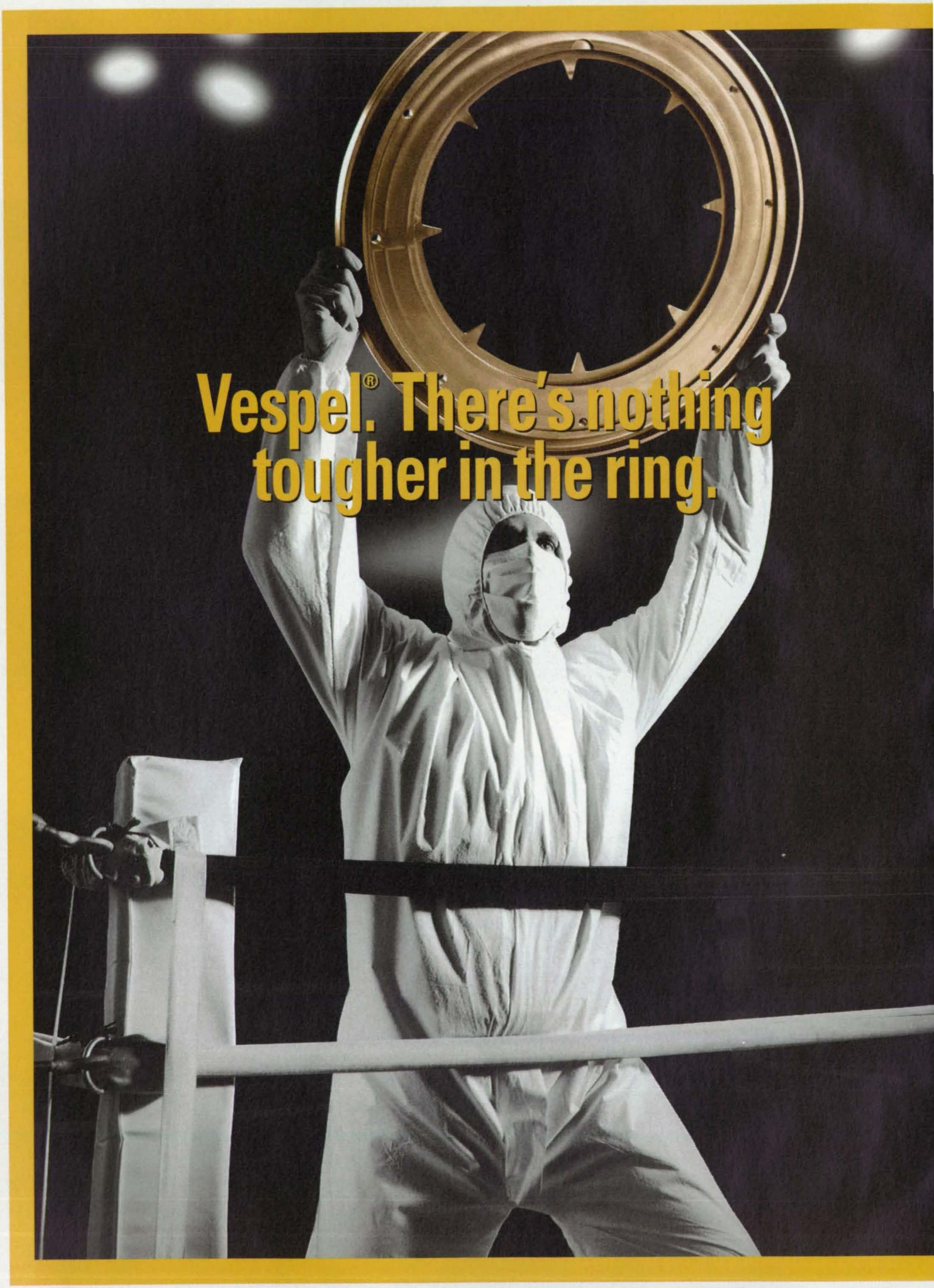
ELECTRONICS TECH BRIEFS

June 1999



Cover photo courtesy Rohm Electronics USA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A Simulation-Based Test Tool

A new software program from Intusoft simplifies creation of a test sequence for analog controller cards.

Simulation-based test program synthesis resulted in reducing the time needed to define diagnostic tests for analog controller cards used on New York City's subway cars from six months to six weeks. It would have taken an enormous amount of time to manually develop a sequence of the 650 tests to cover the fault universe of 1100 failure modes for the 860 components. Instead, a new simulation-based test synthesis software package from Intusoft of San Pedro, CA, was used to largely automate so that the task could be completed in just 240 hours.

The test engineer involved in the project took advantage of the software's ability to automatically generate a fault dictionary for every node, and a rough cut of a fault tree that sequences the tests to detect every failure mode. The ability to start at this point and simply edit the fault tree to reliably isolate faults saved a huge amount of time.

The project began when Instrumentation Engineering Inc. of Wayne, NJ, was contracted to develop a general-purpose diagnostics test station to service a multitude of analog circuit boards used on all the New York City subway cars. The firm developed a debug station that utilizes a variety of GPIB and PC instruments, all of which are tied to a personal computer that runs the diagnostic routines. Although the customer is responsible for writing the majority of the test sequences, Instrumentation Engineering contracted with Deep Creek Technologies of Phoenix, AZ, to develop the test sequence for the propulsion controller circuit board, which is used on the majority of the subway fleet. This card controls propulsion and braking based upon inputs from the operator interface, CPU, and other signals, and was selected for development of the initial diagnostic test sequences because its exceptional complexity made it a good candidate for proof-of-concept testing.

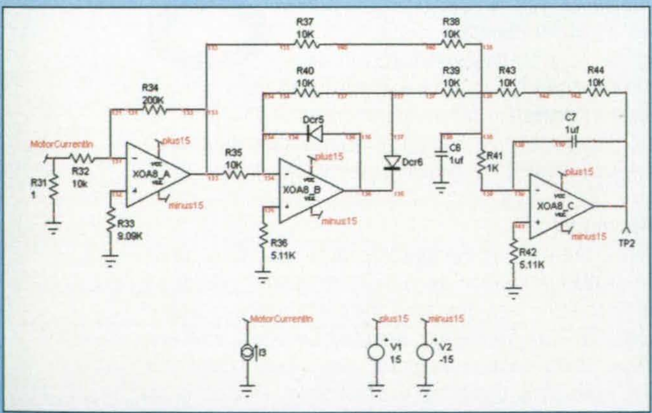


Figure 1. Motor current transducer input circuit.

The 18 final verification tests were assigned by the customer. The diagnostic test sequences were required to isolate the cause of a failure in any of these tests. Until a year ago, the lack of availability of simulation-based test synthesis tools for analog and mixed signal circuits would have made it necessary for the test designer to manually analyze each circuit to determine the voltage that would be generated at each node in response to various signals. Several hours would have been spent analyzing each failure mode, and a considerable amount of estimation would have been needed, because there would not be enough time to thoroughly simulate every possible failure mode.

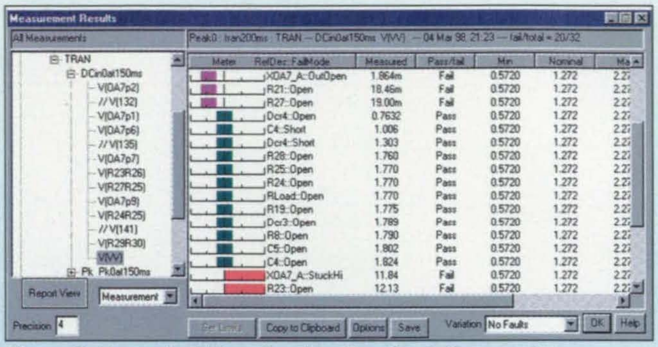


Figure 2. Example dialog showing the simulation results.

Then the test engineer would have to tabulate all calculations and predictions and then analyze that data in order to manually develop the test strategy used to code the automatic testing sequence. Again, much guesswork would be required because there would not be enough time to reevaluate isolation characteristics of every subsidiary branch when the detection characteristics of one or more tests were changed, or the tests were resequenced.

Enter automation

Fortunately Intusoft's simulation-based synthesis tool offers the ability to automate analog and mixed signal circuit test simulation, fault analysis, and fault isolation, and generates detailed test strategy reports. Test Designer includes a fully integrated schematic entry tool, extensive model libraries, a state-of-the-art SPICE3-based analog and mixed signal simulator, and a graphical data postprocessor. More than 13,000 part models are provided, and most include predefined failure modes. All key data entry, analysis, and reporting features are graphically driven, so the user does not have to write any scripts or code to define a model, fault, measurement, or test. This software package costs $12,000 and runs on a personal computer under Windows 95/98 or NT.

The circuit was parsed into logical segments (Figure 1) such that no feedback loops crossed segments. The software does not require segmenting or parsing of the circuit in any way. Each segment was entered into Test Designer using the program's graphical drag and drop schematic entry features.

The program provided the component failure modes defined in the CASS Red Team Package, and allowed the engineers to define custom failure modes as required in a few cases. For example, the default open resistor value of 100 megohms was replaced with a value of 1 gigohm where necessary. Component tolerances are also supported for use in subsequent Monte Carlo analyses.

The next step was simulating the circuit (Figure 2). Each go-line supplied static DC voltages as stimuli, and used static DC voltage as the observed output parameter. The software generated a simulated value for every defined circuit measurement, and the results were viewed and used to guide further refinement of the tests and their limits.

Setting limits

Initial test limits were defined very rapidly for all nodes by selecting a global set of +/-1 volt. The Test Designer software package then developed a fault dictionary that identified every failure mode the could cause each test to fail (Figure 3). At many

nodes, diagnostic test limits were refined by noting the output parameters for each failure in the failure universe and selecting a limit midway between the expected "no fault" range of values and the nearest failed value. These test limits were expanded where necessary to include failed parameter value clusters in the nondetect region if test reliability was improved by such action (Figure 4). An iterative process of selecting highly reliable tests with regard to detection characteristics was used to build the fault tree. Some test limits were adjusted in order to yield improved fault isolation metrics.

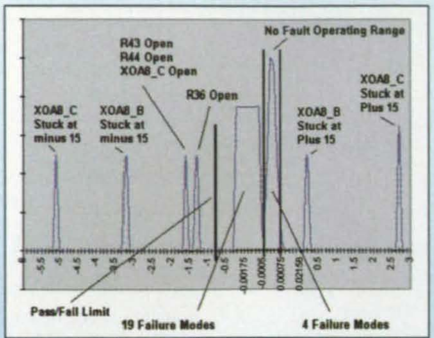


Figure 3. Node 138 voltages for failure modes and no failure.

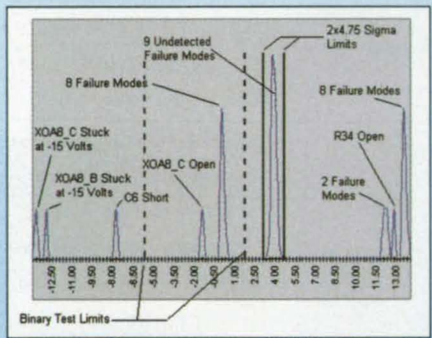


Figure 4. Binary test pass/fail limits set for specific fault detection characteristics.

Fault tree

Many of the 850 components on the controller card have multiple types of failure modes such as stuck at VCC, stuck at VEE, etc. As a result the Test Designer diagnostics isolated more than 1100 failure modes. Test Designer's model-based fault tree computation algorithms made it a simple matter to identify the most robust circuit measurements, refine the test limits to insure reliability, and assemble the fault tree (Figure 5). At each branch of the fault tree, the algorithm was invoked to suggest which test should be next in the diagnostic sequence. The availability of reliable failure isolation tests at each node made it an easy task to assemble the fault tree. Test Designer kept track of the failure modes that had already been detected and isolated, thereby eliminating what is typically a paperwork headache.

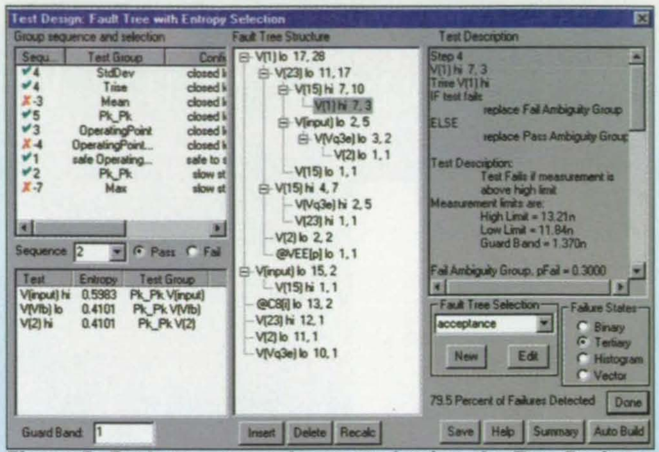


Figure 5. Fault tree example, created using the Test Designer program.

Sometimes a situation arose in which a calculated measurement value was directly on the pass/fail limit. Such a condition would yield unpredictable results, so the engineer would typically rearrange the test sequence so that a prior test would reliably isolate that fault and therefore remove it from the fault universe. When such a change was made on an upper node of the fault tree, Test Designer recalculated all of the isolations below that node. By first simulating only the go-line tests while collecting the no-fault and faulty circuit behavior characteristics at every node and globally assigning coarse test measurement limits, the desired isolation metrics were achieved by performing each go-line test in sequence and, upon failure of such a test, probing the circuit without changing the applied stimuli. Test Designer can generate the fault coverage statistics and call-out lists at any point in this process, so the test engineer can easily assess whether or not the fault coverage and isolation requirements are being met.

As the fault tree was developed, Test Designer displayed all pertinent detailed test information. Once the fault tree was finalized, Test Designer generated documentation that defined the test sequence, again eliminating a tedious manual task. The program can generate ATE pseudo-code in two formats: an ATLAS-like ASCII text version, and C code. This pseudo-code was supplied to Pat Cupo, senior systems engineer for Instrumentation Engineering, who was responsible for writing the software program that executes the fault tree. This program provides the operator with explicit instruction concerning which test to perform next, based upon the results of the previous test. Cupo said that this company was pleasantly surprised to obtain such exhaustive diagnostic routines under tight budget and delivery constraints. The project demonstrates how the use of simulation-based synthesis makes it possible to complete the entire diagnostics process—simulation, test design, and fault tree development—in one quarter of the time required using manual methods.

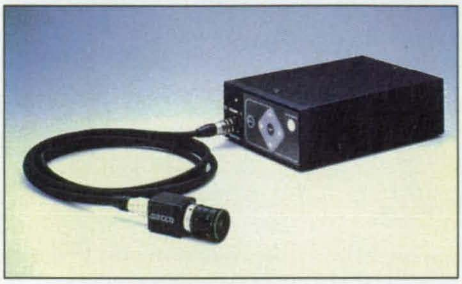
For more information, please contact Harry Dill, president of Deep Creek Technologies and the author of this article, at Deep Creek Technologies, PO Box 93118, Phoenix, AZ 85070-3118; (602) 283-0898; fax: (602) 283-0997; E-mail: Test Designer@csi.com; www.deepcreektech.com.

Electronics Tech Briefs

1998

Readers' Choice Product of the Year

Readers' votes for *Electronics Tech Briefs'* 1998 Product of the Year have been tallied, and the winners are:



Gold Winner

and

Product of the Year:

Sony (Park Ridge, NJ) XC-333 Color CCD Micro-Camera Module, incorporating a digital signal processing chip for control

Silver Winner

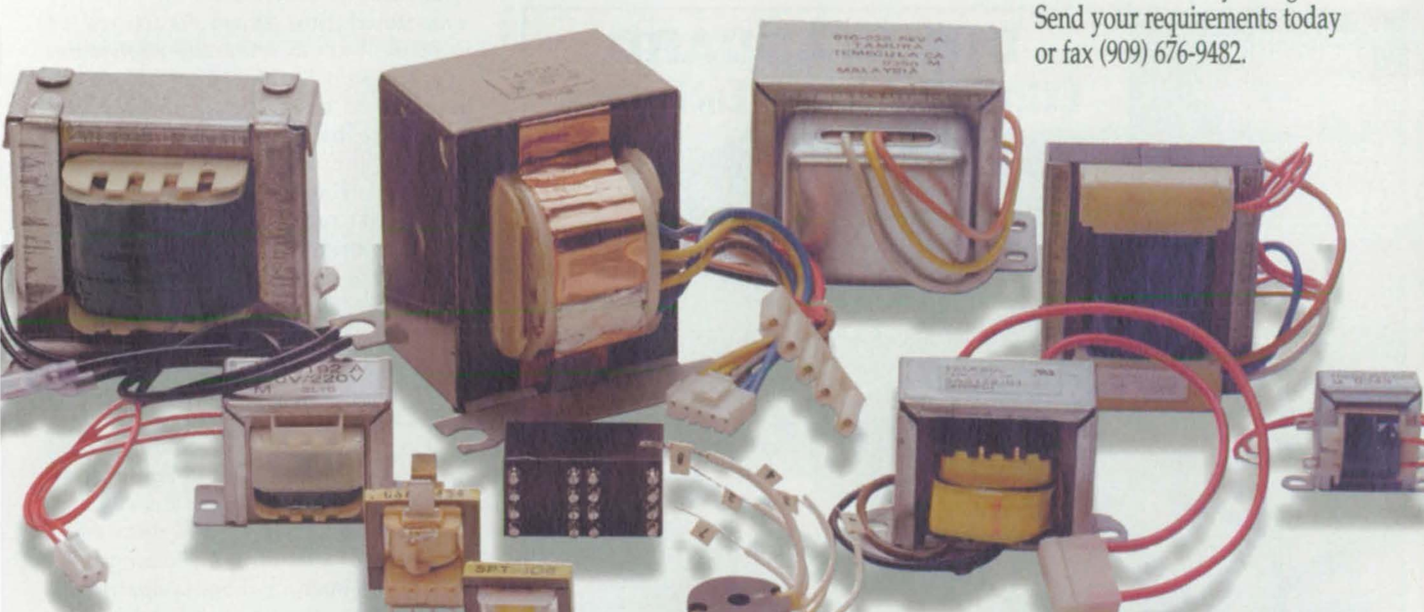
Thomas & Betts (Memphis, TN) Metallized Particle Interconnections, utilizing a flexible conductive polymer material with embedded metallized particles for direct socket connection of microprocessors

Bronze Winner

National Instruments (Austin, TX) IMAQ Vision 4.1.1, a library of machine vision and image processing functions for LabVIEW™ and BridgeVIEW™ incorporating MMX technology

Other finalists include **ACCEL Technologies** (San Diego, CA) Web-Based Product Data Management Software, **AMP Inc.** (Harrisburg, PA) Right-Angle Power Tap Receptacle and Power Pin, and **Honeywell** (Plymouth, MN) Model 83C51 High-Temperature Microcontroller

Winners were chosen by reader vote on *Electronics Tech Briefs'* web site from among the six Products of the Month nominated by the editors during 1998.



A Hybrid Position and Displacement Sensor

The ASET sensor measures interfacial stresses in real time.

Sensor Products, East Hanover, New Jersey

Sensor Products has recently filed two patents for, and introduced, the ASET® sensor for measuring interfacial stresses in real time. The sensor does not measure force, but rather the amount of surface area under compressive load. The principle of the ASET, which is a hybrid of a position and a displacement sensor, lies in treating the entire sensing element as a potentiometer. In the typical linear format design of the ASET sensor, not only can surface area of contact be determined, but position along the line can be sensed as well.

The one caveat of the sensor's capacity to detect surface area is that the tactile surface of the object coming in contact with the sensor must be a solid continuous surface. The ASET sensor is available in thicknesses similar to the force sensing resistor (FSR) and piezo sensors described below. Unlike the resistive ink sensors (RIS) and piezo sensors, the ASET does not require complicated or time-consuming calibration. The ASET sensor is a rugged, durable device that can withstand repeated applications of contact and impact under a wide range of environmental conditions.

As noted above, ASET, conceptually similar to a linear potentiometer, reveals both interpolated force and position of an object (or object dimensions), and can sense the position and interpolated force, by virtue of surface area of contact on a deformable mass, of a single- or multiple-contact actuator. The ASET sensor system does not rely upon a reading of electrical resistance to determine the shunting level (percentage of circuit surface area that is shorted), but rather a ratio of the starting resistance to the final resistance.

In addition, a typical RIS sensor has a limited life, as the elastomeric compound that is integral to it begins to fatigue and compress with use. Thus these sensors are not well suited as embedded devices in a product or system.

ASET bears comparison with other sensor technologies on the market. Magnetic RIS sensors convert mechanical stresses into electrical charges. RIS sensors consist of two sheets, one with a semiconducting polymer, the other with a printed conductive ink (dielectric). Typically these two compounds are coated onto Mylar substrates, resulting in a total package thickness of 4 to 6 mils. A traditional RIS sensor measures force disbursement by measuring actual pressure or force load applied to the sensor element. This method is fraught with difficulties: extreme environmental sensitivity, low repeatability, sensor deformation over time, acute and frequent calibration requirements, and low accuracy. Furthermore, the resistance-pressure relationship for RIS sensors is hyperbolic and changes with time.

Capacitive sensors are relatively similar to RIS sensors but much more accurate and stable. At the same time they are much thicker. These sensors cannot be made on flexible substrates, and therefore are difficult to use to monitor interfacial stresses.

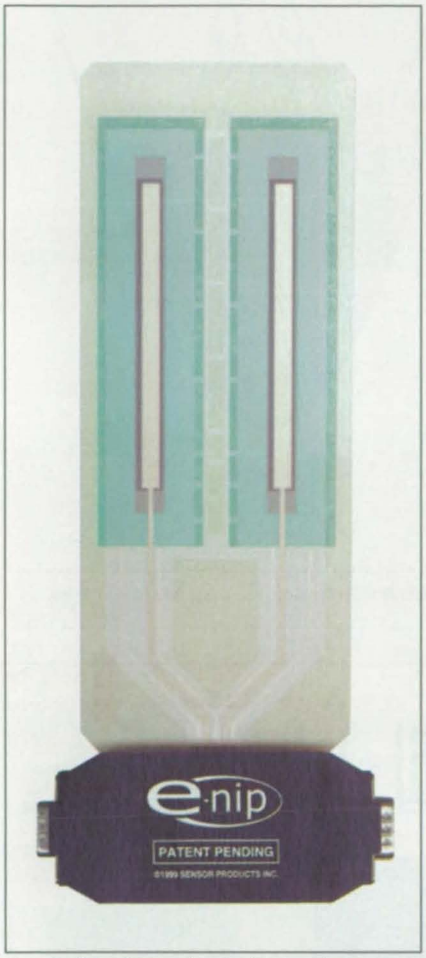
Piezo-film sensor elements are used to reveal tactile force distribution as well, but given their abrupt and unpredictable decay time, are primarily relegated to very brief event recorders. Neither piezo-film or the RIS are instrument-quality devices suited for precision measurement.

Potential applications for the ASET are checking roller pressure in real time, and in others where it would be embedded into smart structures or objects. It could serve any application requiring a ball or ball joint, where it is essential to know the relative position and force being applied on the ball. Another use would be in any application involving linear motion of an object that requires knowledge of that object's position or amount of force or surface area of the object.

Another application area would be where a solid or semisolid object is moving in three-dimensional space and there exists a need to monitor where and when a component of the object is striking or mating with another solid surface. Yet another would be where an object changes dimension as a result of compression or impact and there exists a need to measure this dimensional increase. Finally, a robotics application exists where object grip and surface area of contact and other important considerations need monitoring.

Some product-specific aspects of the ASET sensor include the following: it has both dynamic and static load capability; its linearity and hysteresis combined are ±0.2 percent of full scale; it is self-calibrating, relying on ratios of starting-state resistance versus finished resistance; it is environmentally stable, with an operating range of -40 to +225 °F (storage: -55 to 225 °F); its accuracy is ±1.6 percent of full scale; its sensitivity is 0.01 in.; its repeatability cycle to cycle is ±0.2 of full scale; its repeatability part to part is the same; and its creep is 0.01 in. per day.

These sensors can be made as thin as 4 mils. Virtually any shape, size, and resiliency can be manufactured. The



The E-nip® electronic nip impression system, incorporating the **ASET Sensor**.

sensor elements are made in a carefully controlled environment to ensure uniform resistor and dielectric deposition onto the Mylar substrate. Temperature, humidity, and mixing ratios of the various compounds have a considerable effect upon the final accuracy of the sensor element, and consequently need to be monitored. After the resistor and dielectric depositions are applied and dried, the sensor is then laser-planed to remove surface aberrations. After each lot of sensors is manufactured they are calibrated and individually identified.

This work was done at **Sensor Products Inc.**, *188 Route 10, East Hanover, NJ 07936-2108; (973) 884-1755; fax: (973) 884-1699; E-mail: sales@sensorprod.com; www.sensorprod.com. For more information, contact Jeffrey Stark at Sensor Products.*

A Commercially Viable Asymmetric Ion Trap for Environmental Analysis

The device produces sensitive mass spectra with simultaneous presentation of the cation and anion components.

Pacific Northwest National Laboratory, Richland, Washington

Basic research on ion-trap mass spectrometry (IT/MS) in the Environmental Molecular Sciences Laboratory (EMSL) at Pacific Northwest National Laboratory has resulted in a new patented design for an asymmetric ion trap instrument. This advancement, primarily supported by DOE with leveraged funding from other sources, greatly increases potential applications of this approach for analysis of environmental samples.

Advances in ionization techniques have enabled ionization of almost any type of sample for mass spectrometric analysis. Considerable work in the EMSL's Chemical Structure and Dynamics (CS&D) research group has focused on laser ablation/desorption and matrix-assisted laser desorption/ionization, as well as electrospray ionization techniques. The challenges inherent in the analysis of nanoparticles and aerosols also have been considered in this development effort. The development of this asymmetric ion-trap technology addresses some of the major instrumental challenges of environmental mass spectroscopy, such as sample inhomogeneity, the design of field-deployable instruments, and containment of instrument cost.

Solids analysis has been assisted greatly by being able to observe both the cation and anion spectra from the components in a sample. In many sophisticated instruments, these data can be obtained from the same analyte by sequential data acquisition. In field-deployable systems, however, it is difficult to ensure that the analyte remains unchanged from measurement to measurement; therefore, simultaneous mass spec-

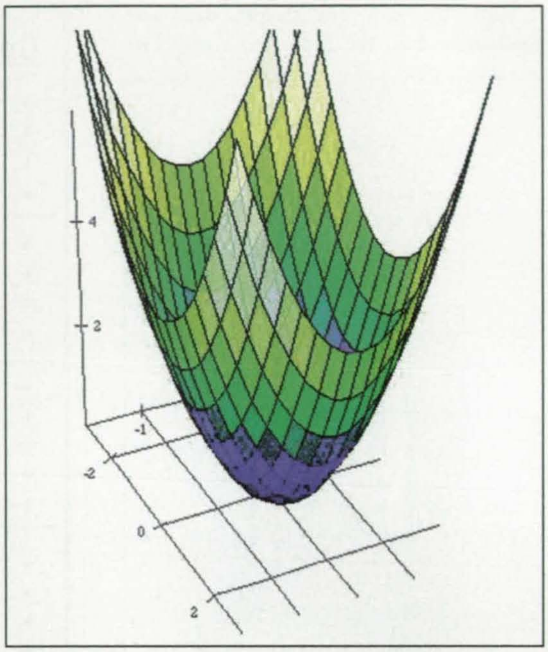


Figure 1. Spectral distribution for a **Standard Ion Trap**.

tra of both charge signs and the highest precision possible are needed. Some workers, notably in the single-particle aerial analysis research community, have addressed this problem by combining two time-of-flight mass spectrometers with a single source region, thus producing an instrument that, while effective, is large and cumbersome.

The Paul or radio-frequency (RF) trap first stores ions in an RF field. Typically, ions are detected by either resonant or instability ejection through an endcap electrode to a detector. The conditions for storage and ejection depend on only the absolute value of the mass-to-charge ratio, not the sign. In recent years, many manufacturers of IT/MS have added a feature that allows users to select either positive or negative ion detection, but not both, because the shot-to-shot jitter in the signal requires considerable signal averaging to give good-quality spectra. Much of this jitter can be traced to the symmetrical electrode design that is almost universally used. It has also been recognized that synchronizing ion production with the RF field improves the signal reproducibility, but the question remains whether resonant or unstable ions exit through the endcap toward or away from the detector. In a "perfect"

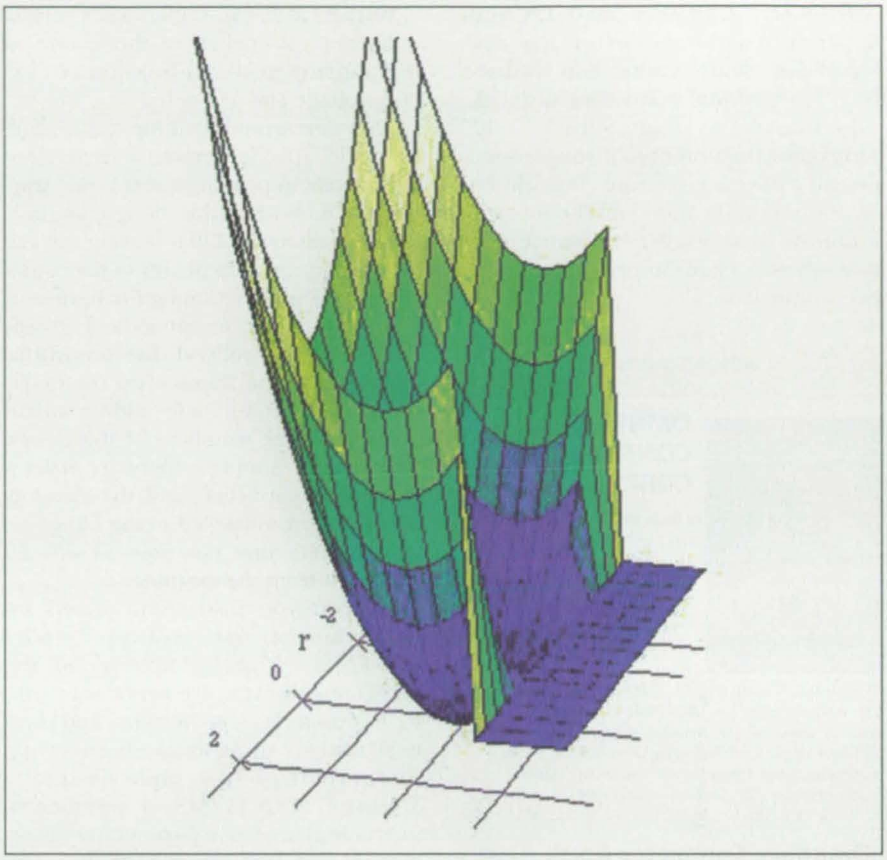


Figure 2. Compared with the standard, the **PNNL Ion Trap** forces all ions to exit the well on the low side and toward a detector, which allows for more reliable analysis.

symmetrical trap, the exit direction depends on the phase of the ion. Significant improvement was realized by J. Franzen and coworkers at PNNL, who introduced higher-order "odd" terms into the potential through intentional distortion of the hyperbolas. With this modification and the incorporation of their secular resonance ejection scheme, major improvements have been reported.

Workers at PNNL undertook a careful mathematical analysis of the nature of the trapping field as a function of trapping voltage and geometry.

They determined that the trap designer could specify certain independent parameters to produce a harmonic trapping well. Within this design latitude, they also discovered that moving the exit or detection endcap nearer to the center of the trap while retaining the harmonic character of the trapping field greatly increases the likelihood that ions will be ejected from the trap toward the detector without intentionally adding anharmonicities. The simplicity of this design and its electronic requirements make it particularly attractive, and the development of a prototype led to the filing of a patent claim that was granted without comment from the examiner.

A prototype instrument based on these concepts was constructed under the EMSL project, building on the CS&D team's extensive experience with RF ion traps, laser techniques, and practical analysis using mass spectroscopy. The prototype was built around a Teledyne 3DQ IT/MS, a commercial instrument that was particularly attractive because it is designed to be easily modified, it is price-competitive, and the manufacturer was willing to cooperate in the development of modifications. This cooperation included providing access to source-code software, detailed drawings of the trap, and spare vacuum vessels. The prototype instrument, including pumping and control electronics, is about the size and weight of a standard desktop computer, and can be easily controlled by a PC.

Tests were made with both electron impact ionization of the fluorocarbon FC-43 and laser desorption/ionization of trichloroethane from a ceramic rod. An example of these spectra is shown in Figure 2; Figure 1 shows a typical spectrum with a standard ion trap. An unexpected result of these prototype tests was the observation of unusually narrow spectral linewidths, which is a natural consequence of the asymmetric design.

This work was done by Stephan E. Barlow, M L. Alexander, and colleagues in the William R. Wiley Environmental Molecular Sciences Laboratory at **Pacific Northwest National Laboratory**, *902 Battelle Blvd., PO Box 999, Richland, WA 99352; (509) 376-9051; E-mail: se.barlow@pnl.gov. PNNL interior funding and DOE Basic Energy Sciences funding supported this work. Patent No. 5,693,941 was issued for this invention.*

An Innovative Material for In-Chamber Semiconductor Applications

SEMICONDUCTOR

Vespel polyimide has several characteristics crucial for fabrication equipment.

DuPont Engineering Polymers, Newark, Delaware

Vespel parts are made from a unique polymer by DuPont that has been called a problem solver for the semiconductor industry. Vespel SPC is a new generation of Vespel polyimide parts and shapes for semiconductor manufacturing, with improved performance and added value in etching chambers and other demanding wafer processing environments.

According to Dr. Gary Poovey of Lam Research Corp., a designer and manufacturer of processing equipment used in the fabrication of integrated circuits, Vespel has several characteristics which are crucial for in-chamber applications. Vespel survives high temperatures, resists heat cycling, and holds its shape under pressure. It is also very stable in plasma environments, and demonstrates excellent mechanical strength. Finally, because Vespel does not transfer heat, it does not attract depositions as readily as other materials, leading to greater cleanliness in the chamber.

Dr. Ray DeColibus, developer of the Vespel SCP formulation, confirms that Vespel's metal ion contamination levels tend to be very low compared with other polymers. Vespel is very stable oxidatively, even at very high temperatures, and offers enhanced plasma resistance, which is particularly critical to semiconductor manufacturers.

The largest current consumer of Vespel in the semiconductor industry is the etch segment, where it is used for wafer clamping rings, gas distribution plates, insulator rings, chamber liners, edge rings, confinement rings, screws and clips, and lift-pin components. These Vespel parts contribute to improved die yield through increased etch uniformity and reduced edge effect. Vespel is also used in PVD, CVD, ion implant, and other processes.

Because of its unique combination of properties, Vespel is being used to replace quartz in a variety of semiconductor applications. Many semiconductor manufacturers are successfully substituting Vespel for quartz without making any changes in their processing conditions, while simultaneously seeing benefits to their overall wafer-fabrication processes. For example, in wafer clamping rings, Vespel's greater toughness prevents fracturing that can occur with the use of quartz. Cover rings and focus rings have also been converted to Vespel, to take advantage of its superior etch uniformity and cleanliness.

In recently documented applications, parts made of Vespel have lasted up to three times longer than standard polyimides. Through its durability, reliability, long life, reduced maintenance, and increased yields, it helps semiconductor manufacturers reduce their cost of ownership in current etch systems and in next-generation high-density plasma systems. At the time of initial purchase, and over the lifetime of the part, the cost of Vespel parts is highly competitive with quartz and ceramic.

To meet the need for larger parts that can stand up to aggressive chamber conditions and protect process purity, DuPont offers Vespel in diameters ranging from one-quarter inch up to 22 inches. The king-sized parts are ideal for larger confinement rings, shield rings, focus rings, and various other uses.

For more information, visit the **DuPont Semiconductor Enterprise** *web site: www.dupont.com/semiconductors, or the Vespel web site: www.dupont.com/enggpolymers/americas/products/vespel.html or call 1-800-972-7252.*

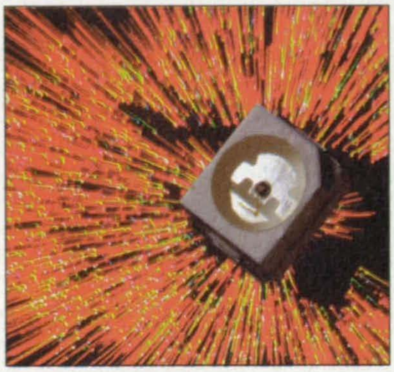
Table 1. Vespel Cleanliness — Quantitative ICP Analysis

Sample		Vespel Test by User (in ppm)
Aluminum	Al	0.12
Calcium	Ca	0.31
Chromium	Cr	<0.1
Copper	Cu	0.21
Iron	Fe	0.14
Magnesium	Mg	0.12
Nickel	Ni	<0.1
Potassium	K	<0.1
Sodium	Na	0.23
Titanium	Ti	<0.1
Zinc	Zn	0.11

ICP results are affected by material composition, sample handling, and sample machining and preparation. Samples submitted without proper cleaning after machining will be representative of both product, machine tool, and cutting fluid characteristics and not truly representative of the product itself.

NEW PRODUCTS

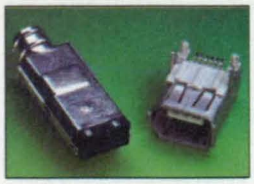
PRODUCT OF THE MONTH



Surface-Mount White LED

Sharp Microelectronics, Camas, WA, introduces the GM5WT95200A, a single-chip surface-mount white LED. The imitation white light is obtained by the integration of a high-luminosity blue LED chip and a fluorescent YAG phosphor into a single package. When part of the blue light is absorbed into the fluorescent material, the latter emits yellow-green light, which, mixed with the blue, produces a pseudo-white color. Measuring 3.4 × 2.8 × 1.9 mm, the LED has a viewing angle of 120°. Typical luminous intensity is 200 mcd with a 20-mA drive current. Applications include instrument panels for automobiles, electronic signs, backlights in portable tools and instruments, and general-purpose illumination.

For More Information Circle No. 751



Plug and Socket Interconnects

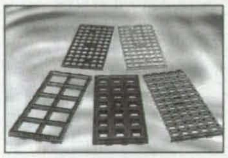
Keystone Electronics, Astoria, NY, offers IEEE-1394 plug and socket interconnects that enable consumer electronics and computer devices to communicate on a standard digital interface. The user can daisy-chain up to 63 peripherals, transferring data at speeds of 100, 200, or 400 Mb/sec over a single wire. Both plugs and sockets are manufactured with phosphor bronze shells and thermoplastic UL 94V-O insulators. The sockets incorporate snap-in PC tails designed to secure the parts in place for wave soldering.

For More Information Circle No. 752

Real-Time Failure Analysis Systems

Nicolet Imaging Systems (NIS/SRT), San Diego, CA, calls its NXR-20HR real-time failure analysis system the ideal tool for inspection and verification for surface-mount board manufacturers. Capable of up to 300× magnification, the x-ray system uses five-axis sample manipulation—rotate and tilt, and X-, Y-, and Z-axis movement—for image acquisition. The unit has a 130-kV x-ray source, a power range from 5 to 30 W, and an 8-micron focal spot. Data acquired from the instantaneous image sampling is enhanced with NIS/SRT's patented AIP digital image processor.

For More Information Circle No. 753



Ultrahigh-Temperature Material

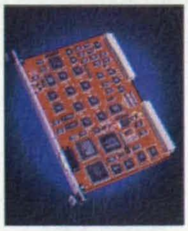
3M Electronic Handling & Protection Division, Austin, TX, has developed a new "olive" ultrahigh-temperature material for use in JEDEC trays that withstand the high-temperature processing needs of the electronics industry. 3M says the product's low outgassing and non-sloughing, its dimensional stability and electrical properties permit its potential use across a wide range of high-temperature applications. The company notes excellent thermal characteristics up to 230 °C for short-term exposure and 215 °C for long-term. It can be molded to meet thick (0.480″) or thin (0.300″) form factors.

For More Information Circle No. 754

Thermally Conductive Material

The Gap Pad™ 1500 from Bergquist Co., Minneapolis, MN, is a thermally conductive material that acts as a thermal interface between a heat sink and an electronic device. The company says that the new pad provides a higher thermal conductivity than standard Gap Pad VO™ or Gap PadVO Soft™ for demanding applications that generate more heat. It is a highly conformable low-modulus material that has no Fiberglass carrier. Gap Pad 1500 is available in thicknesses from 0.020″ to 0.250″ with a liner on both sides, in both die-cut parts and sheets. Standard sheet size is 8″ × 16″.

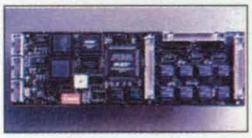
For More Information Circle No. 755



CCSDS Interface for VME Bus

SBS Technologies, Carlsbad, CA, offers the Model 4428-V, a complete CCSDS interface for the VME bus. It has a digital signal processing core design on a single VME 6U form factor, allowing what SBS calls flexible user control to perform Advanced Orbiting System uplink or downlink operation. The control extends to either sending or receiving of CCSDS data from the frame-transfer level down to the packet encoding/decoding level. The Model 4428-V has a block level transfer D64 slave engine to facilitate high-speed transfers from the on-board 256-kbyte memory buffer.

For More Information Circle No. 756



Embedded Microcontroller

The IFC-XT interface controller from StacoSwitch, Costa Mesa, CA, is a multipurpose microprocessor-based embedded microcontroller that the company has designed to manage clusters of lighted pushbutton switches and indicators. It does this by means of serial data links to a host computer. Inputs can be tied to normally open, momentary single-pole, single-throw switches. Outputs are rated for high power applications at 250 mA at 5 V DC, 25 °C derated. Other features include 32 input and output channels, programmable foreground and background intensity levels, and output driver multilevel fault detection.

For More Information Circle No. 757

High-Vacuum Furnace

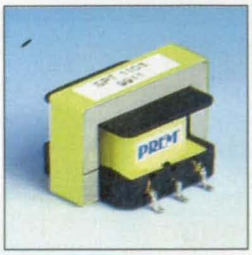
EOI Hetherington, Santa Barbara, CA, introduces the B5000 high-vacuum furnace that incorporates a residual gas analyzer. Its work zone is 15 in. in diameter and 30 in. high, and it can achieve a vacuum level of 1×10^{-7} torr, rated at 1100 °C. High vacuum capability is provided by a CTI cryopump. The system is equipped with a cool-down blower to speed up the cooling cycle. Typical process capabilities include heat-treating of medical devices, flat-panel manufacturing, tantalum capacitor sintering with tantalum hot zone, titanium sintering, and aerospace applications.

For More Information Circle No. 758

Isolated Differential Bus Transceiver

The new ISO422 from Burr-Brown Co., Tucson, AZ, is a highly integrated isolated differential bus transceiver for industrial data communications. Designed for point-to-point or multipoint high-speed data transfer in electrically noisy environments, it provides full- or half-duplex communication at up to 2.5 Mb/sec over long distances. The ISO422 supports Fieldbus, RS-422, RS-485, and CANbus systems. Continuous isolation rating is 1500 V RMS. It is available in a 24-pin single-wide PDIP; a 24-pin surface-mount package will be available shortly.

For More Information Circle No. 759



Surface-Mount Telecom Transformer

Prem Magnetics, McHenry, IL, makes available the SPT-1103 telecom transformer for surface-mount technology. The company says that the SPT-1103 offers a very low profile of 0.48 in. maximum, and is suitable for voice and most data applications. With its 1500 V AC dielectric strength (HIPOT) rating, it conforms to FCC and DOC requirements. Using a gull-wing style of leadframe, the transformer is 0.790 in. long maximum and has a toe-to-toe dimension of 0.730 in.

For More Information Circle No. 760

Eight-Bit Analog-to-Digital Converter

National Semiconductor Corp., Santa Clara, CA, offers the ADC1175-50, a low-power 8-bit video analog-to-digital converter. The company says the device typically consumes just 125 mW from a single +5-V supply. Tested and guaranteed for 50-MHz performance, the ADC1175-50 will function with clock frequencies from 1 MHz to 55 MHz. National Semiconductor says the converter has a superior signal-to-noise ratio of 46 dB. According to the company, the device is ideal for use in video and imaging equipment such as digital still cameras, camcorders, communications, and medical imaging.

For More Information Circle No 761

Special Coverage: Computers and Peripherals

Improved Computer-Based System for Handling Shuttle Data

Telemetry and command data in 4,800-bit blocks are transmitted in Internet Protocol.

Goddard Space Flight Center, Greenbelt, Maryland

The Shuttle Projects Information Frontier (SPIF) Telemetry and Command Processor (TAC) is a personal-computer-based data-handling system that serves as part of an interface for transfer of data between Johnson Space Center and Goddard Space Flight Center (see figure). The data in question pertain to and/or are acquired by payloads that are carried, launched, deployed, repaired, retrieved, or returned by the Space Shuttle Program.

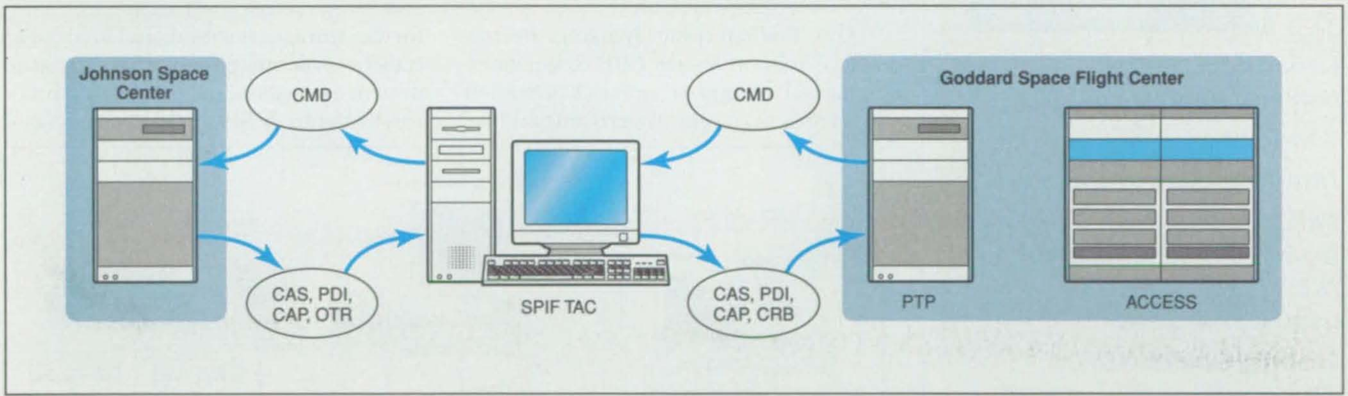
The SPIF TAC receives and transmits NASA communications (NASCOM) blocks encapsulated in user datagram protocol (UDP) packets. The SPIF TAC receives payload data interleaver (PDI), calibrated ancillary system (CAS), and command acceptance pattern (CAP) data from the mission control center (MCC) at Johnson Space Center and performs limited processing before passing the data to the advanced carrier customer equipment support system (ACCESS) in the Attached Shuttle Payloads Center (ASPC) at Goddard Space Flight Center. In turn, the ACCESS sends commands to the SPIF TAC for validation before transmission to the MCC. Should errors arise in the commands, the command response block (CRB) is returned to the ACCESS.

The SPIF TAC supplants an older system called the "SPIF RS" (RS meaning replacement system). It became necessary to replace the SPIF RS with the SPIF TAC because the SPIF RS will not be able to function after the beginning of the year 2000 and cannot handle the transition to NASCOM Internet Protocol (IP). Because of considerations of cost and schedule, it was decided to design a new system (the SPIF TAC) rather than modify the SPIF RS.

UNIX workstations in the SPIF RS were replaced with relatively inexpensive, low-maintenance desktop personal computers in the SPIF TAC. The software for the SPIF TAC was developed by use of Microsoft Visual C++ 5.0. Because of this use of commercial off-the-shelf software, the total cost of development was one-tenth of the cost of replacing the old UNIX computers with new UNIX computers. In addition, the development was completed in one-fourth of the projected time.

The SPIF TAC is ready for the year 2000 and uses IP to communicate with NASCOM. As an added bonus, the SPIF TAC outperformed the SPIF RS while being tested during the STS-87 space shuttle mission.

This work was done by John A. McQueen, Matthew J. Erb, and Amit K. Singh of AlliedSignal Technical Services Corp. for **Goddard Space Flight Center.** *No further documentation is available.*
GSC-14011



The **SPIF TAC** performs limited processing of data that it transmits between Johnson Space Center and Goddard Space Flight Center. (CMD is command and PTP is programmable telemetry processor.)

Program Estimates Run Time on a Parallel Computer

The main advantage of this program is relative simplicity and speed.

NASA's Jet Propulsion Laboratory, Pasadena, California

The Pathcalc computer program estimates the time needed to execute a given application program on a parallel computer of given computation and network capabilities. Pathcalc can be used to analyze the effects of changes in such parameters as central-processing-unit (CPU) speed, network bandwidth, and network latency. Pathcalc is written in Java and should be executable on most computers.

Pathcalc could be used to determine how long it would take to execute the same application program on a different parallel computer or whether a specified faster network or a faster CPU could execute the program in an acceptably short time. It could also be used to determine what part of a parallel system is slowing down execution of a given application program the most: For example, by artificially setting the CPU speed very high, one could determine how much time is used in communication; or by artificially setting the communication speed very high, one could determine how much time is consumed in CPU operations.

It is not necessary to understand the application program or to mathematically model the network in order to use Pathcalc. All one needs is the trace files (one such file for each CPU of the computer) from a previous run of the application program. Pathcalc then generates its estimate on the basis of the trace files and the network parameters provided by the user.

The estimate is valid only (1) for a computer with the same number of nodes used to generate the trace files; (2) provided that message passing is restricted to such simple routines as send, receive, and barrier calls; and (3) provided that the execution of the application program can be relied upon to always follow the same path through the code, regardless of changes in network response times. In situations in which these restrictions are acceptable, Pathcalc offers advantages of simplicity and speed over a number of other programs that estimate execution times of application programs; this is because unlike those estimators, Pathcalc uses only the trace information instead of executing the application programs themselves.

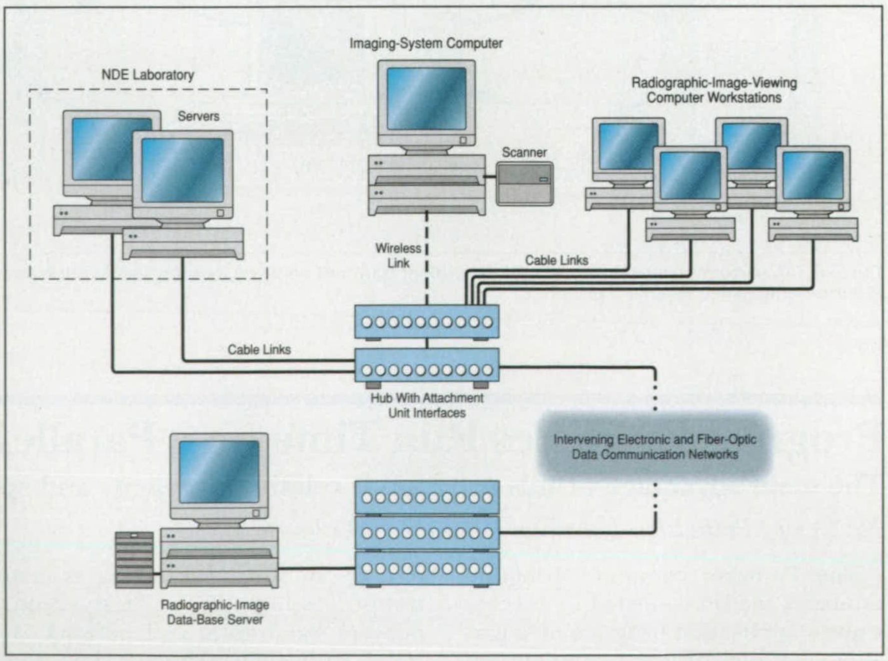
This work was done by Paul Springer of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Information Sciences category.*
NPO-20237

Computer Network for Distribution of Radiographic Images

The network would also be used for training in radiography.

John F. Kennedy Space Center, Florida

The Radiographic Imaging Performance Support System (RIPSS) is a developmental computer network intended to serve as (1) a central electronic archive for the storage, retrieval, and analysis of radiographic images generated in nondestructive-evaluation (NDE) laboratories at Kennedy Space Center and (2) a



The **Radiographic Imaging Performance Support System** is a developmental computer network for centralized storage, retrieval, and analysis of radiographic images, without need to distribute original radiographic films.

system for training users in radiographic techniques and in the analysis and interpretation of radiographic images. The archival, analytical, and training subsystems are being developed concurrently and integrated to the extent possible to take advantage of synergies among them and thereby maximize the potential to enhance the performances of both NDE learners and practicing NDE professionals.

The RIPSS would supplant the present system, in which there is no central archive, and in which both analysis and training are impeded by the need to distribute original radiographic films for comparison. The RIPSS (see figure) would include a scanner and a database server computer, which would store the digitized information from the original radiographic films, making it unnecessary to handle the films after scanning them. Storage of the image information in electronic form would reduce the cost of distribution, provide some redundancy for protection against loss, provide systematic means for preventing access by unauthorized users, and enable the use of automated computational techniques for retrieval and analysis.

The subsystems for storage, retrieval, and analysis of images would incorporate object-oriented data structures and Internet-based multimedia formats for efficiency in development and deployment. Large multimedia files (for example, files containing images with text and audio annotations) could be accommodated. Advanced file-management features would be provided: One particularly notable feature of this type is the query by image contents (QBIC), which can be implemented with commercially available software. For example, if a specific section of pipe were tested on several occasions and its radiographic image scanned into the system on each occasion, then subsequent retrieval of one of the images would facilitate access to all like images. The software would find all images of segments of pipe having the same bend. The search could be narrowed by use of various parameter filters. This feature could be an excellent tool for the comparative analyses that are often performed in analyzing radiographic images.

The training subsystem of the RIPSS is based partly on the Kennedy Space Center developed "Web Interactive Training" where: the capabilities afforded by the Internet and by state-of-the-art multimedia data-presentation techniques are exploited to deliver training from a server computer to client desktop computers on demand. Training can be interactive, and interactivity can be exploited to provide for testing and recording of a trainee's progress. The fully developed RIPSS would enable a trainee or other user to visually inspect a radiograph and to click on a section containing a discontinuity suspected to represent a defect. Underlying image-map coordinates would direct the user to a page that would describe the discontinuity and present case-study information about the radiograph. The user interface for both training and routine use in inspection of parts would be the same.

This work was done by Alexander H. Ladd, formerly of I-NET, Inc., and David Metcalf of Merrimac Interactive Media Corporation for **Kennedy Space Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Information Sciences category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Technology Programs and Commercialization Office, Kennedy Space Center, (407) 867-6373. Refer to KSC-12000.

Satellite Radio Relay Internet Link for the South Pole

The connection is made via the Tracking and Data Relay Satellite System (TDRSS).

Goddard Space Flight Center, Greenbelt, Maryland

The South Pole TDRSS Relay (SPTR) is a satellite radio relay communication system that provides an Internet link for a station at the South Pole. As the name of the system suggests, the radio connection is made via the TDRSS. The northern end of the link is located at the TDRSS ground-terminal complex at White Sands Test Facility.

The concept of a radio link with the Internet is not new; what is new here is the use of the TDRSS for transmission and reception of data at high speed according to the Internet Protocol (IP).

The visibility of Tracking and Data Relay Satellite 1 (TDRS-1) from the South Pole was a consideration in the choice of the TDRSS (instead of another satellite system) for the SPTR; the inclination (>9.5 °) of the orbit of TDRS-1 makes this satellite visible from the South Pole for more than 3.5 hours each day, and the period of visibility is expected to increase in the long term. In addition, the capabilities of the TDRSs are greater than those of other satellites visible from the South Pole.

The SPTR was designed to provide the following services:

- K-band transmission of data from the South Pole to White Sands at a rate up to 50 Mb/s,
- K-band file-transfer service from the South Pole to White Sands at a rate between 2 and 10 Mb/s, and
- S-band bidirectional IP service at a rate of 1.024 Mb/s.

The SPTR was installed in December 1997. By the next month, it was fully operational, providing the services listed above. Both the South Pole and White Sands terminals were assembled from mostly commercially available equipment. The South Pole equipment (see figure) includes the following:

K-Band Subsystem

- file-server computer
- convolutional encoder
- binary phase-shift keying (BPSK) modulator
- 20-W traveling-wave-tube (TWT) amplifier
- 4-ft (1.2-m) antenna.

S-Band Subsystem

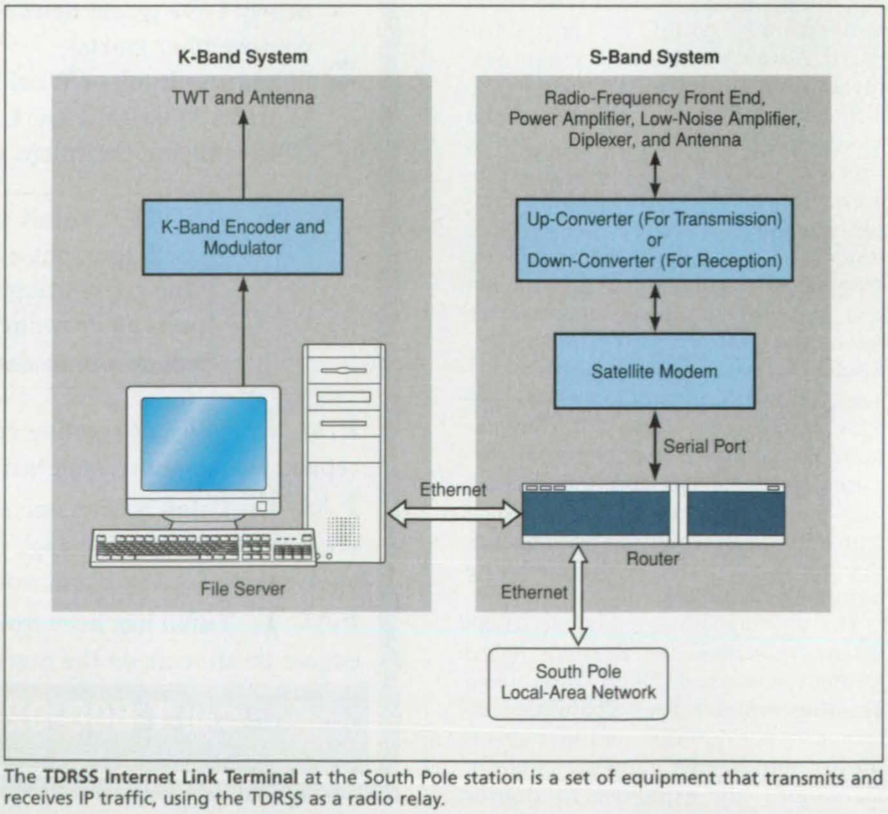
- router
- satellite modem
- up- and down-converters
- 10-W power amplifier
- 4-ft (1.2-m) antenna.

The SPTR additions to the White Sands ground terminal include the following:

- new 1.024-Mb/s connection between the terminal and the Internet
- file-server computer for K-band transfers and the Internet File Transfer Protocol (FTP)
- router for connections among the Internet, the TDRSS, and a local-area network (LAN)
- TDRSS interface that provides coding, scrambling, and descrambling.

The main advantage of the SPTR is that it provides high-level Internet service between the South Pole and other locations. Any IP software can be used, and it is possible to make full use of commercial standards and new developments consistent with the IP. The only major disadvantages are that satellite-communication delays affect the bidirectional IP service and that radio-communication noise could raise the bit-error rate beyond the maximum allowable level of 10^{-5}. The basic SPTR concept could be applied to establish Internet links at field camps and aboard balloons and airplanes.

This work was done by David J. Israel of **Goddard Space Flight Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*
GSC-14037



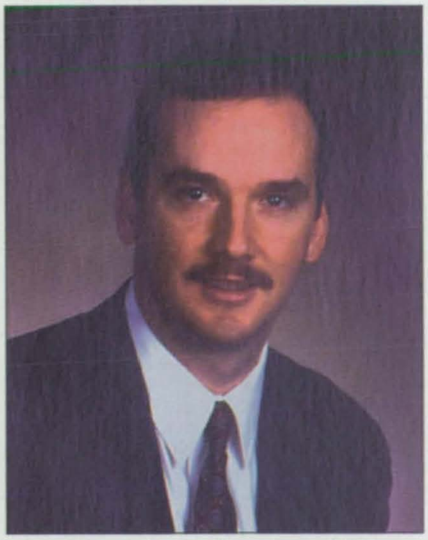
The **TDRSS Internet Link Terminal** at the South Pole station is a set of equipment that transmits and receives IP traffic, using the TDRSS as a radio relay.

Technology Forecast

Regularly, we will be featuring Technology Forecasts by leading executives from the technology areas featured in our Special Coverage sections. This month, two executives from Compaq Computer Corporation's Workstation Division discuss the direction in which the professional workstation market is heading. John Thompson, Vice President and General Manager; and David Parsons, Director of Workstation Marketing for North America, were interviewed recently by Chief Editor Linda L. Bell at Compaq's Innovate Forum '99 in Houston.

Thompson: We are seeing changes overall in the market and in the industry that are causing us to proactively re-think how we're going to build our customer base. For example, there are really two types of customers out there. One tends to be more low-end; there is a big volume push in the low-end part of the market space, which is characterized primarily by the Windows NT-based workstation. On the other end of the spectrum is the power user – the very high-end CAD or EDA user – who typically is looking for more of an Alpha UNIX-based or traditional UNIX-like workstation.

What we're doing is aligning the way we're going to develop our products, and how we go to market, based on this trend that we're seeing. One alignment is to take the Intel-based workstations and proactively align it with the PC products from an engineering development perspective. Right now, for example, we ship millions of PCs each year out of PC manufacturing plants that are dedicated to that, as opposed to different plants that do more of the higher-end enterprise or server units. There are a lot of cost-efficiencies that we hope to pass on to our end-users – volume capability, logistics capability, and other cost-efficiencies – by aligning this more closely with the desktop models.



John Thompson, Vice President, General Manager

On the other end of the spectrum, we think this efficiency can be accomplished by aligning our RISC-based offerings more closely from a development perspective with the Alpha server product line. Instead of having two different engineering teams, you can still have synergy between those development teams in terms of bringing products to market.

So, in terms of the end user or customer, nothing's really changed. There's one workstation division and we work to understand customer requirements, particularly in the engineering and design space. From a unit perspective, the Intel-based workstations tend to be very high-volume products. Overall, in the industry, there is more growth in the NT-based workstation than in the UNIX workstation. However, there is still clearly a need for that UNIX workstation.

There are some companies that are choosing not to address both segments of the market. For example, if you look at Dell, they offer an NT solution, and they really don't offer a true UNIX solution. Sun, on the other hand, offers a UNIX solution, but doesn't really offer an NT solution. Hewlett-Packard offers both. Part of our strategy is to leverage the Compaq engine, from a volume perspective, which is PC products, as well as integration of the high-end products to push that volume forward.

We'll continue to target our core markets, which include CAD, and packaging and bundling deals with software companies who are our channel partners.

The other trend we're seeing, from a graphics perspective, is a broader range of graphics. We're finding that customers are asking for a choice in the graphics area. You might find one graphics company who manufactures a card that fills the needs of 50% of the market, but another 50% want something else. It's increasingly difficult to bet on the right horse. Our approach is going to be to work with OEMs on the graphics products themselves, working in conjunction with our channel partners to provide multiple solutions.

David Parsons, Director of Workstation Marketing for North America

We also see the market segmenting into three areas: the traditional RISC-UNIX workstation; the NT workstation; and the NT unbranded workstation, which takes a high-end desktop product and incorporates workstation-like features such as multi-gigabytes of memory, 300 gigabytes of database storage, larger displays up to 21", and running workstation applications. We intend to capitalize on that.

Parsons: There are three other mini-initiatives that we're continuing to drive: 64-bit computing, and what we'll be able to provide to clients in that space, particularly in the technical world; UNIX/NT interoperability and integration; and Linux. Surrounding all of it will be the concept of high-performance technical computing and clustered workstations, that when networked together, provide Cray-like performance at desktop-like price points.

For more information, contact Compaq at 1-800-AT-COMPAQ, or visit their web site at www.compaq.com

LITERATURE & WEB SITE SPOTLIGHT

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SHIELDING SYSTEMS FOR INDUSTRIAL APPLICATIONS

Lindgren RF Enclosures, Inc., offers an 8-page brochure on its Double Electrically Isolated (DEI) RF Enclosures, which provide the highest level of EMI/RFI shielding for many industrial, communications, and government applications. DEI enclosures meet high-performance requirements for pager, cordless and wireless repair, cellular system production, security, research, and EMI/RFI testing and calibration. Lindgren RF Enclosures, Inc., 400 High Grove Blvd., Glendale Heights, IL 60139; Tel: 630-307-7200; Fax: 630-307-7571; www.lindgrenrf.com

Lindgren RF Enclosures, Inc.

For More Information Circle No. 620

VIRTUAL INSTRUMENT TOOLS FOR C/C++

With LabWindows/CVI, you can build data acquisition and instrument control systems using your favorite C/C++ development tools. LabWindows/CVI combines user interface, analysis, and instrumentation libraries with a high-productivity development environment. Features include: drag-and-drop UI editor; integrated analysis libraries; 650 instruments drivers are available. Call or visit our Web site for a FREE evaluation version. National Instruments; Tel: 512-794-0100; 800-661-6063 (U.S. and Canada); Fax: 512-683-9300; e-mail: info@natinst.com; www.natinst.com/cvi

National Instruments

For More Information Circle No. 621

SOFTWARE SHOWCASE

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National Instruments

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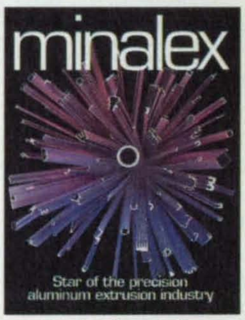

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Azonix

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See an actual live demonstration of Algor's FEA-based Mechanical Event Simulation software. Each demonstration answers often-asked questions about Algor software. You can e-mail software questions, view replays of Algor live webcasts, and also get a schedule of upcoming live webcasts from www.algor.com or order your FREE CD which contains a version of Algor's web site. Address: 150 Beta Dr., Pittsburgh, PA 15238; +1 (412) 967-2700; info@algor.com; or Fax: +1 (412) 967-2781.

Algor, Inc.

For More Information Circle No. 626

LEARN ABOUT MULTIPHYSICS FROM WWW.ALGOR.COM

Multiphysics combines capabilities of Algor's stress, thermal, fluid flow, and electrostatic products to model and analyze parts. Discover the different types of analyses Algor software can perform. View replays of Algor live webcasts and also get a schedule of upcoming live webcasts from www.algor.com or order your FREE CD which contains a version of Algor's web site. Address: 150 Beta Dr., Pittsburgh, PA 15238; +1 (412) 967-2700; info@algor.com; or Fax: +1 (412) 967-2781.

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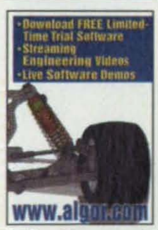

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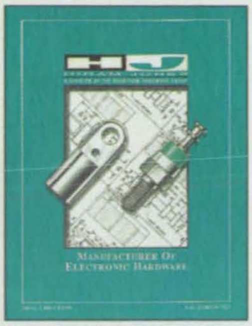
GEOTEST'S 1999 CATALOG

The new, free 120-page 1999 PC-Based Test Solution Source Book from Geotest (Marvin Test Systems Inc.) features more than 100 PC-based products for ATE, data acquisition, process control, and test-and-measurement applications. New products include: GT5150 Dynamic Digital I/O; GT1160 - 60 MS/Sec AWG and DDS signal source; GTXI7700 PCI and ISA Instrumentation Chassis; power supplies, and more. Call for your free copy: Geotest/Marvin Test Systems, Inc., Tel: 888-TEST-BY-PC (837-8297) or 949-263-2222; e-mail: sales@geotestinc.com; www.geotestinc.com

Geotest/Marvin Test Systems, Inc.

For More Information Circle No. 629



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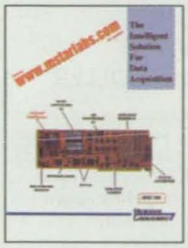

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Seastrom Mfg. Co. Inc.

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The new 1999 Envoy Data PCMCIA source catalog features the latest PCMCIA drives USB, PCI, and SCSI.

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Envoy Data Corporation

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Penn Engineering & Manufacturing

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For More Information Circle No. 635

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Strainsert

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METAL BELTS AND DRIVE TAPES

This brochure describes the various attributes that make metal belts and drive tapes an exceptional and exciting option for design engineers. Manufactured by Belt Technologies, Inc., for over 25 years, this family of products has helped design engineers overcome challenging application requirements in electronics, aerospace, biomedical, optical, and packaging industries. Belt Technologies, Inc., 11 Bowles Rd. Agawam, MA, 01001; Tel: 413-786-9922; Fax: 413-789-2786; www.belttechnologies.com

Belt Technologies, Inc.

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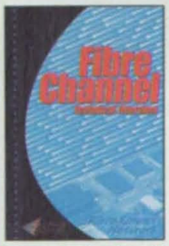

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VIBRATION ISOLATION & IMPACT ABSORPTION

New, full-color brochure describes the dynamic properties of Sorbothane, the unique vibration isolation and impact absorption material. New test data details the damping properties of Sorbothane compared to other elastomers. Sorbothane is a patented visco-elastic polymer. Includes information on Sorbothane's new line of advanced vibration isolation/shock absorption products, as well as applications engineering, manufacturing capabilities, and the many applications for Sorbothane. Sorbothane, Inc.; Tel: 330-678-9444; Fax: 330-678-1303; e-mail: webmaster@www.sorbothane.com; http://www.sorbothane.com

Sorbothane, Inc.

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VACUUM CLEANING SYSTEMS

This new, six-page brochure features Nilfisk's full line of industrial vacuum cleaning equipment, including: continuous-duty and wet/dry vacuums; vacuum-assisted power tools; and specialty products such as explosion-proof, compressed air, and mercury vacuum cleaners. Highlights include product application photos, and illustrations of the three filtration systems available. Nilfisk-Advance America, Inc., 300 Technology Dr., Malvern, PA 19355; Tel: 610-647-6420; Fax: 610-647-6427; www.pa.nilfisk-advance.com

Nilfisk-Advance America, Inc.

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The Interface Controller, IFC, provides flexible, low-cost digital I/O. Features include up to 16 inputs and 64 outputs @ 250 milliamps and 50 VDC; serial communication to the host processor via RS-232 or RS-422/485 ports; simple software driver set. Controllers are small size, for easy direct mount or DIN Rail mount. StacoSwitch; Tel: 714-549-3041; Fax: 714-549-0930; e-mail: mrktg@stacoswitch.com; www.stacoswitch.com

StacoSwitch

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WAVE/COMPRESSION SPRING CATALOG NO. WS-98

Catalog # WS-98 contains hundreds of NEW stock sizes of wave/compression springs, including spring-design formulas, materials guide, and typical applications. This 40-page engineering/parts manual describes advantages of Smalley's edgewinding manufacturing process. Special Springs are easy too! Smalley springs are produced by circle coiling flat wire, with no dies or special tooling charges. Smalley Steel Ring Co., 385 Gilman Ave., Wheeling, IL, 60090; Tel: 847-537-7600; Fax: 847-537-7698; www.smalley.com

Smalley Steel Ring Co.

For More Information Circle No. 642

METRIC AIR SPRING MANUAL FROM FIRESTONE

Firestone Industrial Products has revised its *Metric Engineering Manual and Design Guide* for Airmount® isolators and Airstroke® actuators. The manual provides complete spring specifications in metric dimensions, including height, force, and static data. Airstroke actuators are a low-cost equivalent to conventional pneumatic and hydraulic cylinders; Airmount isolators feature a compact installed height and unsurpassed isolation capability. Firestone Industrial Products Co., 12650 Hamilton Crossing Blvd., Carmel, IN 46032; www.firestoneindustrial.com

Firestone Industrial Products Co.

For More Information Circle No. 643

TOOLING COMPONENTS AND CLAMPS

This 500-page catalog contains an assortment of components including toggle clamps, modular fixturing, clamping devices, power workholding, chuck jaws, pins, knobs, drill bushings, leveling feet, and much more. Carr Lane Manufacturing Co., 4200 Carr Lane St., PO Box 191970, St. Louis, MO 63119-7970; Tel: 314-647-6200; Fax: 314-647-5736.

Carr Lane Manufacturing Co.

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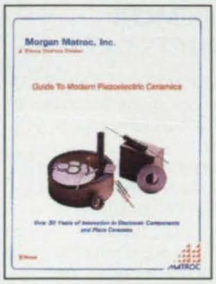

PIEZOELECTRIC CERAMICS

A 28-page brochure is a design guide for piezoelectric ceramics in a variety of shapes and sizes. Piezoelectric and electromechanical properties for various PZT materials (lead zirconate titanate) are included, and various types of piezoceramic configurations, including stacks and bimorphs® are described. Morgan Matroc Inc.; Tel: 440-232-8600; Fax: 440-232-8731; e-mail: morgan-ecd@juno.com; http://www.morganmatroc-ecd.com

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For More Information Circle No. 646

INSTRUMENT DATA ACQUISITION

The SoftwareWedge™ directs serial (RS-232, RS-485, RS-422) data from any instrument into any Windows 3.x, 95, or NT application such as Excel, MMIs, VB, Control, and Statistical applications. This configurable driver provides full data acquisition and control of PLCs, data loggers, scales, flow meters, lab instruments, etc. Please contact TAL Technologies, Inc., 2027 Wallace St., Philadelphia, PA 19130; Tel: 800-722-6004 or 215-763-7900; Fax: 215-763-9711; http://www.taltech.com

TAL Technologies, Inc.

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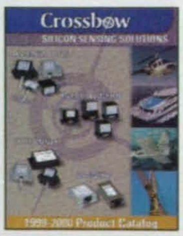


ACCELERATION, TILT, GYRO, MAGNETIC SENSORS

Free product catalog features a broad selection of Crossbow's solid state sensors with many new products. The catalog includes Acceleration, Tilt, Gyro, and Magnetic Orientation Sensors plus Data Acquisition Accessories. Crossbow's spectrum of intelligent multi-sensor solutions have fully signal-conditioned output, analog & digital interfaces, and on-board & host software. Tel: 408-965-3300; Fax: 408-324-4840; e-mail: info@xbow.com; www.xbow.com

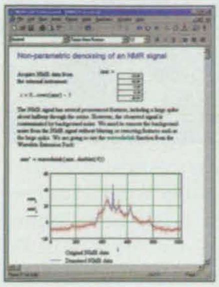
Crossbow Technology, Inc.

For More Information Circle No. 648

New on DISK

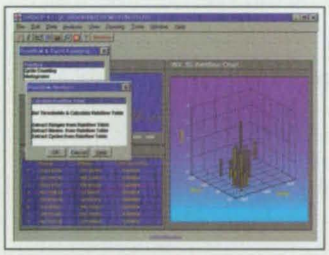
Wavelet Technology

The Mathcad Wavelets Extension Pack from MathSoft, Cambridge, MA, is available for users of Mathcad 8 Professional technical computing software. It includes more than 60 wavelet functions covering five orthogonal and biorthogonal families and is designed to provide advanced techniques for signal reconstruction, denoising, data compression, and special numerical methods. All functions are seamlessly integrated into Mathcad's core environment. The Wavelets Pack also integrates with Mathcad's other extension packs, including those for signal and image processing. **Circle No. 734**



Data Analysis

DSP Development Corp., Cambridge, MA, has released DADiSP/Rainflow, an add-on module for DADiSP engineering spreadsheet software. DADiSP/Rainflow performs Rainflow and Cycle Counting analysis. Cycle counting, comprised of several fatigue-analysis methods, is widely used in the automotive and aerospace industries. DADiSP/Rainflow includes the following cycle counting procedures: level-crossing, peak, simple-range, and rainflow. The basic DADiSP software provides a spreadsheet-like, icon- and menu-driven environment for displaying and analyzing data. **Circle No. 725**

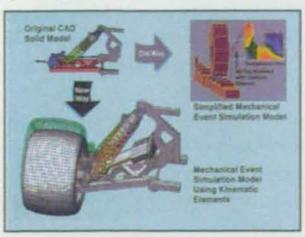


Mechanical Design

Baystate Technologies, Marlborough, MA, has released DRAFT-PAK 98, a mechanical design enhancement package for use with the company's Windows-based CADKEY 98 and CADKEY WIREFRAME CAD solutions. DRAFT-PAK provides database-driven programs for creating complex features, fasteners, and mechanical elements. DRAFT-PAK 98 includes one-step solutions for generating 2D, 3D wireframe, and solid models of features including drilled/reamed, tapped, counterbored, countersunk, and counter-drilled holes, pipe threads, slots, and pockets. This release also includes optional animation for component positioning of all mechanical elements, along with configurable rotation increments for animated rotational placements. **Circle No. 727**

Kinematic Finite Elements

Algor, Inc., Pittsburgh, PA, has announced that its Mechanical Event Simulation software now offers faster FEA processing of highly detailed models using new 2D and 3D kinematic finite elements. Kinematic elements are rigid elements that move like regular, flexible finite elements. The elimination of stress processing for kinematic elements reduces processing time. This enables engineers to quickly simulate an event using a complete CAD solid model or assembly on a desktop computer. Users can also speed processing by using kinematic elements in relatively rigid areas of a model while using regular finite elements to obtain stresses only where needed. Kinematic elements are available with Release 12 of Algor's FEA software. **Circle No. 730**



New on the MARKET

Vibration Control

The JAGUAR Closed-Loop Vibration Control System from Spectral Dynamics, San Jose, CA, is a workstation-based, distributed-process solution for structural, acoustic, and closed-loop vibration control. JAGUAR is designed to control the shaker tables that simulate vibration stress, take measurements from the object being tested, and display results such as transfer functions and PSDs (Power Spectral Densities) in real time. Features include up to 98 measurement channels per Acquisition Control Peripheral (ACP) and Patented Adaptive Control and linear phase filters suited to transient and modal applications. A 200-MHz RISC processor is central to the Micro Digital Signal Processor III card included in each ACP. **Circle No. 714**

Pressure Transducer

Series 520 pressure transducers and transmitters from Barksdale, Los Angeles, CA, offer four different output signals (5V, 10V, 100mV, and 4-20mA) and 10 operating pressure ranges from 5 to 10,000 psig. They are packaged in a welded, stainless-steel NEMA 4 enclosure measuring 1" in diameter by 3-1/4" long. All models feature a diffused silicon pressure sensor designed to provide long-term stability of 1% FSO, accuracy of 1% (LH&R), and a typical life span of 100 million cycles. The sensor is isolated from the media by a stainless-steel diaphragm, making it compatible with corrosive gases and liquids. **Circle No. 715**

Precision Sensors

A line of precision sensors designed for high performance has been introduced by Kaman Instrumentation, Colorado Springs, CO. Standard features include measuring ranges from 0.002" to 2.50", high-speed analog and digital signal conditioning, and rugged stainless-steel and PEEK housings. Single-coil systems are available, in addition to dual-coil and matched differential pair systems designed to minimize temperature, radiation, and other environmental effects. Sensors operate in temperature ranges from 4°K to +1000°F (+538°C). **Circle No. 718**

Instrumentation Recorder

The DATALite™ digital instrumentation recorder from R.C. Electronics, Santa Barbara, CA, is a self-contained 8- or 16-channel instrument no bigger than a lunch box. It is designed to offer continuous recording at bandwidths up to 40 kHz per channel, 90 dB dynamic range, individual A/D converters, brickwall anti-aliasing features, programmable gain amplifiers, and simultaneous sampling. The recorder features a Pentium processor, Windows NT operating system, built-in monitor, and a 6-GB hard drive (expandable). The system's programmable differential amplifiers enable the recorder to record static, vibration, acoustic, sonar, and pyroshock tests. **Circle No. 722**

New LITERATURE

Plastic and Metal Components

An eight-page brochure from Bruce Plastics, Pittsburgh, PA, outlines an assortment of stock and custom-molded plastic and metal parts. Products include handles, bumpers, feet, Polylastomer components, thread protectors, fasteners, binder posts, nameplates, case hardware and components, and fan blades. Materials range from commodity grades to sophisticated engineering polymers and thermoplastic elastomers. **Circle No. 737**

Coating Thickness Gage

CMI International, Elk Grove Village, IL, has published literature on the CMI 200 Series gage for measuring coating and plating thickness. The gages, which are available in eddy current and magnetic induction models, offer a scanning option for uneven or textured substrate materials. Other features include a compact, rugged design and a memory capacity of more than 12,000 readings. **Circle No. 738**

Test and Measurement

A 312-page 1999/2000 Test & Measurement Catalog from IFR Americas, Wichita, KS, features specifications on commercial and wireless test sets, signal sources, analyzers, counters, and power meters. A 12-page product-overview section is included, along with ordering information. **Circle No. 741**

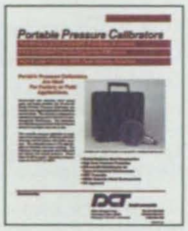
Spring Products

Bauer Springs, Pittsburgh, PA, offers a brochure describing spring elements and precision components. Products include disc springs and spring elements manufactured to almost any specification. Processing extends from spring steel to high-strength titanium, and includes appropriate heat treatments. Applications range from household appliances to aerospace. **Circle No. 742**

Sensors and Amplifiers

Analog Modules, Longwood, FL, has published an eight-page sensors and amplifier catalog describing hybrid laser rangefinder receivers, analog photodetector-amplifier modules, linear and logarithmic amplifiers, pulse stretchers, and fiber-optic links. Product applications include medical, military, scientific, and industrial markets. **Circle No. 744**

Portable Pressure Calibrators



Literature from DCT Instruments, Columbus, OH, details the Portable Pressure Calibrator Series, designed as a traceable transfer pressure standard to transducers, gages, meters, or transmitters in the field. Two accuracy levels are offered: the Model JK with 0.2% accuracy, and the Model AK with 0.05% accuracy. Both feature an enhanced-resolution 4-1/2 digit display. **Circle No. 745**

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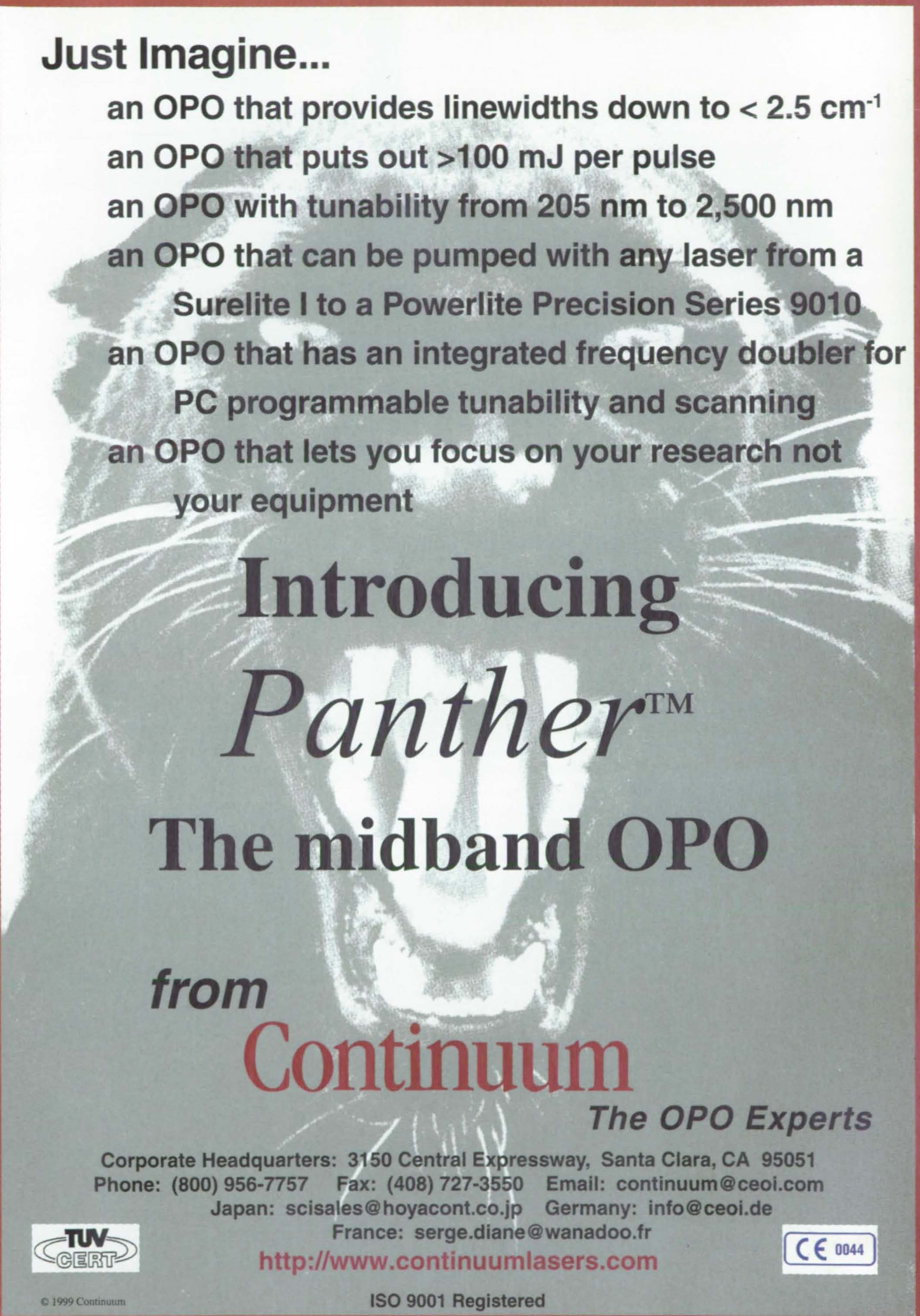
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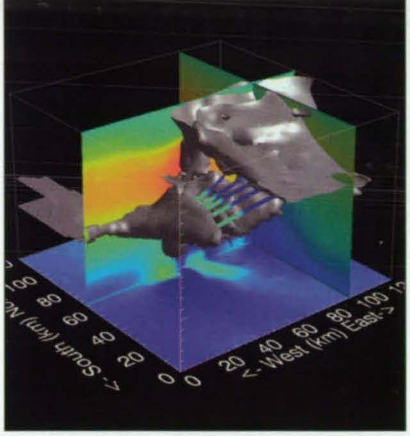

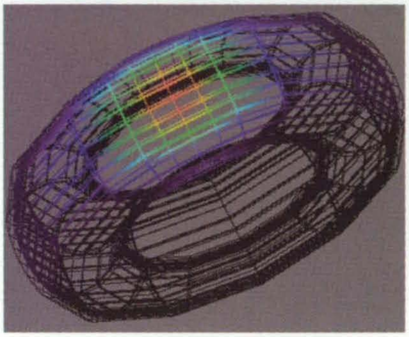

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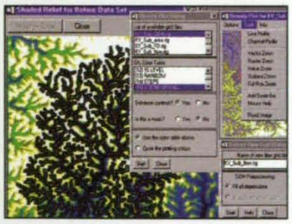

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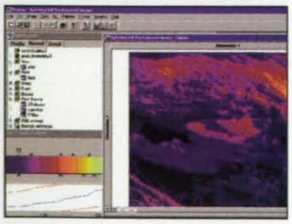

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