NASA Tech Briefs

Official Publication of the
National Aeronautics and
Space Administration
February 1993 Vol. 17 No. 2

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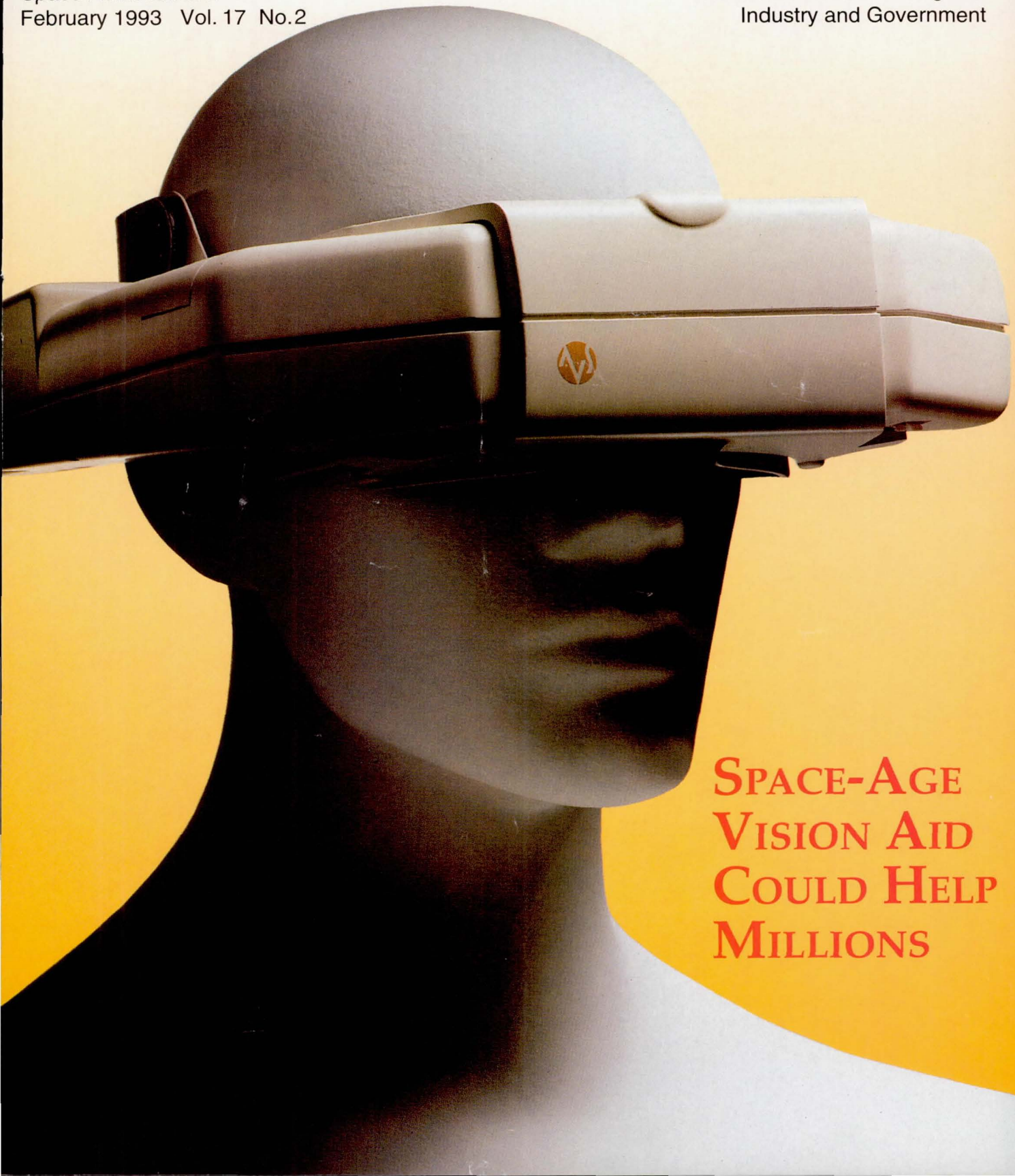

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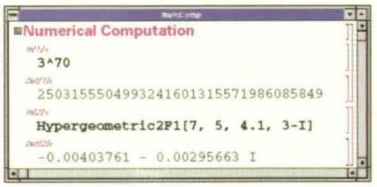
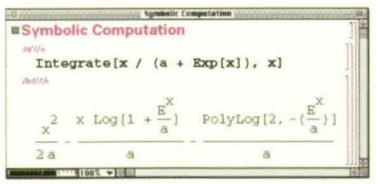
Basic function: Integrated environment for numerical, symbolic, graphical computation, interactive programming.

Users: Scientists, engineers, mathematicians, programmers, financial analysts, students. Over 150,000 worldwide. Includes all 50 largest U.S. universities.

Numerical computation: Arbitrary-precision arithmetic, complex numbers, special functions (hypergeometric, elliptic, etc.), combinatorial and integer functions. Matrix operations, root finding, function fitting, Fourier transforms, numerical solution of differential equations, function minimization, linear programming.

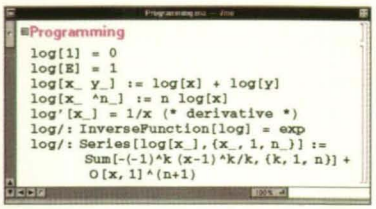


Symbolic computation: Equation solving, symbolic integration, differentiation, power series, limits. Algebraic operations, polynomial expansion, factorization, simplification. Operations on matrices, tensors, lists, strings.



Graphics and sound: 2D, 3D plots of functions, data, geometrical objects. Contour, density plots. 3D rendering with intersecting surfaces, lighting models, symbolic descriptions. Color PostScript output, combining and labeling, publication quality graphics, animation (most versions). Sound from waveforms and data (most versions).

Programming: High-level, interactive, symbolic language. Procedural and functional programming constructs. Transformation rules and pattern matching. Fully compatible on all platforms. No built-in limitations on computation size.



External interface: Input of data (numbers, records, text) from files, programs. Output in TeX, C, Fortran, PostScript. Calling of external programs and functions. General *MathLink*® interprocess communication mechanism.

User interface: Electronic book interactive documents mixing text, graphics, animations, calculations. Graphics, animation, sound interapplication compatibility. Style sheets, hierarchical outlining. Computation kernel can run on remote computer (most versions).

Additional material: Journal, newsletters, more than 30 books. Add-on packages, free *MathSource*™ electronic resource.

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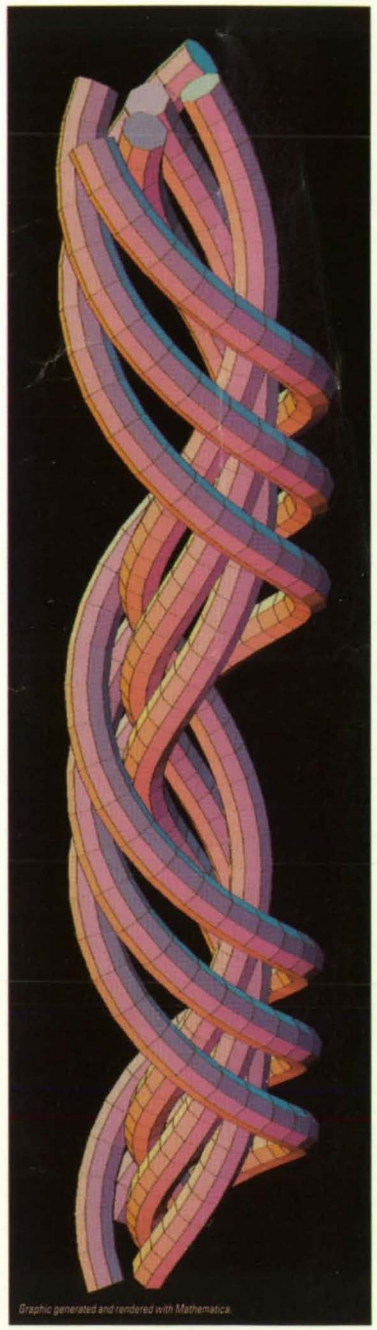
Graphic generated and rendered with Mathematica.

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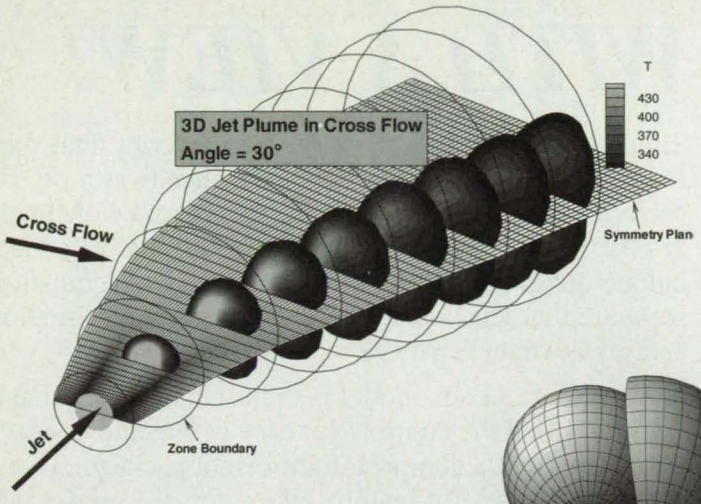

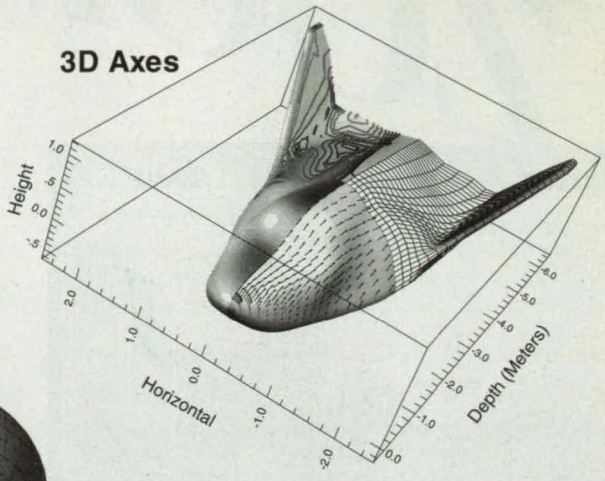

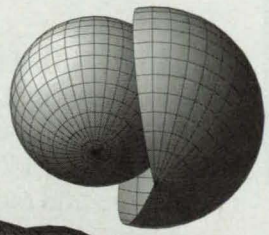

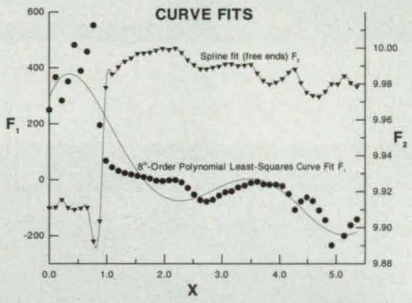

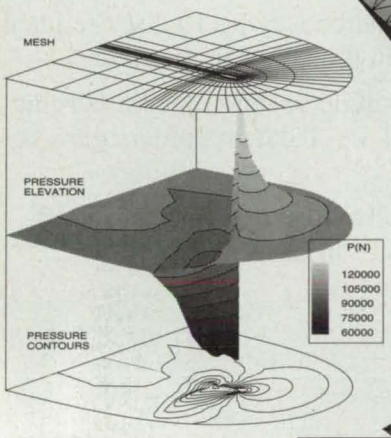

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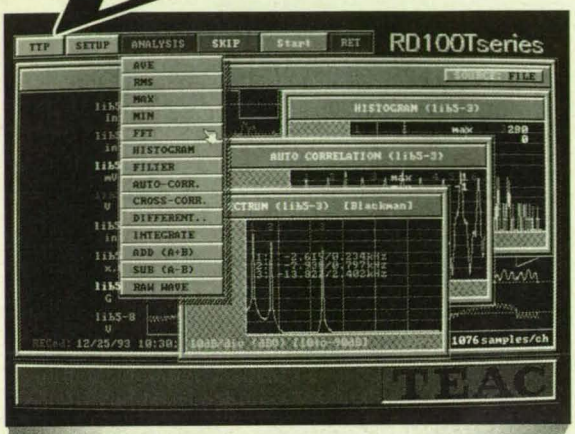

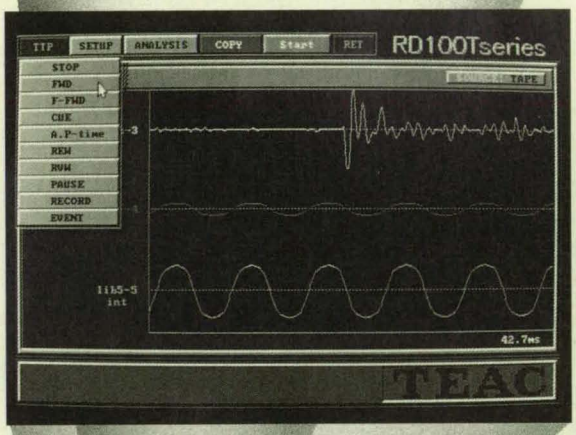

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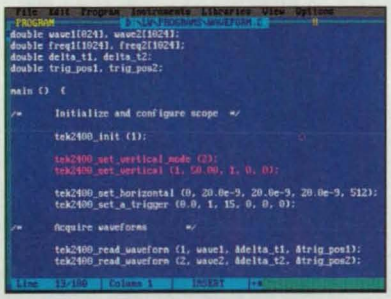

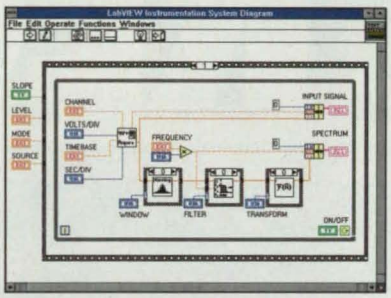

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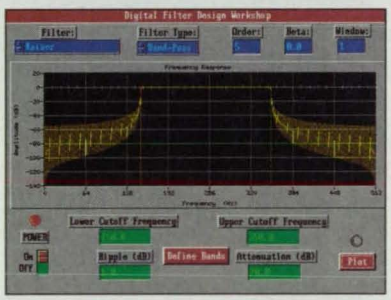
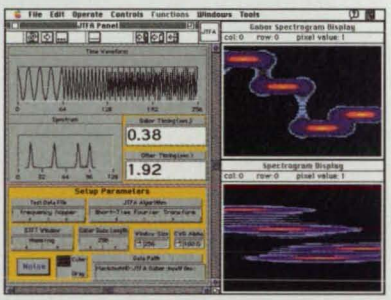
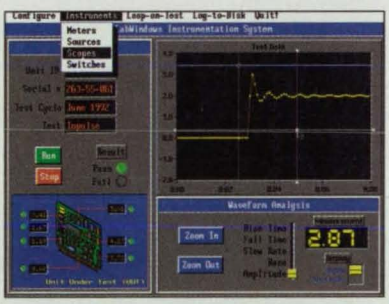
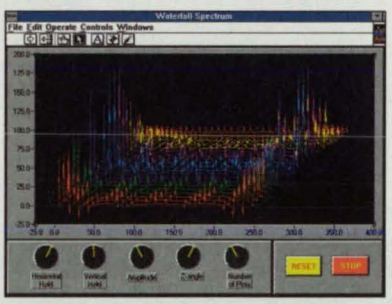




DSP • Statistics • Linear Algebra • Filters • Windows

PRESENTATION





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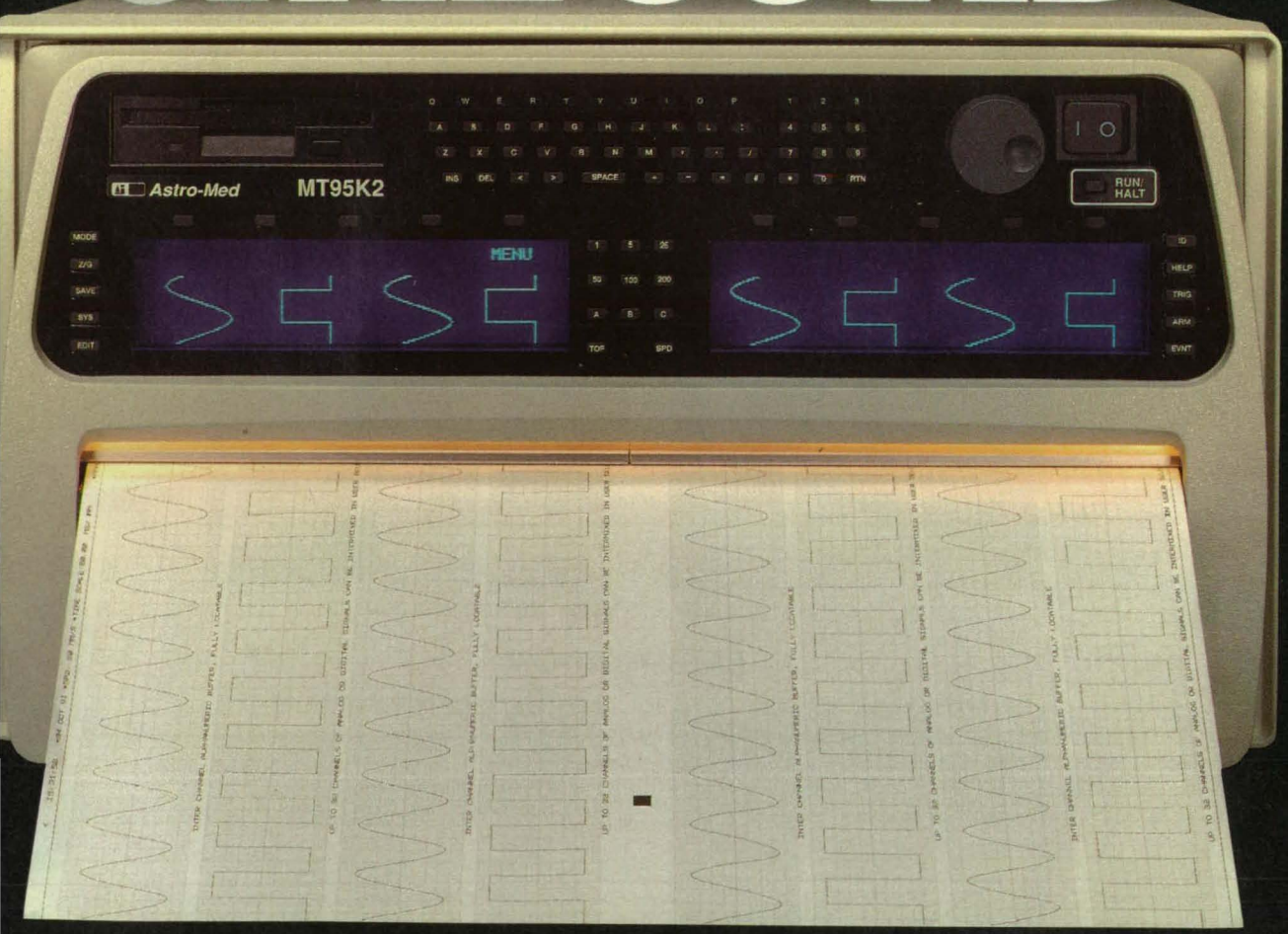

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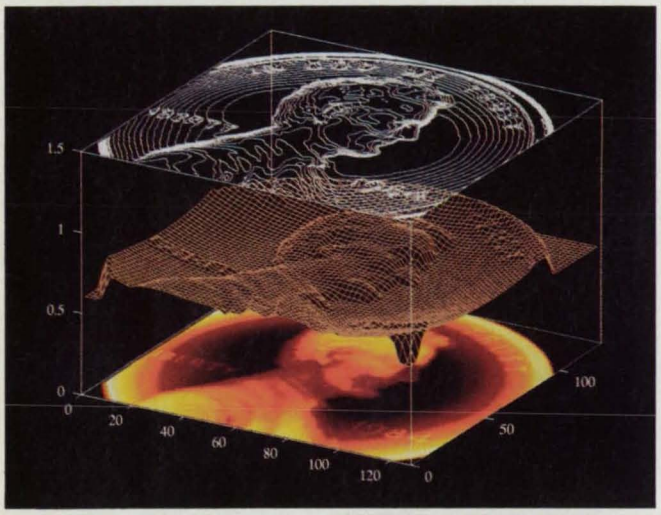
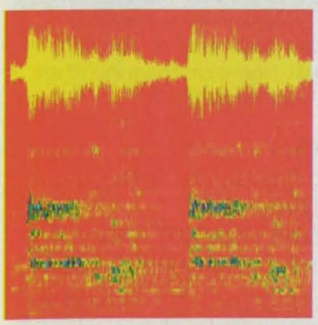


Three views of the surface height of a penny show user customizable object-oriented graphics in MATLAB 4.0. Data courtesy of NIST.

Combine advanced visualization with the powerful computation of MATLAB, and gain new insight into your most challenging problems.

The MathWorks introduces MATLAB 4.0

MATLAB 4.0 blends visualization techniques and numeric computation into a seamless interactive environment that redefines how you can solve complex problems. You can analyze data numerically and visually, simulate models and see the results immediately, or explore ideas and test them interactively.



Spectrogram of Handel's Hallelujah Chorus, *computed and displayed with MATLAB 4.0 and the Signal Processing Toolbox.*

More than meets the eye

MATLAB 4.0 provides engineers, scientists, and other technical professionals with an extensive library of built-in computational tools, combined with a powerful fourth-generation language.

As a result, MATLAB offers the convenience of a pre-packaged application program and the extensibility and flexibility of a high-level language. Much easier to use than Fortran or C, MATLAB yields tremendous gains in productivity and creativity—for over 100,000 users worldwide.

MATLAB® 4.0
Picture the Power

New feature highlights

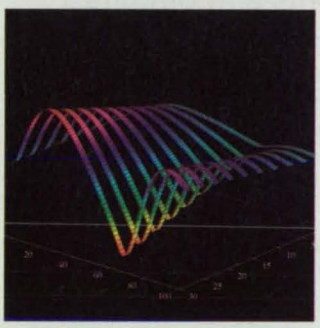
With our flexible new object-oriented Handle Graphics™ system, you can customize practically every attribute of your plots. New graphics capabilities include:

- *3-D shaded color surface graphs*
- *3-D contour plots*
- *3-D data trajectories*
- *Image display*
- *Light sources*
- *Surface rendering*
- *Animation*

Beyond the visual

Other new features in MATLAB 4.0 include:

- *Over 100 new functions*
- *Sound output*
- *Graphical user interface (GUI) toolkit*
- *Flexible file I/O*
- *Integrated debugging environment*
- *Sparse matrix support*
- *Ability to call MATLAB as a computation engine from C and Fortran programs*
- *Enhanced on-line help*
- *New, expanded documentation*
- *Faster interpreter and graphics*



Frequency responses of a family of control systems, modeled, simulated and visualized in MATLAB 4.0.

SIMULINK:™ Expanding the uses of MATLAB

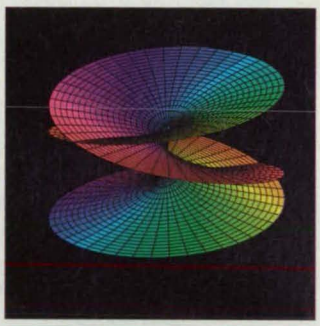
Add SIMULINK to MATLAB 4.0 and you can perform dynamic system simulation of nonlinear models in a graphical, mouse-driven environment.

Powerful, versatile toolboxes

Application toolboxes, designed and written in MATLAB by world-class experts in their fields, provide specialized solutions. They're based on MATLAB, and they combine prepackaged functionality with an open systems approach that allows you to see the algorithms and to modify them to suit your needs.

The comprehensive MATLAB toolbox family includes:

- *Signal Processing*
- *Control System Design*
- *Robust-Control Design*
- *Mu-Analysis and Synthesis Design*
- *System Identification*
- *Neural Networks* NEW
- *Nonlinear Optimization*
- *Spline Analysis*
- *Chemometric Analysis*



Riemann surface of the complex cube root function shows the capability of MATLAB 4.0 for mathematical visualization.

MATLAB 4.0 is available now for Sun SPARCstations, and will soon ship for other standard MATLAB platforms including: 386/486 PCs, Macintosh, HP/Apollo, DECstation, VAX/VMS, IBM, Silicon Graphics, Convex, & Cray.

For more information, please call us at (508) 653-1415.

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Volume 17 Number 2

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FEATURES

TECHNICAL SECTION

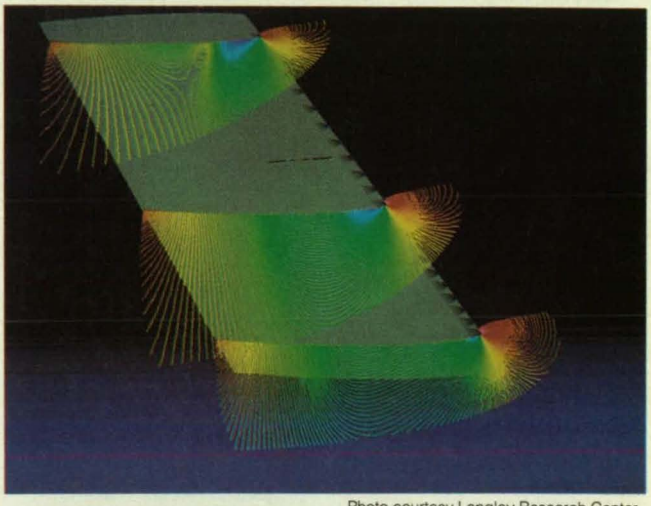
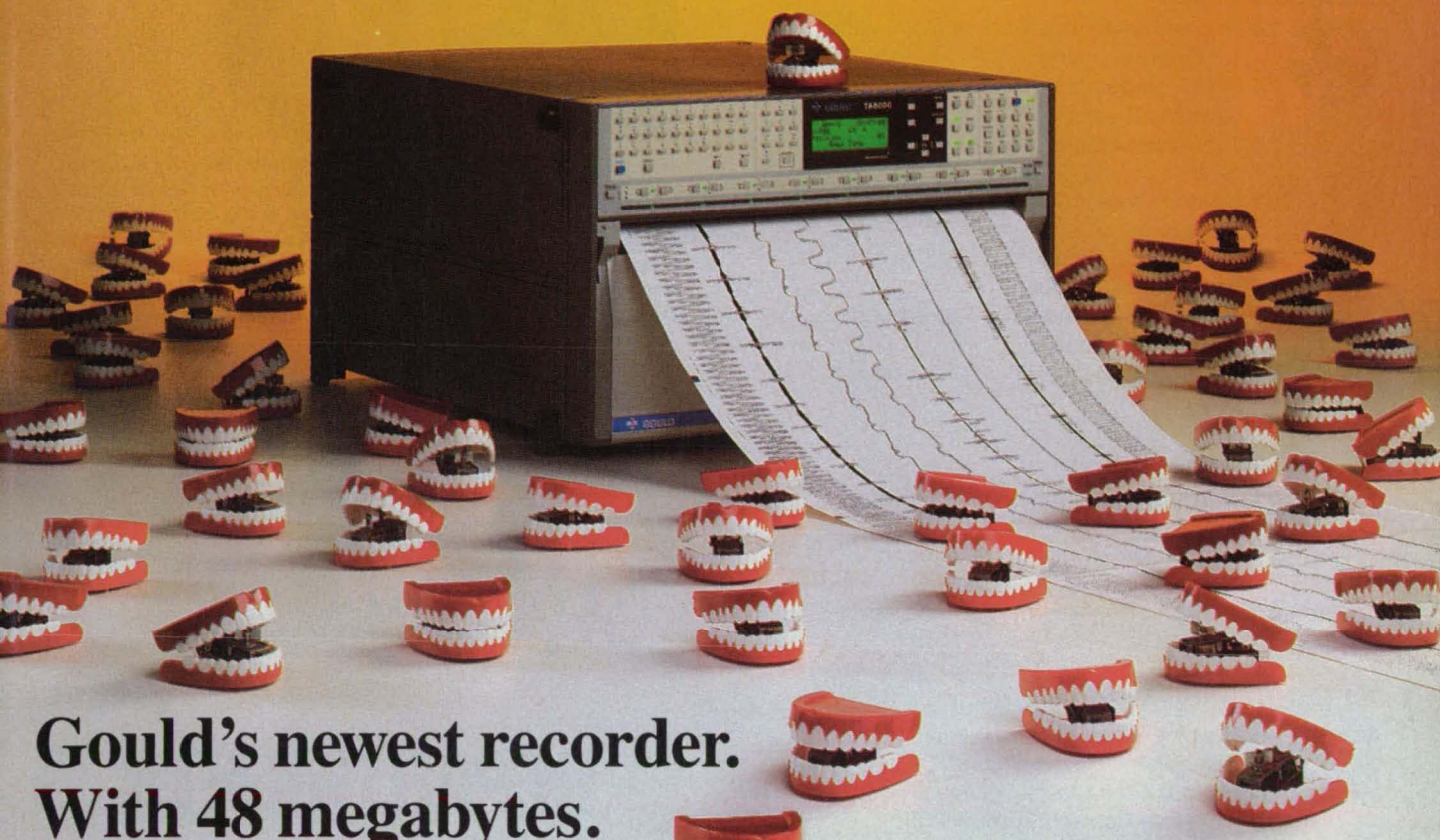


Photo courtesy Langley Research Center

TAWFIVE, a CFD modeling program developed at Langley Research Center, predicts transonic flow over the wing of an M6 ONERA aircraft. See the tech brief on page 73.

(Continued on page 8)

GOULD
Electronics



Gould's newest recorder. With 48 megabytes.

The new Gould TA5000 offers an unprecedented memory capacity that's bound to make you smile. This is the only 24-channel recorder with a 15" thermal array printhead and up to 48MB of on-board memory. Which means you can record over longer periods of time *and* increase your sample rate to 250kS/s on all channels. So you're guaranteed the bandwidth you need for comprehensive analysis.

And when we say the TA5000 has the flexibility to record what you want, how you want it, we're hardly making idle chatter. Modular design allows for easy configuration or expansion for 8, 16 or 24 channels. The widest selection of the most accurate signal conditioners are yours to choose from. And our single, thermal array printhead lets you position traces anywhere in full overlap or discrete channels – with no blank zones.

In addition, Gould's Micropulsing™ technology provides reliable operation and the resolution you need to see your signals clearly, at every frequency and chart speed.

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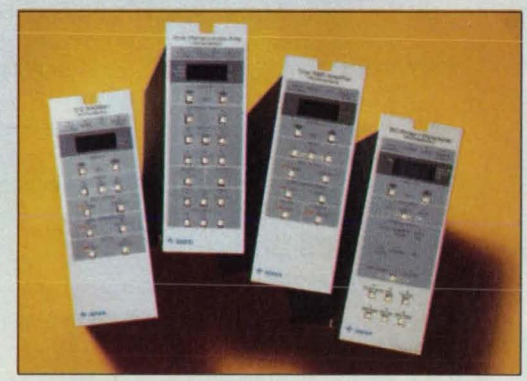

NTB 2/93

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Contents *(continued)*

The Mechanical Response Tissue Analyzer (MRTA), incorporating technology pioneered at Ames Research Center, uses vibration to measure bending stiffness in the joints of astronauts, whose bone strength significantly changes with space travel. The MRTA, which has spinoff potential in the fitness and medical fields, is one of hundreds of innovative products displayed at the Technology 2002 conference in December. See our show report on page 14.

ABP CBPA

DEPARTMENTS

on the cover:

A low vision system developed with NASA's aid compensates for the specific limitations of a wearer's vision and also permits manipulation of magnification and focus to suit different tasks. The system offers help to those with chronic vision impairments, caused by conditions such as macular degeneration or diabetic retinopathy, that cannot be corrected with eyeglasses, medicine, or surgery. Turn to NASA's Innovators, page 20.

Photo courtesy Wilmer Eye Institute

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SCIENCE/SCOPE®

Corporations in Great Britain now will be able to transmit data via rooftop satellite dishes instead of using their current terrestrial-based telecommunications systems. It's the result of British Telecom's new satellite business network using Hughes Aircraft Company's Very Small Aperture Terminal technology. The satellite service provides business customers with high-quality data circuits to potentially thousands of remote sites throughout the U.K. and Europe. Supported applications include database access and downloading, reservations, stock transactions, credit card verifications, electronic mail, data broadcast, and business television.

To ensure the smooth flow of transportation on crowded freeways and highways, Hughes is incorporating many of its existing advanced technologies into an electronic toll road system. This system can perform active, simultaneous, multi-lane communications with vehicles through a single, above-the-road gantry, maintaining continuous, reliable toll collection and enforcement. Among its other communications applications, the Hughes system can also help reroute cars and give traffic advisories. The Hughes electronic toll road system sets the standard for advanced two-way vehicle-to-roadside communications systems.

Inexpensive aluminum clips help trim nearly $200,000 from the cost of a satellite. The clips were designed and used by Hughes to hold major structural elements of the new HS 601 communications satellites together. Previously, the satellites were bonded together, a time-consuming process because of the close tolerances involved and the approximately one week required for each bond to cure. With about 250 structural joints per satellite, the clips save nearly $200,000 in hands-on labor per spacecraft. Another benefit of the technique is the elimination of bond testing. Verifying the torque, a much faster process, is all that's required with the new process.

TV viewers in all parts of the country are getting more and more regional coverage, as networks are increasingly turning to satellites for maximum flexibility. Hughes has been a major player in Cable TV distribution, and now will enter into the broadcast network market by teaming with CBS. CBS will purchase 12 transponders on two new Hughes satellites. On a given Sunday afternoon, CBS supplies affiliates with as many as 16 different football game feeds. This enables viewers to get programming most suitable to their interests. CBS began converting from land lines to a satellite-based distribution system in 1982, and now almost all affiliates have their own earth station.

A new audio and video entertainment and communications system will soon enable passengers on Northwest Airlines' jumbo jets to play video games, select movies, make phone calls, receive flight information and order merchandise while aloft. Called Worldlink by the airline, the interactive system will be available at every seat in the aircraft to provide a new level of in-flight passenger entertainment and conveniences. It will be installed on Northwest's Boeing 747s beginning this fall under a $70 million contract with Hughes. The contract also marks the entry of Hughes into the business of airborne merchandising; the company will establish merchandising centers around the world to maintain inventories of in-flight sales items and fill customer orders.

For more information write to: P.O. Box 80032, Los Angeles, CA 90080-0032

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ABP BPA

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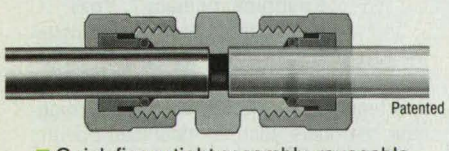

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- Quick finger-tight assembly, reuseable
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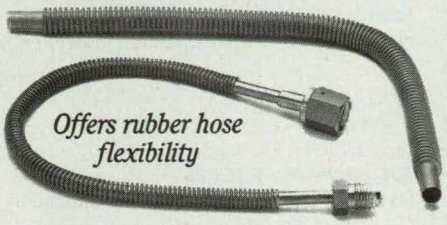
- 1/16″ to 1-1/2″
- Use with undersize tubing
- Variety of configurations
- Brass & 316 stainless steel
- Temperatures to 450°F (232°C)

Flexible Tubing



- 321 stainless steel construction
- Compressible by 20%, extendable by 50%
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- 1/4″ to 1-1/2″ tube O.D.
- Nominal lengths 1″ to 36″

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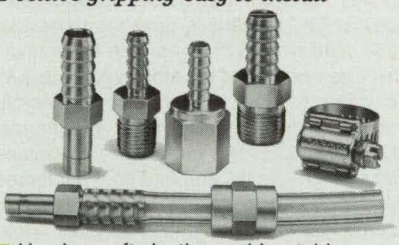
- 6″ lengths

Hose Connectors

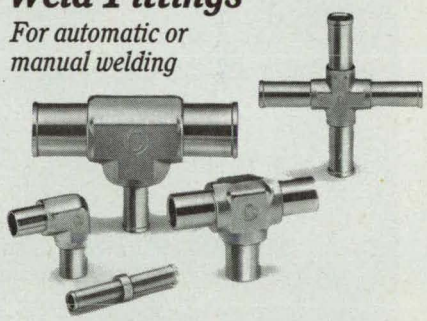
Positive gripping-easy to install



- Used on soft plastic or rubber tubing
- NPT & Tube Adapter ends
- Hose clamps for safety
- Reuseable
- 316SS and brass
- 1/8″ to 3/4″

Weld Fittings

For automatic or manual welding



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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:

Large-Area Projection Liquid-Crystal Video Display System With Inherent Grid Pattern Optically Removed

(US Patent No. 5,161,027)

Inventor: **Hua-Kuang Liu**, Jet Propulsion Laboratory

A small, low-cost system projects a large, bright television image onto a screen. Eliminating the need for a large cathode ray tube, the system employs a miniature liquid crystal array driven by video circuitry to produce a pattern of transparencies corresponding to a television image. Light is directed against the rear surface of the array to illuminate it, while a projection lens in front of the array projects the image of the array onto a large screen. Grid lines in the array are eliminated by a spatial filter comprising a negative of the grid's Fourier transform.

For More Information Circle No. 801

Low-Toxicity, High-Temperature PMR Polyimide

(US Patent No. 5,171,822)

Inventor: **Ruth H. Pater**, Langley Research Center

Ms. Pater has developed a high-temperature polymerization of monomer reactants (PMR) system that exhibits better processability, toughness, and thermo-oxidative stability than PMR-15, with lower toxicity. The flexibility of the ether linkage in 3,4'-oxydianiline, the material's key monomer reactant, provides improved toughness. Called LaRC-RP46, it is readily processed into a high-quality, graphite fiber reinforced composite with excellent reproducibility and can be used as a high-performance adhesive or molding.

For More Information Circle No. 802

Quantum-Well, Beam-Deflecting, Surface-Emitting Lasers

(US Patent No. 5,159,603)

Inventor: **Jae H. Kim**, Jet Propulsion Laboratory

Recent advances in surface-emitting lasers (SELs) have stimulated interest in such potential applications as monolithic 2D arrays, optical interconnects in very-large-scale integrated circuits, optical parallel processing, and optical neural networks. Mr. Kim's SEL offers higher efficiency and output power and lower threshold current density than conventional SELs, while being compatible with other optoelectronic devices and conventional monolithic IC fabrication techniques. The new SEL has a pair of vertical oscillator mirrors and integrated 45° beam deflectors formed in parallel grooves by tilted ion beam etching from a broad-area multilayered wafer.

For More Information Circle No. 803

Bar-Holding Prosthetic Limb

(US Patent No. 5,163,966)

Inventors: **William E. Norton**, **Thomas W. Vest**, **Jewell G. Belcher**, and **James R. Carden**, Marshall Space Flight Center

A prosthetic limb for below-the-elbow amputees improves a user's ability to perform heavy duty tasks, particularly to lift and manipulate horizontal bars or tubes such as the bar on a chainsaw. More affordable, durable, and comfortable than current prostheses, the limb features a removable end effector that is offset from the body and has C-shaped slots to receive a horizontally-oriented bar. A pair of semicircular gripping members are pivotally mounted near the closed end of the slots and biased closed by a C-shaped leaf spring.

For More Information Circle No. 804

High-Speed Magneto-Resistive Random Access Memory

(US Patent No. 5,173,873)

Inventors: **Jiin-Chuan Wu**, **Henry L. Stadler**, and **Romney R. Katti**, Jet Propulsion Laboratory

The inventors have constructed high-density, high-speed, nonvolatile, and radiation-hard MRAM elements. A sandwich of magnetizable, ferromagnetic films surrounds a magneto-resistive film that is sensitive to the magnetizable layers. Data is stored by changing the resistivity of the magneto-resistive layer by altering the magnetization of at least one of the magnetizable layers. The magneto-resistive film can be constructed of a high-resistivity, high-magneto-resistive material capable of higher sensing current—permitting higher read voltages and thereby faster read operations.

For More Information Circle No. 805

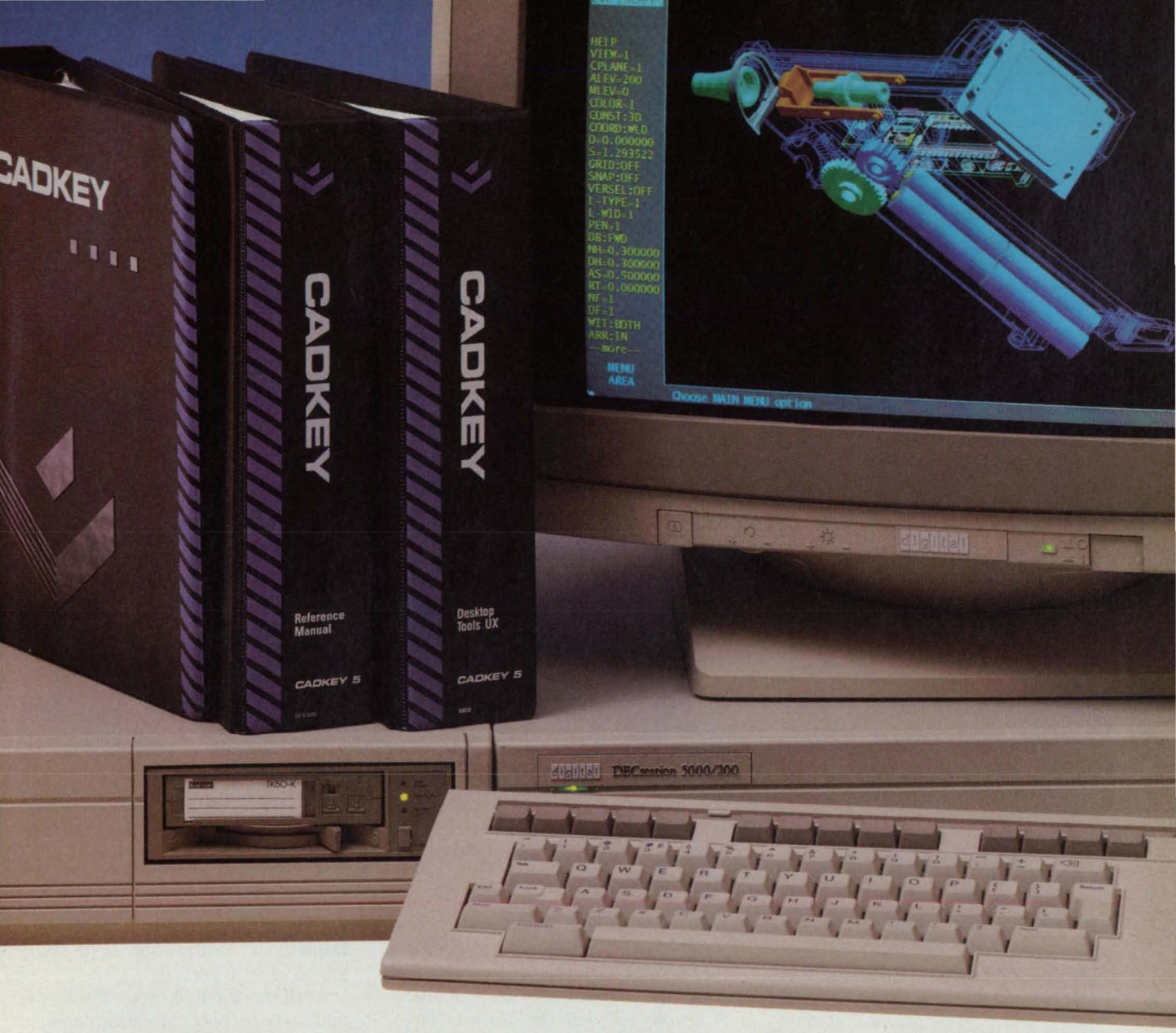
Method Of Characterizing Residual Stress In Ferromagnetic Materials Using A Pulse Histogram Of Acoustic Emission Signals

(US Patent No. 5,164,669)

Inventors: **Min Namkung**, **Peter W. Kushnick**, **William T. Yost**, and **John L. Grainger**, Langley Research Center

A novel method and apparatus characterizes residual uniaxial stresses in ferromagnetic members such as steel load-bearing structural beams and girders, wheels, and gears. Use of both MAC (magnetoacoustic) and MAE (magnetoacoustic emission) measurement circuit means enables distinguishing between stresses resulting from compression or tension forces.

For More Information Circle No. 806



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For More Information Circle No. 558

Editorial Notebook

Technology Transfer Takes Center Stage

They came from every state in the Union, from companies large and small, from an incredibly wide range of industries. Nearly 6000 engineers and executives came to Technology 2002 in Baltimore to listen to and meet top-level dignitaries, visit some 60,000 square feet of exhibits, and hear 120+ papers presented in the symposia and workshops, making Technology 2002 the largest tech transfer conference and exposition ever held.

Technology 2002 was the centerpiece of National Technology Transfer Week, and the President's National Technology Initiative and MIT's Entrepreneurial Tech Transfer Conference were the figurative bookends. Maryland governor William Donald Schaefer officially opened the week with a ribbon-cutting on Monday evening, November 30. Maryland senator Barbara Mikulski keynoted the first day's plenary session and was joined by the secretaries of Commerce, Barbara Franklin, and Energy, James Watkins, and NASA administrator Daniel Goldin—which gives you an indication of the importance of Technology Transfer at the highest levels of government.

Sam Iacobellis, COO of Rockwell International, was Wednesday's Plenary Speaker. And that evening, Norman Augustine, Chairman and CEO of Martin Marietta, within ten days of having acquired GE Aerospace for some $3 billion and doubling the size of his company, still took the trouble to keynote the Technology Transfer Awards Dinner. I had to follow Norm to the podium to speak. Talk about a tough act to follow...it'd be easier following Arnold Schwartzenegger in a body beautiful contest.

Fortunately, I had an ace in the hole. The year before, at the Technology 2001 Awards Dinner, I had presented an award for Excellence in Technology Transfer to Advanced Interventional Systems of Irvine, CA. They had taken excimer laser technology pioneered at NASA's Jet Propulsion Laboratory and developed a laser angioplasty technique. We wrote about the company and award in *NASA Tech Briefs'* "Mission Accomplished" column. I received the following letter after we published that story, which I read to this year's dinner audience:

Hello Bill,

Did you know you are in the business of improving peoples' livelihoods, and probably saving lives?

I've been suffering with a coronary artery problem for almost a year. Specifically, an extensive (about 8 cm) occluded right coronary artery. All standard angioplasty techniques were judged to be ineffective to remedy my condition.

As I was reading my March 1992 issue of NASA Tech Briefs, *the article on page 108 jumped out at me. "Mission Accomplished" described the new excimer laser technology, and referenced Advanced Interventional Systems Inc., who manufactured such a system for angioplasty.*

A call to the manufacturer disclosed a system presently (then) being installed in a Denver hospital. On subsequent visits to my physician and cardiologist, I gave them a copy of the article. On June 3, I was the seventh patient to undergo successful laser angioplasty at St. Anthony's Central.

Thanks to your article, I am now living a fuller, more productive, and much more pleasant life.

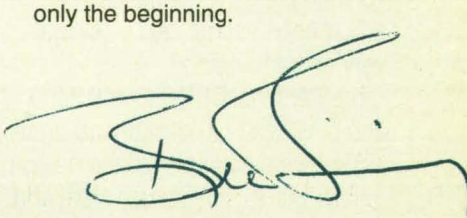
Kindest regards,
Robert A. Botos
Hewlett-Packard Co.

As I told the audience, this letter made the hair stand up on the back of my neck. I shared it with our staff and almost anyone else who would listen to me. And that evening, I didn't just share the letter with everyone at the dinner, I'd "salted" Bob and his wife, Darlene, in the audience so he could talk to us all in person.

Bob Botos tells awards dinner audience how a Mission Accomplished story changed his life.

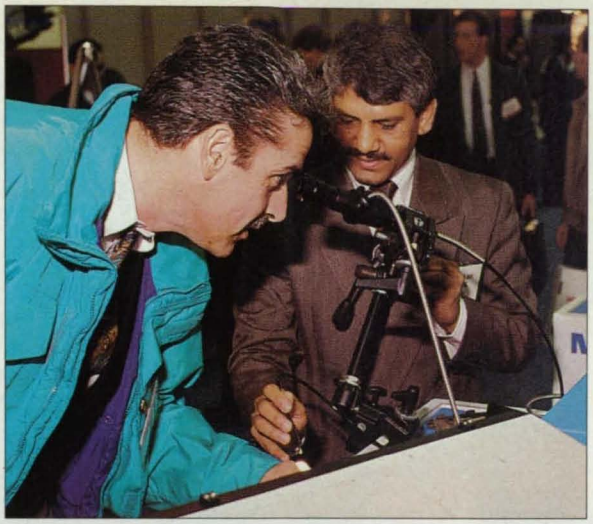
Well, he brought down the house and saved my public speaking career in the bargain. He also helped bring home to us the very real and immediate benefits that accrue from the work we're engaged in...from the inventors and writers, through the publishers, to you who read about the technology and turn it into products and processes that make life better for us all.

The following pages contain images from Technology 2002 as well as excerpts from key speeches. Thanks for being part of the process...and this year, come to Technology 2003 December 7-9 in Anaheim, CA...this is only the beginning.



Bill Schnirring

From left: Technology 2002 general chairman James R. Thompson, Maryland governor William Donald Schaefer, and NASA Tech Briefs publisher Bill Schnirring cut the ceremonial ribbon opening National Technology Transfer Week (Nov. 30 - Dec. 5, 1992).



Among the private sector exhibitors was Machida Inc., which showcased remote visual inspection equipment.

Cybernet Systems Corp. demonstrated a force-reflecting robotic handcontroller developed through NASA's Small Business Innovation Research (SBIR) program.

Above: The Army Aeromedical Research Lab, one of over 60 federal labs that exhibited at Technology 2002, displayed advances in life support and vision technology. Right: Technology 2002 attracted nearly 6000 attendees from across the nation, making it the largest technology transfer conference and exhibition ever held.

The following are excerpts from speeches at the Technology 2002 conference held December 1-3, 1992 in Baltimore, MD.

Putting Technology To Work For America

Daniel S. Goldin, NASA Administrator

One hundred and fifty years ago, the French social observer Alexis de Tocqueville came to our shores—to this nation that literally invented itself—to see what made its people different from those of the Old World. He wrote, "America is a land of wonders, in which everything is in constant motion and every change seems an improvement. ...No natural boundary seems to be set to the efforts of man; and in his eyes, what is not yet done is only what he has not attempted to do."

Today, America is still "in constant motion." The question for our nation is "Are we still bold? Are we still willing to risk and attempt the seemingly impossible?"

America has to get bold again. If we're going to shape our own destiny, rather than have the future shape us, we've got to take some risks and make some investments. For everyone who's worried about the American economy being stuck in a rut, it's vital that we remember the tremendous power of technology to produce growth.

During the days of Apollo, America reigned supreme in the world of technology because we were on the cutting edge of it in space. Over the decades, NASA has generated at least 30,000 known spinoffs from its technology, creating new products and industries worth billions that have changed the face of America.

America created a large federal research effort to fight the Cold War, and we fought it well. But now it's over. America's needs have changed, and the federal government must respond to those needs by putting the Cold War technology base to work for our economy. There is a peace dividend beyond the reduced threat of war and lower defense budgets, important as they are. There is a technology dividend, as we multiply the government's technology transfer efforts.

To dramatically improve the way NASA approaches both the development and transfer of technology and the commercialization of space, we have created the Office of Advanced Concepts and Technology. One of the primary functions of this office is to be NASA's "front door" to businesses who want NASA's help and expertise, or who have new ideas and technologies for us. Our new office will provide one-stop shopping for technology customers and suppliers—whether they are businesses, or universities, or even program offices inside of NASA.

For example, say a small business that makes thermoplastics asks for our help in developing a new manufacturing technique. We could develop a partnership whereby the firm receives technical expertise that improves their product line, while NASA receives new lightweight materials for its own use at a lower cost. Such a win-win approach would enhance NASA's programs, yield more value for the taxpayer, and improve the ecomony by helping the private sector to become more competitive.

The Office of Advanced Concepts and Technology will also set up new mechanisms and improve existing mechanisms to aggressively transfer technology into America's economy. We will do this by seeking the input of the technology user community to figure out the best transfer mechanisms, whether by reading publications like *NASA Tech Briefs*, regional tech transfer centers, Centers for the Commercial Development of Space, cooperative research agreements, or actually coming to work in our labs and other facilities.

But let me stress: customer need must govern the type of tech transfer mechanisms we devise. If it's not user friendly, it's not going to maximize the benefit to the American economy. The true test of NASA as a jobs generator is not how many people are working *for* NASA, but how many people are working *because* of NASA—because of NASA's ability to reach into the future to bring back answers for today.

I believe NASA can be a leading force in our society. The discoveries and technology of the space program provide inspiration for our minds and souls, hope for our future survival, opportunity for renewed prosperity, and catalytic action for peace through international partnerships. NASA can do all this and more if America continues to be bold and keeps reaching for the stars.

Cooperation Must Be Our Hallmark

The Honorable Barbara A. Mikulski, U.S. Senator

There are those who look at the end of the Cold War and see enormous opportunity. I share that vision, and believe that our greatest strategic threats are not military, but economic. And our economic strength will rest largely on our successful development of technology, the transfer of technology, and making sure that our young people have the education and skills to put that technology to productive use.

One of our concerns over the years has been that federal agencies did not cooperate with each other. It was a source of great concern to us in Congress that often it is the very culture of our institutions that impedes our development. Many government agencies are based on a large, hierarchical, trickle-down approach. I would encourage people working in federal agencies to stop worrying about turf and power structures and start focusing on our mission.

I want to be part of a Congress that streamlines its workings and cooperates effectively with the federal agencies and laboratories. The spirit of cooperation needs to be a hallmark of the rest of this century. Government spending should be

organized not to stimulate consumption but to stimulate growth and to make long-term sustainable commitments. I know that for those of you in government, one of the concerns that you have regarding appropriations is never knowing if your project is going to be here today or gone tomorrow. I share that frustration with you. We need to encourage a review of the federal tax and regulatory policy to create a climate conducive to investment in technology. We want pro-growth: that means reinstating the investment tax credit for our private sector. At the same time, we need to look at anti-trust laws created for 19th century monopolies rather than for a 21st century economy which impede potential alliances between government, the private sector, and universities.

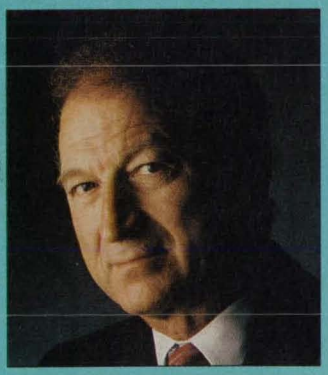
I also want to make sure that if you invent an idea, you get to keep it. One of the vital things we need to do, both in our own country and in our trade negotiations, is to protect American intellectual property.

We need visionary entrepreneurs, world-class universities, and a government at all levels that is a catalyst and a facilitator. We also need a national navigational chart of where we're going in the 21st century. I believe that if we focus on developing critical technologies, this will afford young investigators the opportunities to pursue research. At the same time, our culture needs to shift its focus not only to the pursuit of ideas, but to the development of the ideas into technology, and of the technology into products.

Five Keys To Economic Strength

Sam F. Iacobellis, Executive Vice President and Chief Operating Officer, Rockwell International Corp.

The term "technology transfer" encompasses far more in our country than in many other industrialized nations where government and industry collaboration is the rule, rather than the exception. National security and US competitiveness were the twin horns of the technology transfer dilemma during the Cold War. While our aerospace and defense industries were creating a technology "mother lode," our ability to use it was carefully managed—with national security as the first criterion.



Today, "technology transfer" is also used to describe a component of "conversion"—or the process of commercializing defense and aerospace technologies.

Indeed, our economic viability is highly dependent on the collective competitiveness of American enterprise in the global marketplace. And our ability to compete is in large part dependent on the job we do in maintaining and improving the nation's industrial base—not to mention our efforts in education, training, and capital investment.

But our nation cannot long endure without a reasonable level of defense spending to ensure our readiness for any military contingency and the continued development of technologies that can be converted into competitive, commercial products. NASA and DOD have been the lead horses in pulling much of this nation's high-technology cart. If DOD and NASA budgets are cut to subsistence levels that provide for little R&D and even less prototyping, who will supply the impetus and the resources required to develop anything like, for instance, the $61 billion semiconductor industry.

In fact, granted that the "peace dividend" should come out of defense, it is the aerospace industry into which part of it should be channeled, partly through increases in NASA's civil space, aeronautics, and science programs. This would provide the resources required to stay on the leading edge, to be competitive, and to avoid the technology gap that would be created by wholesale cuts in both defense and aerospace budgets—especially in the critical areas of R&D and prototyping.

With the foregoing points in mind, permit me to convert the key points I've raised into five recommendations that may serve as a starting point when the new Administration takes office:

First, I recommend that the process of conversion be approached in the context of preserving our industrial base and our technology leadership in the long-term, as well as the short-term, while at the same time acknowledging that attempts at "quick fixes" often don't work.

Second, I recommend that the downturn in the defense budget not be implemented precipitously, but that it be managed with an orderly build-down process over a reasonable period of time, and with the constant aim of preserving our technology leadership.

Third, the government should initiate programs that would keep the talent needed to move technology forward while inspiring our youngsters to pursue studies and, ultimately, careers in science and engineering.

Fourth—remembering that small firms sow technology seeds while large companies drive technology research, development and production—taxes on investment should be reduced, thus enhancing productivity, stability, "state of the art" manufacturing technology, and our competitiveness.

Fifth, begin implementing the Council on Competitiveness "Capital Choices" report.

I firmly believe that, if these recommendations are implemented, our nation will remain the strong and secure bulwark of economic and political freedom that it is today, and will continue to be the world leader in science and technology.

Tech Transfer Requires A Transfer of Minds

Norman R. Augustine, Chairman and Chief Executive Officer, Martin Marietta Corp.

Sometimes we forget how far we've come and how fast technology has changed our world. I recall a conversation a few years ago between my father, then 96, my son, 70 years younger, and myself. My son, an engineer, had been describing his work on the Manned Maneuvering Unit, the high-tech "backpack" that will enable an astronaut to maneuver in space while traveling nearly 18,000 miles per hour.

Out of curiosity, I asked my father what technological development had the greatest impact on his life as a youth. Pondering a few moments, he surprised us with the pronouncement:

"the tubular wick for oil lamps." He explained that these newly-designed wicks, due to their increased brightness, made it practicable to read and work effectively well into darkness back in his hometown high up in the Colorado mountains. Tubular wicks—a seemingly minor technological advance, yet one that had a profound impact on many people like my father, allowing them to live more fulfilling lives. And, as a testimony to the pace of technological progress, my father later in his life was to meet astronauts who had been to the moon.

As far as we've come, the challenge in the next few years will be to make technological innovation happen even more rapidly. With the world moving toward a truly international marketplace, we have to find ways to make our economy more productive. How do you do that when your industrial capacity is shrinking or, at best, treading water? You do it not so much by getting more work out of people but by getting people out of the work—at least the more mundane aspects of the work. And that means transferring technology—rapidly—from the lab to the marketplace. From the government to the private sector. From academia to the factory. From the space program to Earth programs.

Such a process is not easy, nor is it cheap. Speaking as a participant in corporate America, I can attest that the difficult global economic climate and the extraordinary pressure on management to produce short-term results is having a chilling effect on private-sector investment in R&D. In today's business world, the distant future too often means the end of the next fiscal quarter. As a result, many companies are cutting back on their R&D investments at a time when it is crucial to do precisely the opposite. In fact, the stock market favors those companies willing to spin off short-term cash and eliminate jobs...in short, willing to liquidate themselves.

The emphasis on "now, now" results, plus the increasing price tag for entering most fields of modern research, means that government research will be looked to more intently as the source of technological spin-offs. Despite the obvious need for a streamlined process for transferring technology from government to the private sector, some major impediments stand in the way.

For example, it is my opinion that when we talk about technology transfer, we are almost always talking about the transfer of *people*. That is, technology transfer is accomplished by "transferring" the minds of people. In most cases, you simply can't separate the technology from the people who know how to implement it. People *are* the bottom line.

Needlessly harsh conflict of interest rules severely restrict the movement of people from government to the private sector and vice versa. If we want the successful transfer of high technologies, we're going to have to allow people knowledgeable in the field to transfer with them.

Perhaps the ultimate "technology transfer" is the transfer of knowledge and hope and wonder that has resulted from our exploration of space. For in the space age it can truly be said that the most important space is the space between the ears. It is humbling to remind ourselves that all the integrated circuits ever built have a combined memory capacity not much greater than 50 human brains.

America's space program costs the average citizen less than 20 cents a day—roughly one-fourth of what we spend on potato chips—and we *can* afford an energetic, promising space program if that is what we wish. The issue is simply one of priorities—of national will—no more, no less. ❑

For information on ordering the complete proceedings or audiotapes of Technology 2002 symposia, turn to page 65.

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NASA's
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High-Tech Help For Low Vision

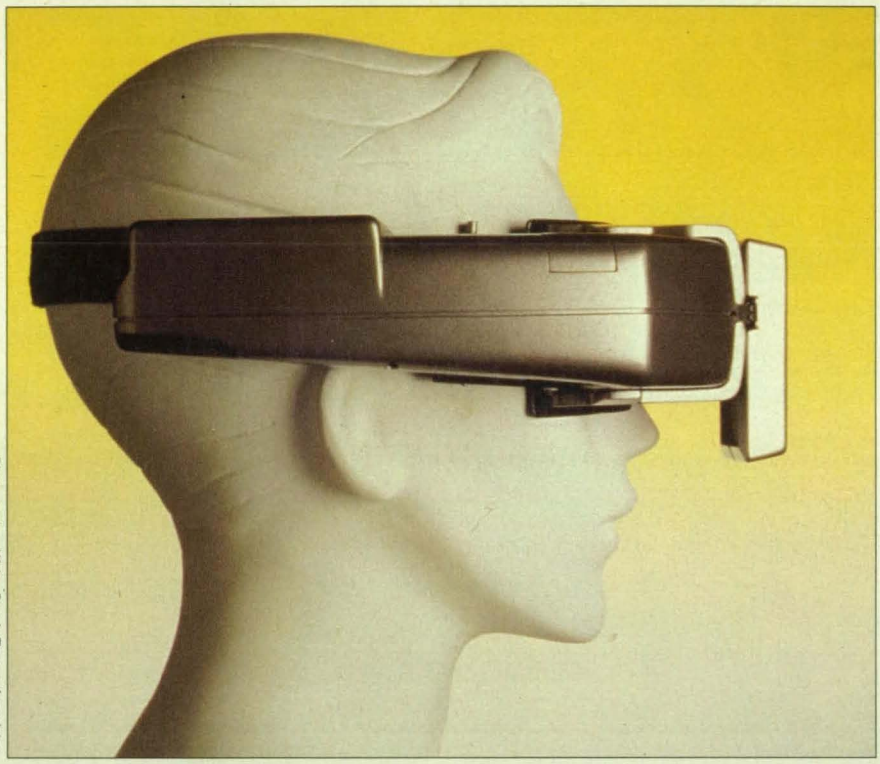

Photo courtesy Walter Dorwin Teague Associates

A device incorporating NASA image processing technology enables low vision sufferers to better accomplish everything from reading to walking to working on a computer. Worn as a head-mounted video display, it serves as a real-time electronic telescope and allows the user to "tune" the focus and magnification to specific tasks.

The invention is targeted to aid those with visual acuity ranging from 20/100 to 20/800. "It could help approximately 1.5 million people in the US and, since most of the diseases causing low vision are age-related, the number is expected to climb as the population ages," said Robert Massof, professor of Ophthalmology at the Wilmer Eye Institute of Johns Hopkins University Hospital and project founder. The low vision system recently earned the institute an Award for Excellence in Technology Transfer at the Technology 2002 conference in Baltimore, MD.

Low vision refers to chronic, disabling visual impairments resulting from diseases of the eye and optic nerve that cannot be corrected with eyeglasses, medicine, or surgery. The major causes of low vision are age-related macular degeneration, which is the leading cause of legal blindness in people over age 65, and diabetic retinopathy, the leading cause of legal blindness for those under age 65. Low vision can also result from glaucoma, inoperable cataracts, multiple sclerosis, and strokes.

The current technology for people with such impairments consists of magnifiers adapted from tools used by jewelers and stamp collectors. Often, the low vision patient must carry around a collection of such magnifiers to fit various circumstances. The search for a better solution began with a meeting between Johns Hopkins and NASA in October 1985.

"We had decided to launch a project to develop a general-purpose low vision aid that allows manipulation of an image to compensate for the specific limitations of a user's vision," said Massof. "That meant going to real-time image processing, in which we had no experience—so we turned to NASA."

They turned to Douglas Rickman, a Stennis Space Center geologist who had extensive experience with ELAS, NASA's software for analysis of remote sensing data such as Landsat images. "Although we couldn't use ELAS directly, because we need something that runs at video frame rates, we did derive concepts from ELAS for use in the low vision system—giving it both flexibility and the ability to grow," said Rickman, who has since moved to the Marshall Space Flight Center but remains NASA's manager of the low vision project.

While NASA worked on the image

Representing the Wilmer Eye Institute, Robert Massof (left) accepts an Award for Excellence in Technology Transfer from* NASA Tech Briefs *publisher Bill Schnirring at the Technology 2002 conference.

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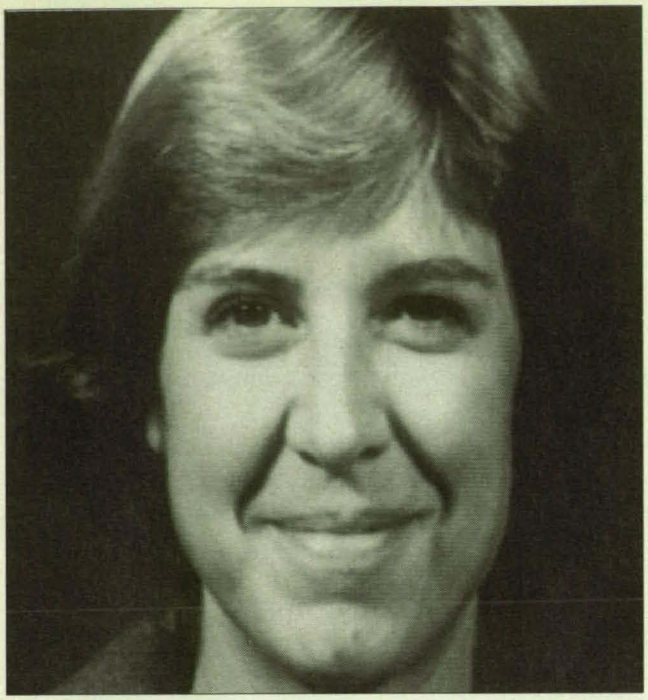

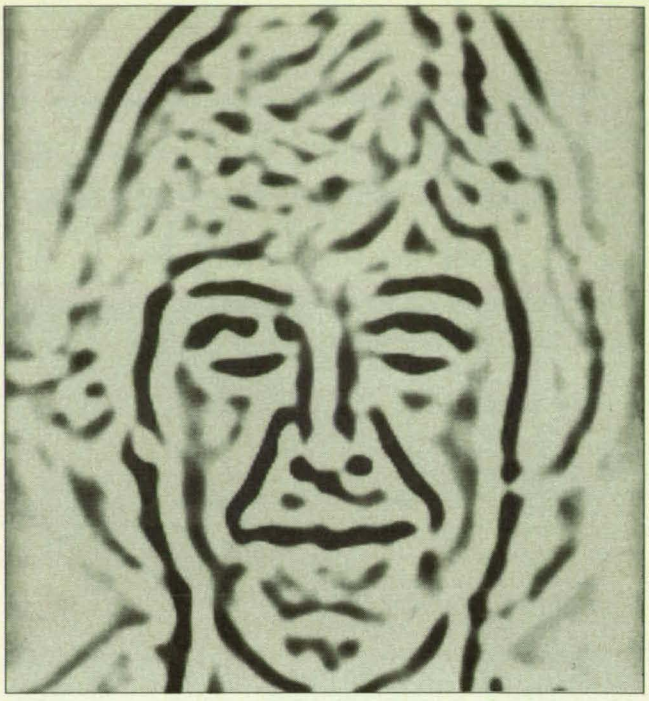

Photos courtesy Wilmer Eye Institute

Special filters in the low vision system enhance the contrast of facial features (see image at right) to make the face recognizable.

processing, Johns Hopkins pursued a headset to house the system. "We wanted a man-portable, battery-operated, head-mounted video display with a large field of view," Massof recalls.

The first commercial version, expected in about a year, will incorporate three cameras. Two, for normal binocular viewing, provide the equivalent of a 60-inch television screen viewed from a distance of four feet. The third, a cyclopian camera, enables variable magnification, focus, and zoom. Weighing approximately one pound, the head-mounted unit will accept input from a television or VCR, and can be connected to a computer monitor while providing a camera for the keyboard.

Massof anticipates the system to cost about $3000 retail. "Ophthalmologists are aware of its impending arrival and many have patients in line to receive one," he said. Designed to be as easy to fit as eyeglasses, the system eliminates the need for glasses by incorporating a user's refractive error correction.

The Department of Veteran's Affairs, involved since the project's inception, has provided funding and conducts clinical evaluations of the prototypes at its hospitals across the country. The third-generation prototype, currently in alpha testing at the VA centers, has met with enthusiastic responses, according to Massof. "The VA's low vision patients are inpatients who use the system over weeks and provide useful feedback regarding comfort and long-term use," he said.

Other project members include Triad Investors Corp., which has funded all prototype development of the head-mounted displays, Polaroid, which made the molds for the optics, and Walter Dorwin Teague Associates, a New York-based industrial design firm, which designed the display.

Although an "enormous improvement over existing technologies", said Massof, the current system is designed for retrofitting in anticipation of numerous enhancements. One primary task is to reduce the system's size and weight, and hence improve user comfort. Massof foresees incorporation of various features onto a computer chip while using lightweight composites in the frame. Advances in thin-film technology could enable higher resolutions—with color. "We need is a high-definition display in a very small package. Currently, we can't offer color because it would decrease the resolution by two-thirds," explained Massof.

Another enhancement will address contrast. "Most of the conditions resulting in low vision cause a loss of contrast sensitivity as well as a loss of resolution—so you need more than magnification to perceive details," Massof explained. "The chief complaint of people with low vision is the inability to recognize faces since facial features have very low contrast."

Special contrast filters will apply the same principle that allows the equalizer in a stereo system to filter out specific sound frequencies to compensate for deficiencies in a component or recording or even a listener's hearing. The low vision system will use filters to alter the spectrum of visual signals while boosting contrast in important regions. In the case of a face, it would boost the contrast of the contours that make a face recognizable, producing what resembles a heavy-lined pencil sketch (see images above).

Further down the road, the project team hopes to incorporate an image remapper to compensate for distortions and blind spots. By remapping, or pushing elements of the image into areas retaining good vision, a user essentially can "read around" a blind spot. Since this feature clearly must follow a user's eye movements, the headset has been designed to accommodate a built-in eye tracker.

A remapper that may serve this purpose has been developed by researchers at Johnson Space Center (JSC) working with the University of Houston. Originally designed for remote vehicle and machine vision applications, the tool is under evaluation to determine its clinical merit. Said Richard Juday, JSC project manager: "Once we determine that a miniaturized, inexpensive, and low-power implementation will offer significant benefit to low vision sufferers, we're ready to go full steam ahead." ❑

For more information about the low vision system, contact Dr. Robert Massof, Wilmer Eye Institute, Johns Hopkins University Hospital, 550 North Broadway, 6th Floor, Baltimore, MD 21205, Tel: 410-955-9653.

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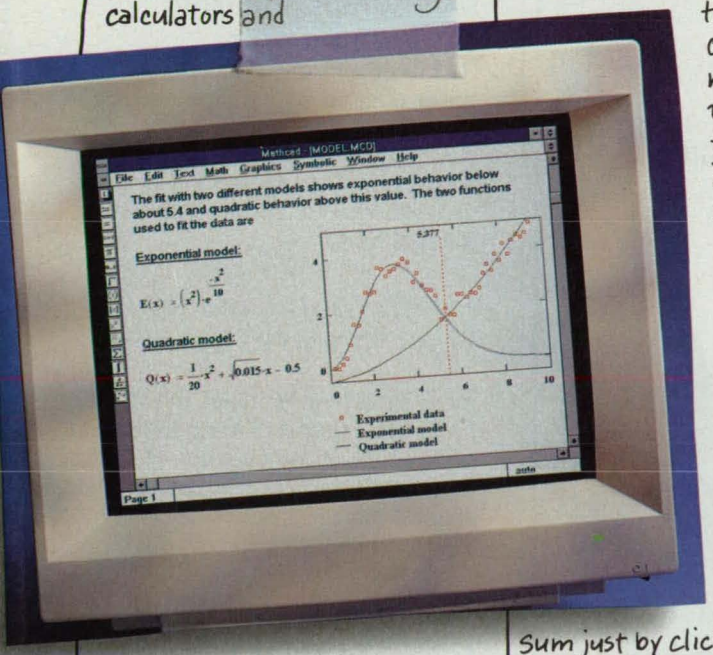

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New Product Ideas

New Product Ideas are just a few of the many innovations described in this issue of *NASA Tech Briefs* and having promising commercial applications. Each is discussed further on the referenced page in the appropriate section in this issue. If you are interested in developing a product from these or other NASA innovations, you can receive further technical information by requesting the TSP referenced at the end of the full-length article or by writing the Technology Utilization Office of the sponsoring NASA center (see page 26). NASA's patent-licensing program to encourage commercial development is described on page 26.

Bioconvective Assay as Alternative to Draize Test

A new protocol can now determine the toxicities of chemicals relatively cheaply by use of equipment packaged in convenient kit form. The kit includes multiple ampoule/syringe units for replication and varying dilutions.
(See page 95.)

Microrover Operates With Minimal Computation

A vehicle of this type navigates, avoids obstacles, and picks up objects by use of a reactive control scheme. The vehicle uses a behavior-description language, which requires less computation than other approaches to artificial intelligence.
(See page 47.)

Movable Cameras and Monitors for Viewing Telemanipulator

Three methods are proposed to assist an operator in viewing a telemanipulator on a video monitor in a control station. Potential applications are in undersea operations, nuclear industry, surgery, entertainment, and manufacturing.
(See page 54.)

Robot-Control Station Would Adapt to Operator

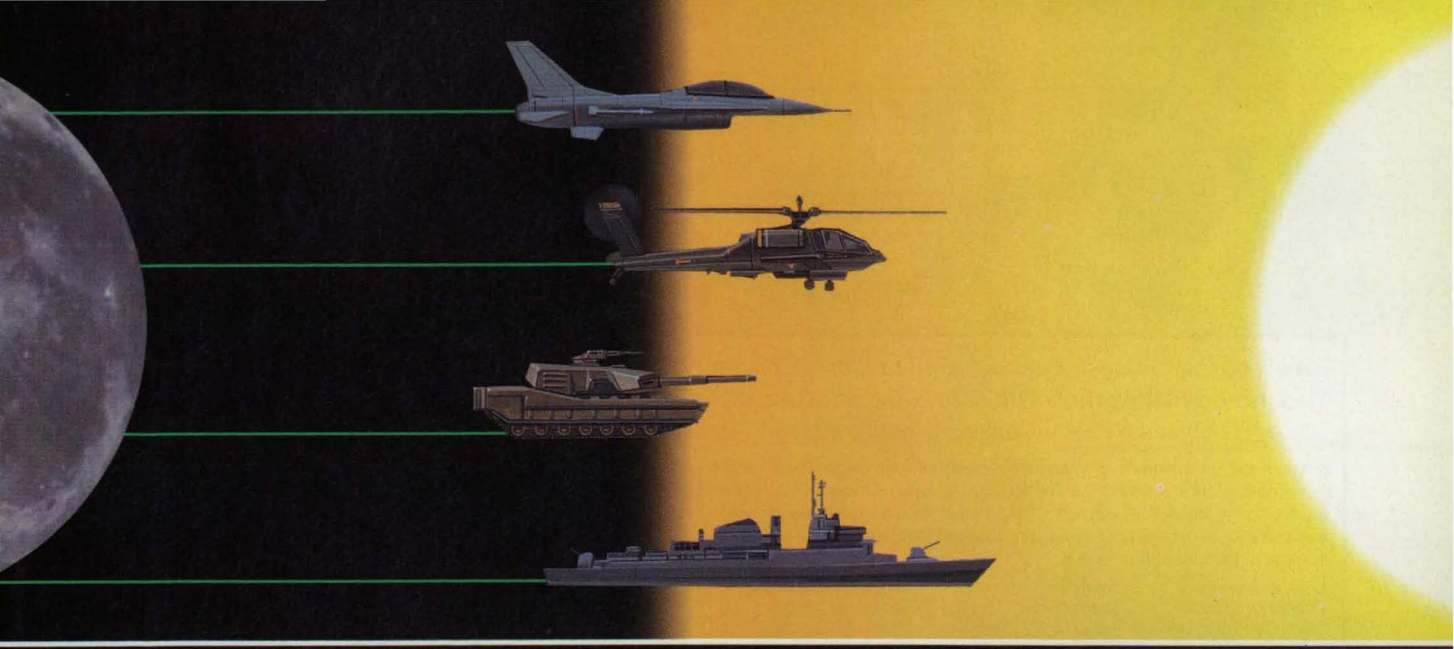
A proposed control station for a remote robot would adapt the control system to personal characteristics and preferences of the operator. Potential applications are in nuclear, underwater, surgical, industrial, and entertainment.
(See page 55.)

Fiber-Optic System Would Detect Leaking Liquid H_2

A proposed instrument would measure both the locations and the sizes of leaks in tanks and plumbing that store and transfer liquid hydrogen. The instrument, based on optical time-domain reflectometry, can be applicable to the detection of other flammable and poisonous fumes.
(See page 60.)

Flame-Retardant Diaminobenzenes Containing Phosphorus

A new synthesis followed by polymerization with a variety of dianhydrides and diacyl chlorides produces fire-resistant polymers. Such polymers would also have high tensile strength.
(See page 66.)



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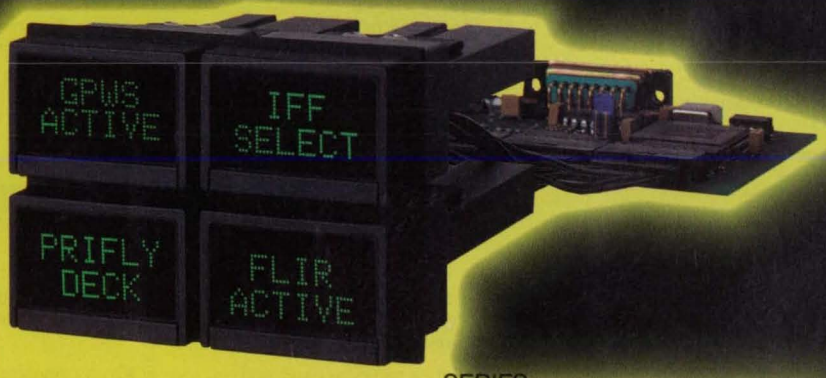

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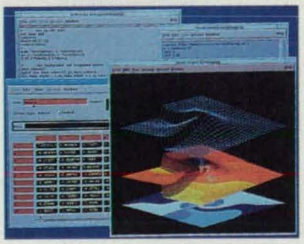

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Improved Dual-Polarized Microstrip Antenna

Low cross polarization and high isolation between feeds are achieved.

NASA's Jet Propulsion Laboratory, Pasadena, California

An improved dual-polarized microstrip antenna features microstrip transmission-line feeds arranged in such a configuration that the cross-polarized components of radiation are relatively low and the degree of isolation between the feed ports is relatively high. Two independent beams of the same frequency with their electric fields polarized orthogonally to each other can be transmitted or received via this antenna, whereas in a more conventional system, two separate antennas — one for each polarization — would be necessary. Thus, the improved design saves space.

Microstrip antennas designed to radiate two independent, orthogonally polarized signals of the same frequency from the same antenna aperture have been investigated before. Typically an antenna of this type exhibits two major deficiencies: (1) poor isolation between the feed ports causes significant crosstalk between them, and (2) the antenna radiates a significant amount of cross-polarized radiation [some of the power that is supposed to be in the horizontally polarized (H) beam is coupled into the vertically polarized (V) beam and vice versa].

The poor isolation and high cross-polarization of the old designs are caused primarily by undesired cross-polarized higher-order modes of the electromagnetic field underneath and surrounding the microstrip patches. The old feed arrangement causes reinforcement of some of the cross-polarized components in the far radiation field; the new design calls for spatially opposed feed points fed with opposite phases, in an arrangement that results in cancellation of the cross-polarized components in the far field (see Figure 1).

In the new antenna, the V and H feed ports are offset from the midpoints of the feed lines to obtain the required opposite phases at the feed-point connections to the microstrip patches (see Figure 2). This phase opposition is necessary, not only to suppress cross-polarized radiation but also to isolate the feed ports from each other by mutual cancellation of signals that would otherwise be coupled between the V and H feed ports via the microstrip transmission lines.

A prototype of the antenna designed for a frequency of 5.3 GHz was tested over a range of frequencies from 5.1 to 5.5 GHz.

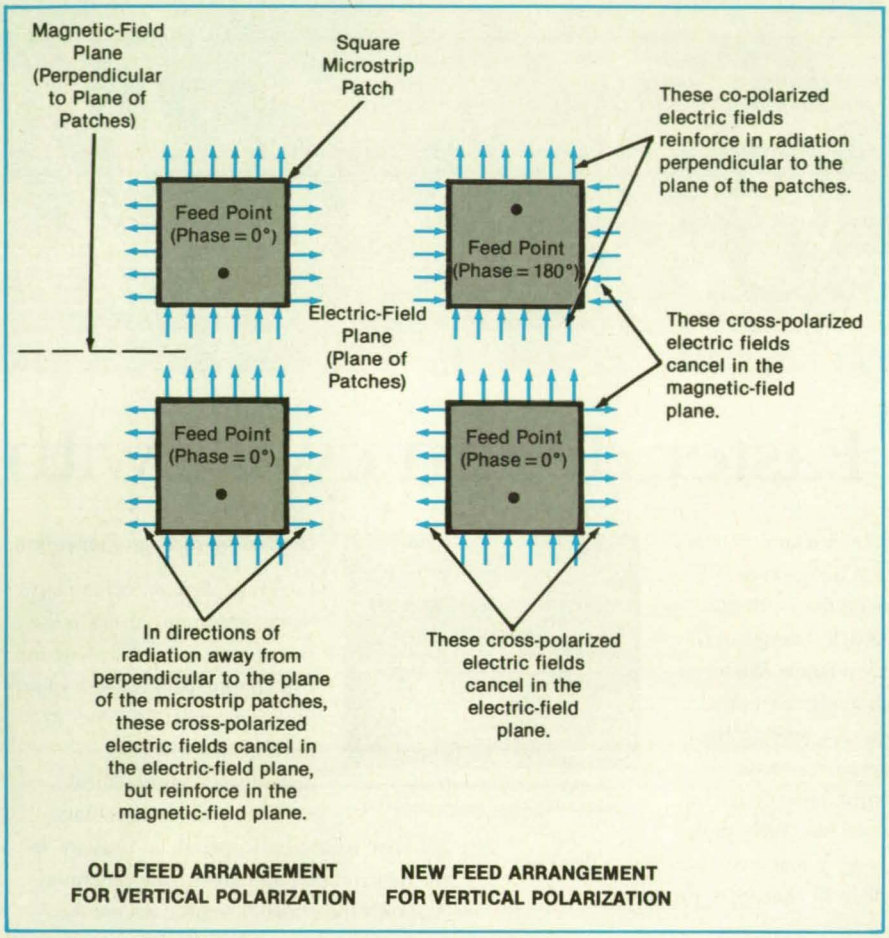

Figure 1. This **Simplified Diagram** illustrates the reinforcement and cancellation of cross-polarized electric fields in the old and new feed arrangements.

The worst-case isolation between the V and H feed ports was about −39 dB; the worst-case cross-polarization radiated in the broadside direction was 28 dB below the copolarization peak. This performance nearly matches that of a similar but more conventional array of two separate apertures, one for each polarization: the array exhibited an isolation of −43 dB and a cross-polarization level of −28 dB.

This work was done by John Huang of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 59 on the TSP Request Card.*

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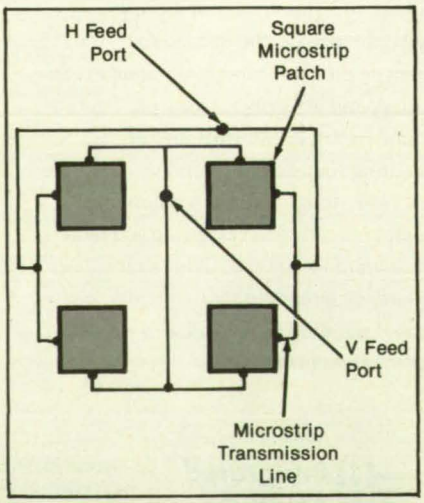

Figure 2. This **Feed Arrangement** provides the spatial and phase relationships needed for cancellation of cross-polarized radiation and isolation between the V and H feed ports.

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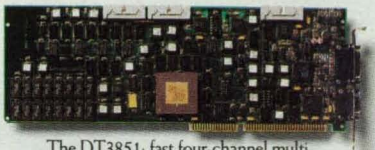

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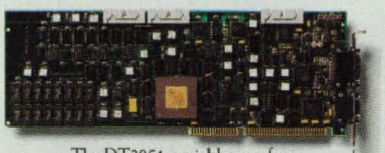

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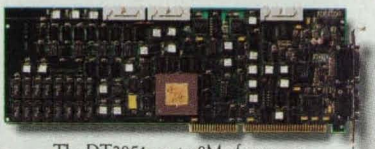

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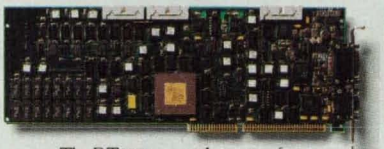

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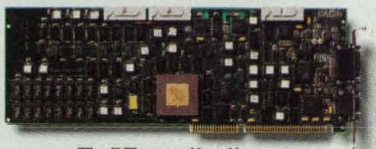

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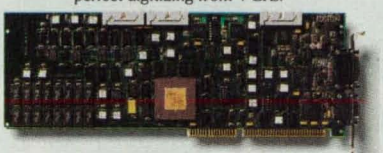

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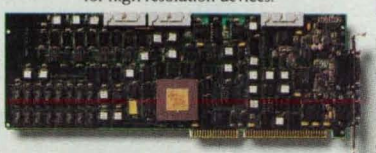

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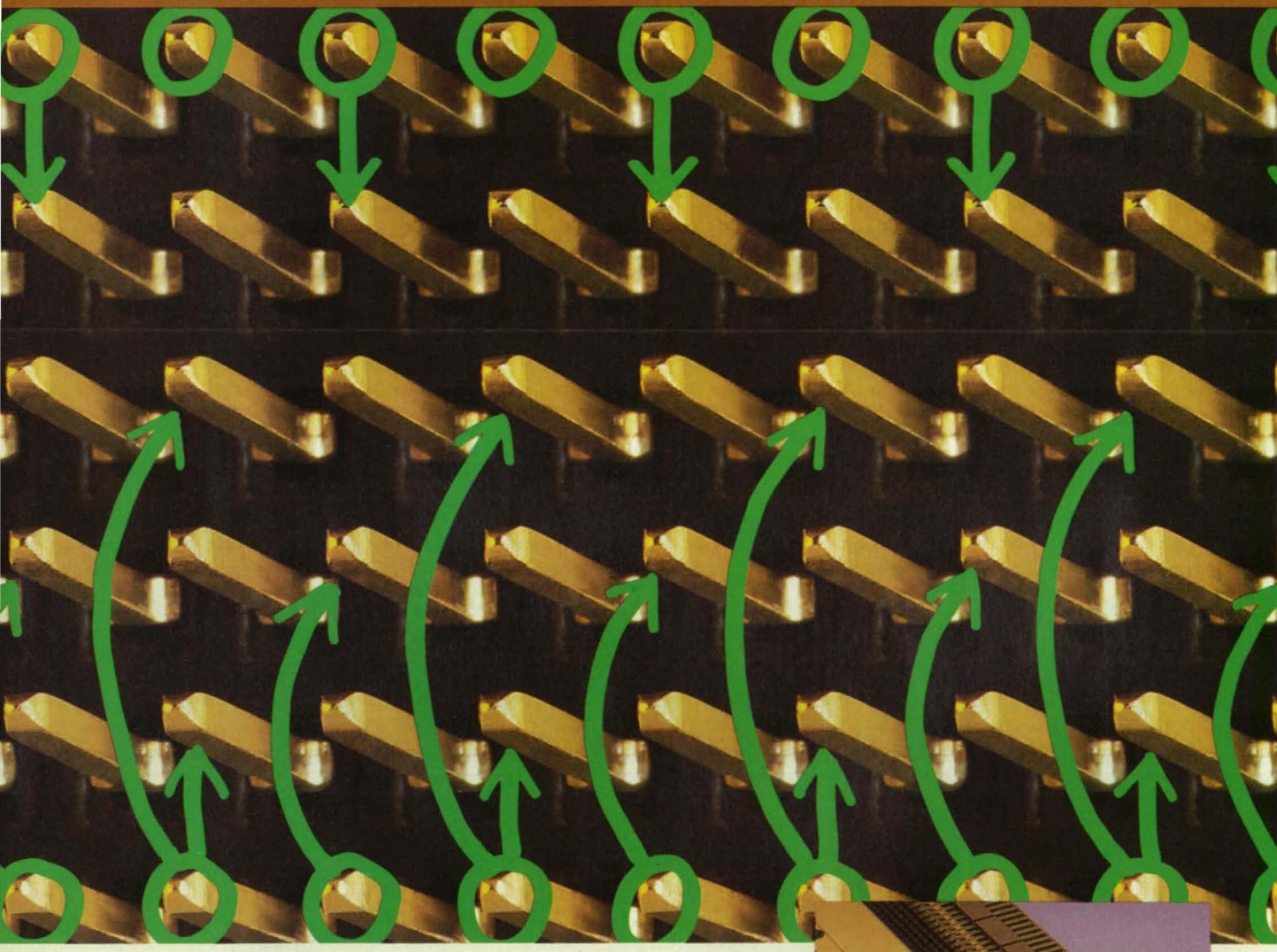

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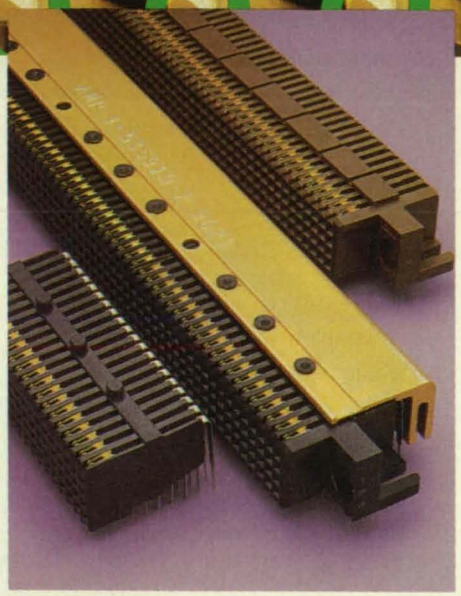

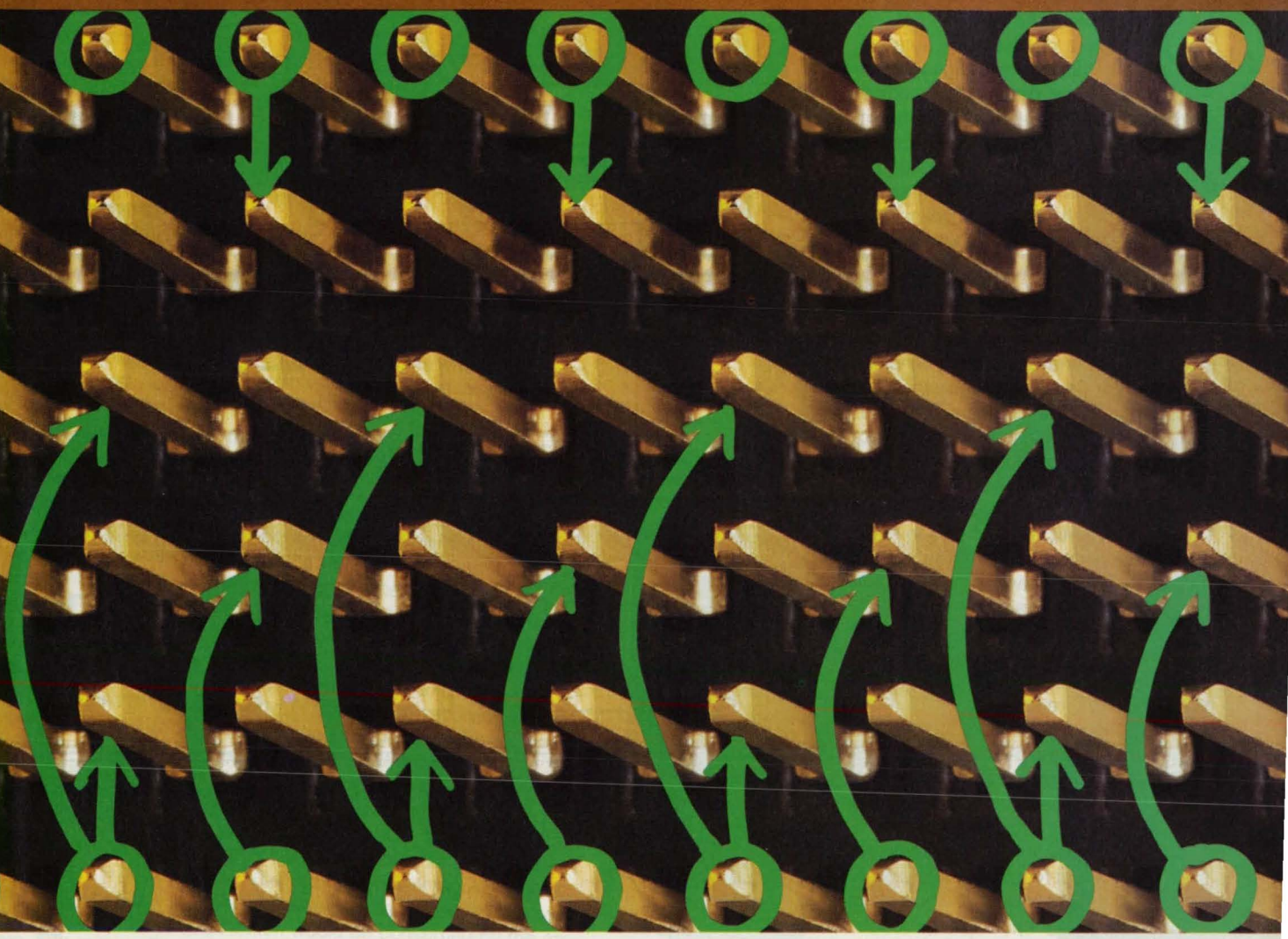

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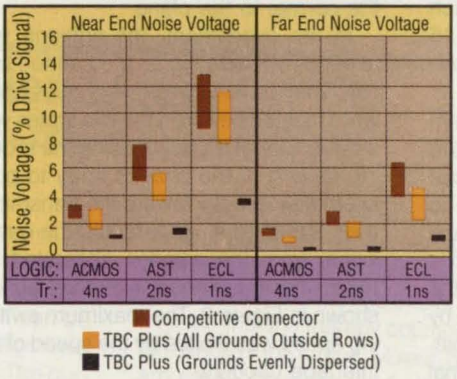

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Optoelectronic Control of Phased-Array Antenna

Radiation patterns can be switched within microseconds.

Lewis Research Center, Cleveland, Ohio

An experiment has demonstrated the feasibility of an optoelectronic concept for rapid steering of the beam transmitted or received by a phased-array antenna. According to this concept, digital beam-steering information destined for a number of phased antenna elements is transmitted in serial multiplex along an optical fiber to an optoelectronic integrated circuit (OEIC), which demultiplexes the information into parallel electronic channels to the phase shifters associated with the various elements.

The motivation for this optoelectronic beam-steering concept is provided by the emergence of phased millimeter-wavelength antenna arrays containing hundreds of elements. Because of the small distances between the elements of such arrays, the compactness of optical fibers makes them attractive for the distribution of beam-steering (phase-shifting) control signals. Multiplexing many control signals onto a single optical fiber helps to make even more efficient use of the narrow spaces available between antenna elements. Optical fibers also offer the advantages of light weight, low attenuation, mechanical flexibility, large bandwidth, and immunity to both crosstalk and electromagnetic interference.

The experimental system included an eight-element phased-array antenna operating at 28.2 GHz, an optoelectronic integrated circuit, an optical fiber, and associated electronic circuitry (see Figure 1). The optoelectronic integrated circuit is a hybrid device that requires a serial optical bit-stream input, as well as electrical clock and synchronizing inputs, and produces 16 parallel, demultiplexed, electrical outputs and a data-valid (clock divided by 16) output. It is capable of operation at speeds up to approximately 300 Mb/s. The antenna includes an eight-way corporate feed network that divides the input power equally among eight phase shifters that, in turn, feed the eight radiating elements. Each phase shifter is a 4-bit device that has 16 possible delay settings in 22.5° increments from 0° to 337.5°.

Because the OEIC and the phase shifters were not designed to be connected directly to each other, an interface circuit compatible with both was interposed to switch the voltages applied to the phase shifters. Rather than controlling all 32 bits of the array (8 shifters × 4 bits/shifter), 8 bits were strategically selected so that by changing only these bits the antenna pattern could be switched between normal to the plane of the antenna and 20° from the normal to the plane.

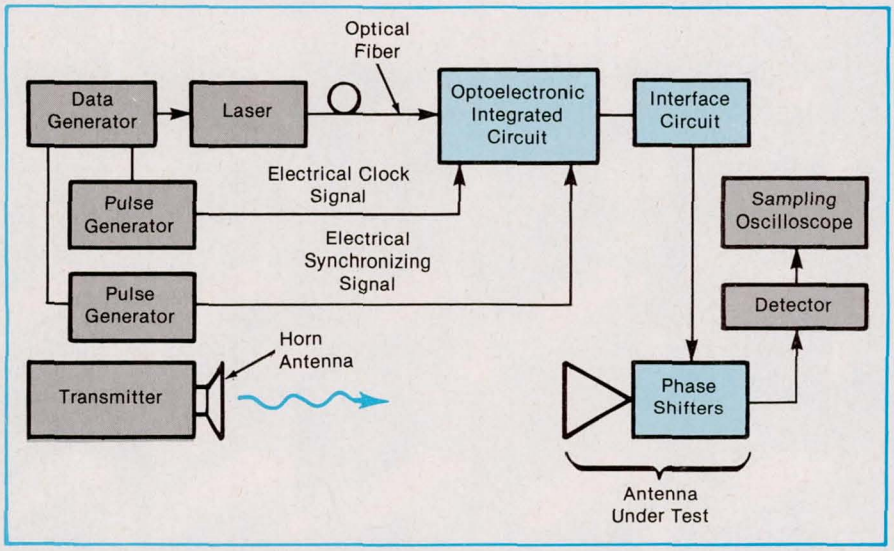

Figure 1. **Digital Signals Transmitted on an Optical Fiber** were converted to electronic signals, which controlled phase shifters to alternate the aim of a receiving antenna between two different directions: one toward the transmitter and one facing away by 20°.

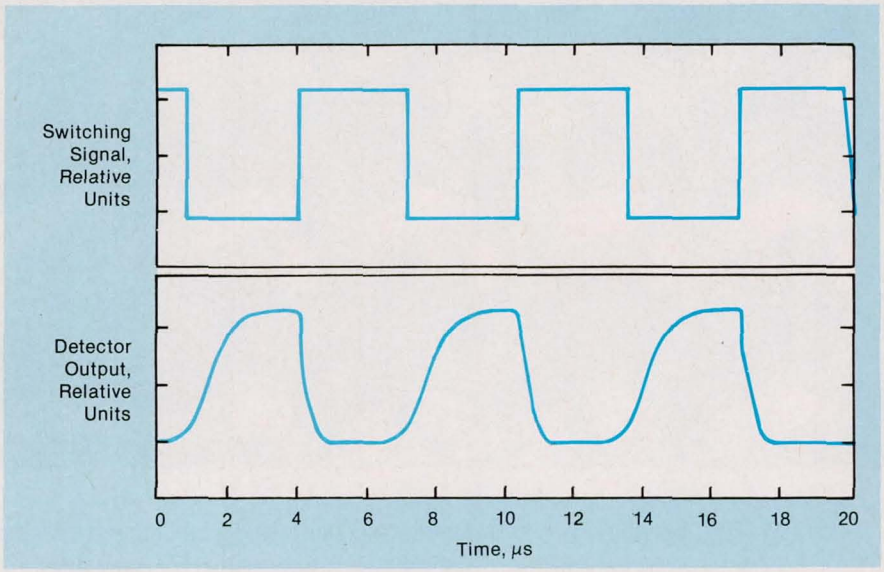

Figure 2. The **Upper Oscilloscope Trace** represents the switching signal on one of the output lines of the optoelectronic integrated circuit. The lower trace represents the output of the detector, clearly showing the effect of switching on the receiving pattern of the antenna.

In the experiment, the antenna was used to receive a signal transmitted by a horn antenna 3 m away. The phase shifters were toggled between the two states with a cycle time of 3.2 μs, causing the receiving pattern of the phased array to point alternately directly toward the transmitter, then 20° from it. As a result, the output signal from the antenna alternated between maximum and minimum values, as shown in Figure 2. The maximum switching speed was limited by the speed of the interface circuitry.

This work was done by K. B. Bhasin of **Lewis Research Center**, *M. A. Richard and P. C. Claspy of Case Western Reserve University, and M. Bendett of Honeywell, Inc. Further information may be found in NASA TM-102550 [N90-21275], "Optical Control of an 8-Element Ka-Band Phased Array Using a High-Speed Optoelectronic Interconnect."*

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LEW-15187

Synthetic-Aperture Antenna Array With Beam-Waveguide Coupling

Receivers would be located centrally, with consequent reductions in complexity and cost.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed synthetic-aperture antenna array for radio astronomy at wavelengths between 60 and 300 μm would include twelve 3.5-m-diameter paraboloidal-dish antennas at various positions along three 0.5-km-long arms of a Y-shaped pattern (see Figure 1). Although the antenna would be erected on the Moon to avoid absorption by water vapor and other molecules in the terrestrial atmosphere in the wavelength range of interest, the innovative features of its design may also stimulate solutions to engineering problems that arise in terrestrial radio systems.

The particular distribution of the antennas along the arms would be needed to obtain the required angular resolution of 10 milliseconds of arc at the shortest wavelength. Heretofore, in terrestrial arrays of radio antennas that operate at longer wavelengths, the incoming radio beams have not been reflected to central receivers, because losses caused by diffraction at the longer wavelengths would be too large. Instead, images of astronomical radio sources have been synthesized from signals detected coherently in a receiver at each antenna. However, at the submillimeter wavelengths of the proposed system, the apertures of the beam-waveguide components that would be needed to reflect the collected radio beams to a central receiving station with acceptably low diffraction loss would be small enough to be practical.

Figure 2 illustrates the principal components of one version of the proposed antenna optics, designed to relay the beam to the central receiving station. Flat mirror 1 would rotate, with the antenna dish, around its elevation axis. Flat mirrors 2, 3, and 4 would rotate, with the structure that supports the elevation axis, about the azimuthal axis. The net effect of flat mirrors 1 through 4 would be to provide a constant beam directed downward toward flat mirror 5, regardless of the orientation of the antenna. Flat mirror 5 would reflect the beam toward 1 of 12 Cassegrain beam-compressing dish antennas located at the central receiving station. The diameters of the beam-compressing dishes for each arm of the Y would range from 0.52 m for the relay from the nearest antenna to 1.61 m for the relay from the farthest antenna.

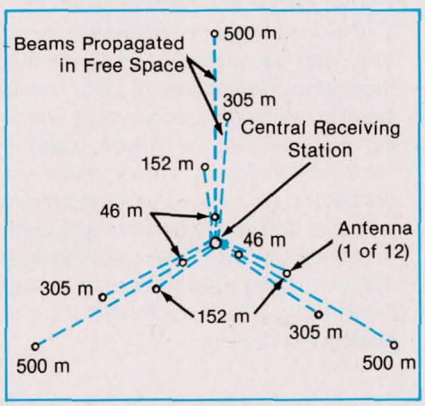

Figure 1. **Twelve Antennas** would be located along the arms of a Y. The radio waves collected by the antennas would be concentrated into beams directed toward a central receiving station.

The principal advantage of this beam-waveguide coupling scheme is that all major power-consuming equipment would be located in the central receiving station, with consequent simplification of maintenance and the distribution of power. For example, all receivers could be located in one or a few cryostat(s), which could be operated at a cost substantially less than that of separate cryostats at all the antennas. The maximum power required at each antenna would be only about 20 W, most of which would be consumed by the antenna-aiming machinery.

This work was done by Michael J. Mahoney and Kenneth A. Marsh of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 106 on the TSP Request Card.*
NPO-18605

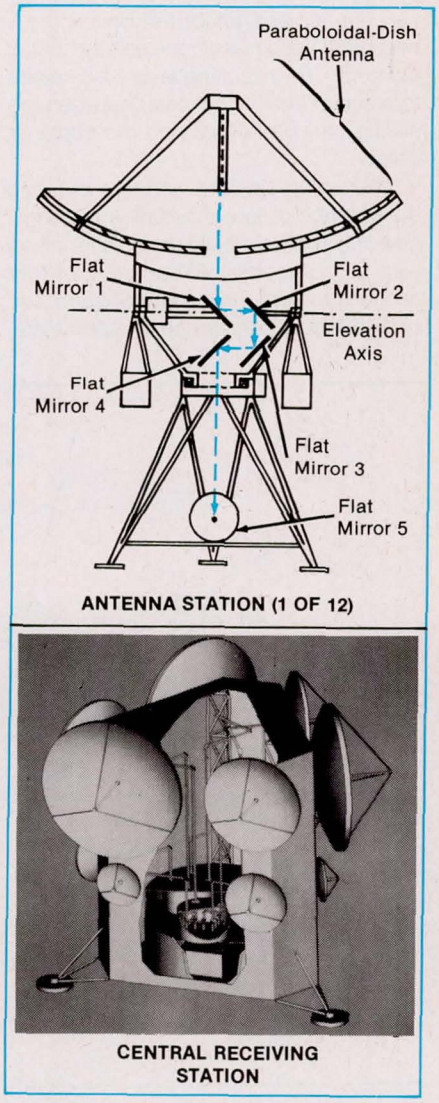

Figure 2. The **Beam-Waveguide Coupling** between one of the antennas and the central receiving station would operate with acceptably small diffraction loss.

Tuners for Coplanar-Strip Transmission Lines

Sliding radio-frequency short circuits are easily adjusted for optimum impedance.

NASA's Jet Propulsion Laboratory, Pasadena, California

Tuning elements are being developed for use in planar integrated circuits that will operate at frequencies from about 10 to more than 1,000 GHz (such circuits are denoted variously as microwave integrated circuits and monolithic microwave integrated circuits). These tuning elements are nearly electrically equivalent to short circuits at the intended operating frequencies (but are open circuits at dc) that can be slid along coplanar-strip transmission lines to adjust their electrical lengths. The purpose of such an adjustment is to adjust the impedance presented to a circuit connected to the nonshorted end of the transmission line and thereby optimize the performance of the circuit. Mixers, oscillators, amplifiers, couplers, and phase shifters

are among the circuits that could be improved by incorporating tuners of this type.

The basic version of the tuning element is a rectangular strip of metal that contains rectangular holes and slides along a coplanar-strip transmission line with a thin insulating layer in between (see Figure 1). Therefore, capacitive and wave-propagation phenomena effect the coupling between the transmission line and the tuning element. The insulating layer also serves to prevent mechanical wear between the sliding tuning element and the coplanar lines.

The tuning element works by creating a sequence of low-impedance transmission-line sections (solid metal) alternating with high-impedance transmission-line sections (holes). The length of each low- or high-impedance section is approximately one-fourth the wavelength on the transmission line at the frequency for which the tuner is designed. As the number of sections is increased, the impedance is reduced. Calculation shows that the impedance can be made smaller than 1 Ω — a value that is regarded as a radio-frequency short circuit in typical applications.

A tuning element for millimeter and submillimeter wavelengths could be made readily by conventional or laser machining or by etching the metal strip. The tuning element can be driven along the transmission line by a micrometer via a connecting wire. For very high submillimeter-wave frequencies where tight control of dimensions is important, the tuning element and drive mechanism can be fabricated using silicon micromachining and plating techniques.

The concept was tested with a large-scale 204-Ω transmission line and tuning element designed for optimum performance at a center frequency of about 2 GHz. The relative power reflected from the tuning element back along the transmission line was measured at frequencies from 1.6 to 2.4 GHz (see Figure 2) and found to exceed 93 percent over a 22-percent bandwidth centered at 1.93 GHz. It has been conjectured that the remaining power leaks past the tuning element along the dielectric substrate. A double-shunt tuning circuit for a planar antenna was also built and tested. The antenna impedance was successfully transformed to a wide range of radio-frequency (rf) impedances by adjusting the two tuners. These results represent the first demonstration of active mechanical tuning of a microwave integrated circuit.

This work was done by William R. McGrath, Victor M. Lubecke, and David B. Rutledge of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 20 on the TSP Request Card.*

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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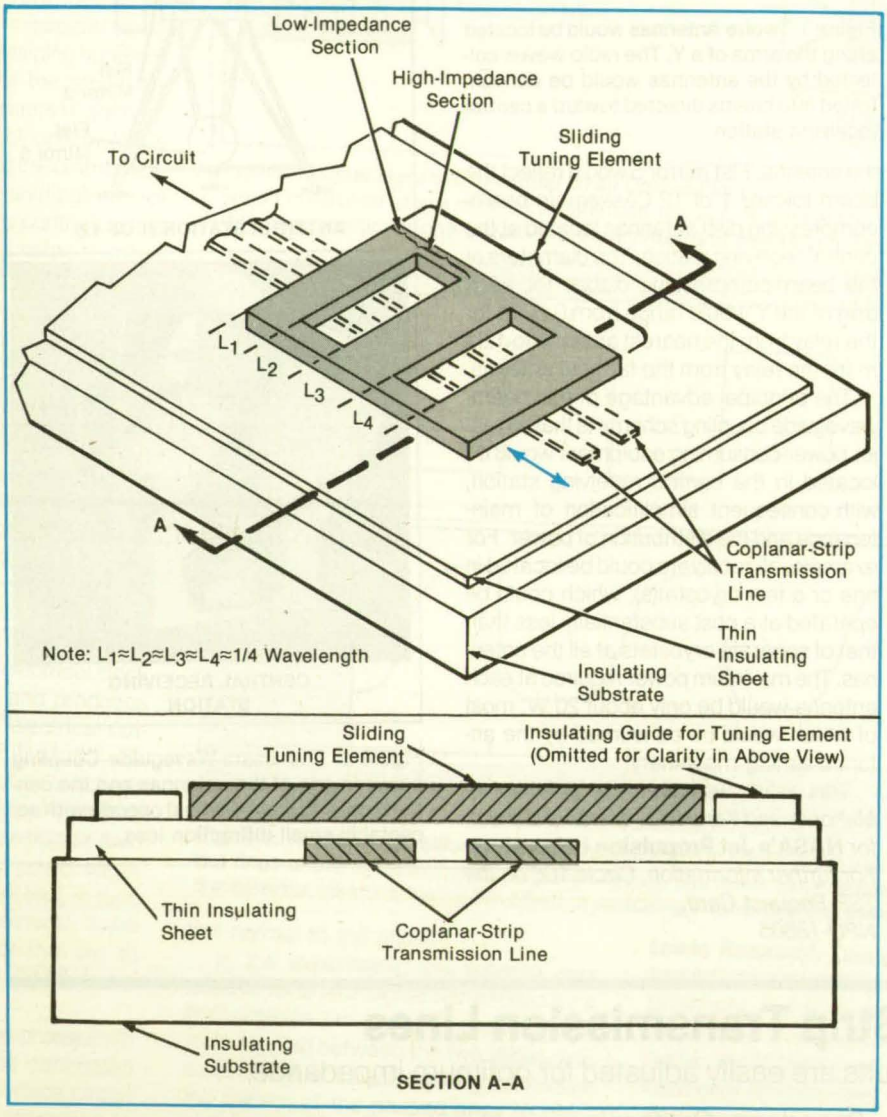

Figure 1. The **Tuning Element** presents a low impedance at the design wavelength and frequency. Its position along the transmission line is adjusted to tune a circuit connected to one end of the line.

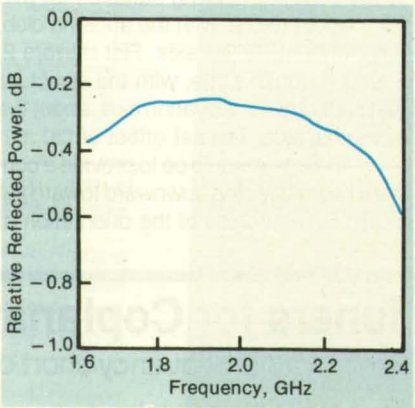

Figure 2. **Most of the Power** incident upon an experimental tuner was reflected, confirming that the tuning element had the desired low impedance and was effective.

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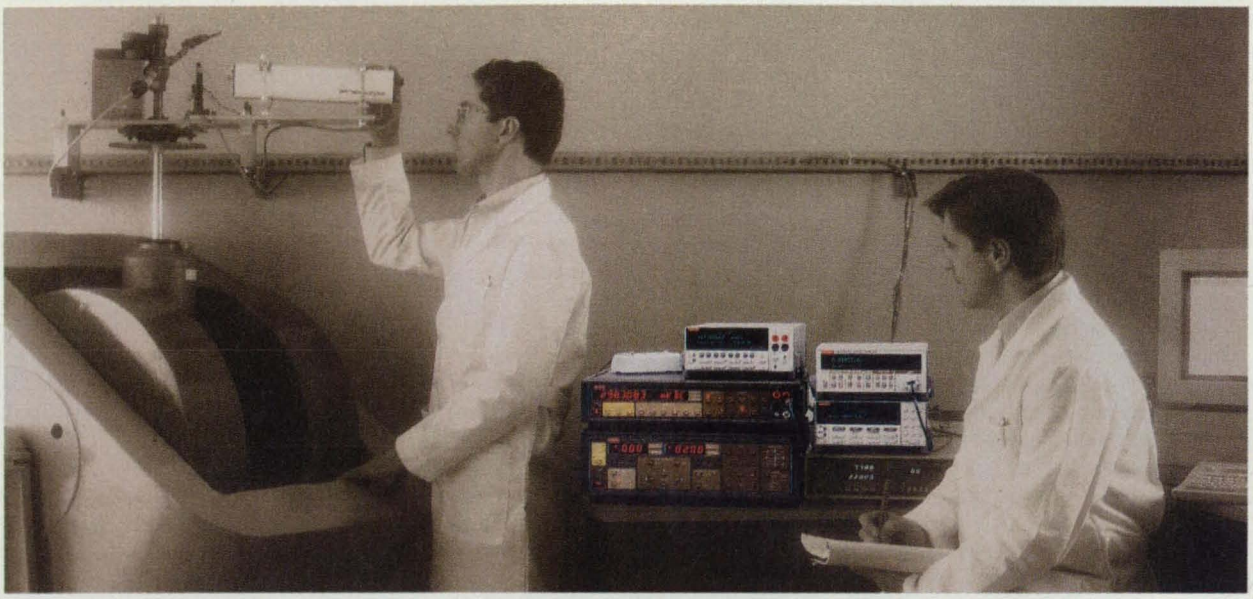

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For More Information Circle No. 619

Compact, Flexible Telemetry-Coding Circuits

One circuit can generate any of a number of selectable codes.

Goddard Space Flight Center, Greenbelt, Maryland

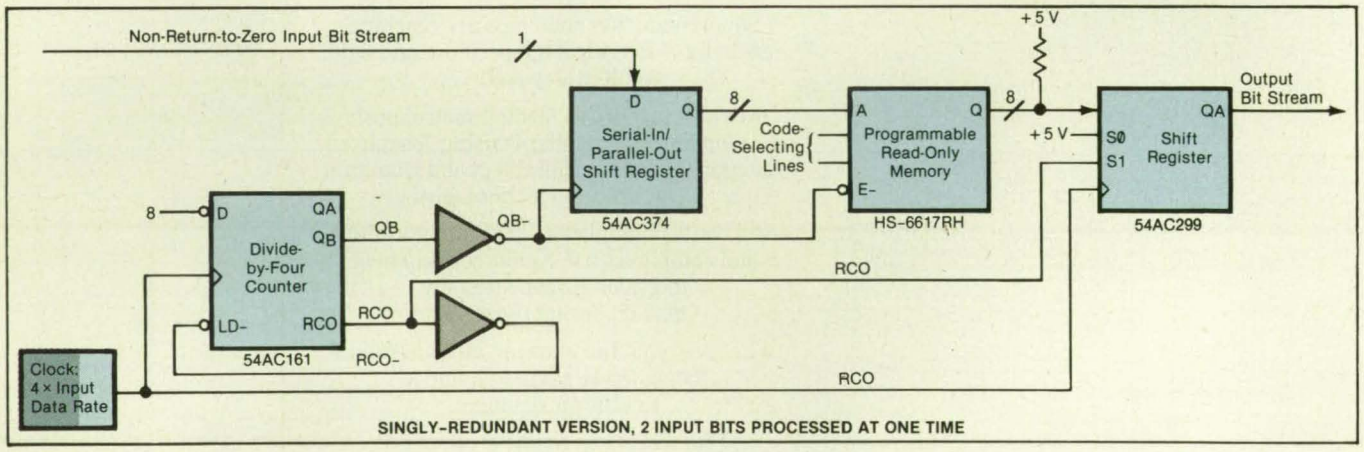
Circuits that encode binary telemetry data have been designed to synthesize any of a number of selectable codes. The circuits (see figure) are designed for use aboard spacecraft, with features that also make them attractive for terrestrial applications: They are simple and compact relative to prior coding circuits, can be built with commercial integrated circuits, and incorporate protective redundancy. In addition, output distortions are minimized, and spurious attenuated and/or abbreviated output pulses (which are common in some prior coding circuits) are eliminated.

The original versions of these circuits can generate any of four codes: non-return-to-zero-level (NRZ-L), bi-phase-level, convolutional with constraint length 7 and rate ½, and convolutional-bi-phase-level (a combination of the preceding two). The convolutional-bi-phase-level code specifies 4 output bits per input bit. The convolutional (only) and bi-phase-level codes specify 2 output bits per input bit. The NRZ-L code specifies 1 output bit per input bit. To accommodate all the codes, the circuit includes an oscillator that generates a clock signal at 4 times the input data rate. For the NRZ-L code, each bit is simply copied four times and is shifted out at 4 times the input data rate; the result is indistinguishable from shifting the input out at the same rate at which it comes in.

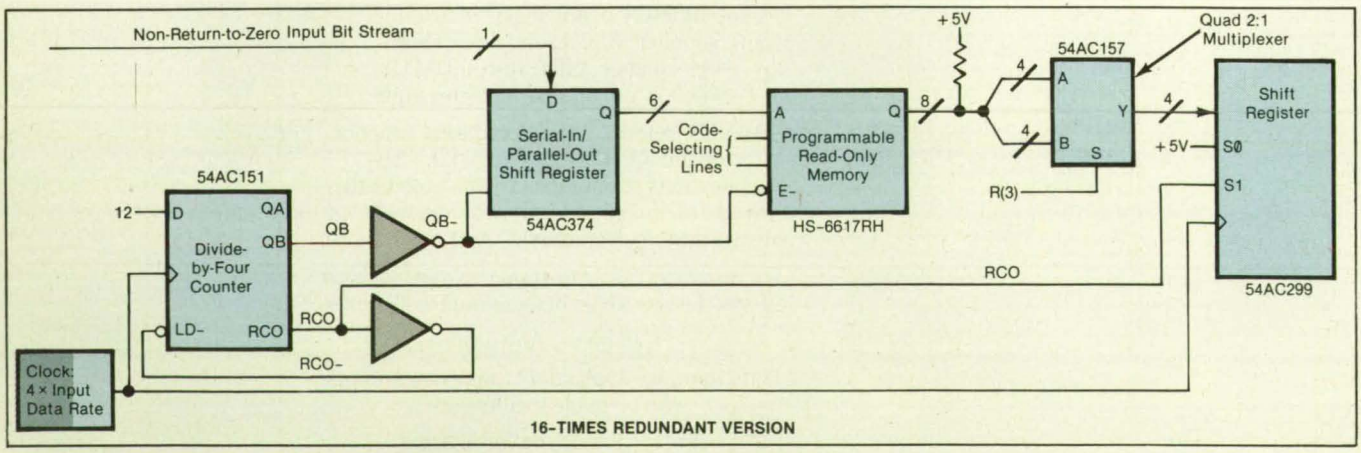
For the bi-phase-level code (in which "1" and "0" are represented by transitions from the "1" to the "0" level or from the "0" to the "1" level, respectively), each input bit is copied twice with its complement concatenated twice. For the convolutional code, each of the two alternating outputs of the encoding algorithm is copied twice and concatenated with two copies of the other output of the algorithm. For the convolutional-bi-phase-level code, the two component codes are concatenated at each output-clock period; extra copies of input bits are not made.

Implementation of the coding algorithms would ordinarily require large circuits. Therefore, for the sake of compactness and economy, precomputed coded output bits are stored in "lookup-table" form. All four codes can be stored redundantly in a 2K × 8 programmable read-only memory. Tolerance of faults is obtained by dividing the memories into redundant blocks, each of which contains all the codes. The redundant storage scheme can be implemented by connecting a spare address-bit line in each memory to an external control register and/or by use of an external quad 2:1 multiplexer and assignment of each half of each word space in memory to contain the duplicate of the information in the other half. The programmable coding is tolerant of any stuck-at condition of the bank-selection lines.

This work was done by Richard B. Katz, Matthew Tooley, and Beverly Settles of **Goddard Space Flight Center**. *For further information, Circle 31 on the TSP Request Card.* *GSC-13514*



SINGLY-REDUNDANT VERSION, 2 INPUT BITS PROCESSED AT ONE TIME



16-TIMES REDUNDANT VERSION

These **Encoding Circuits** process input bit streams into output bit streams in any of four selectable codes. The codes are stored in compact "lookup-table" programmable read-only memories in a fault-tolerant redundant scheme.

Single-Fiber Optical Link for Video and Control

A simple, wideband fiber replaces a complicated, limited-bandwidth metal cable.

John F. Kennedy Space Center, Florida

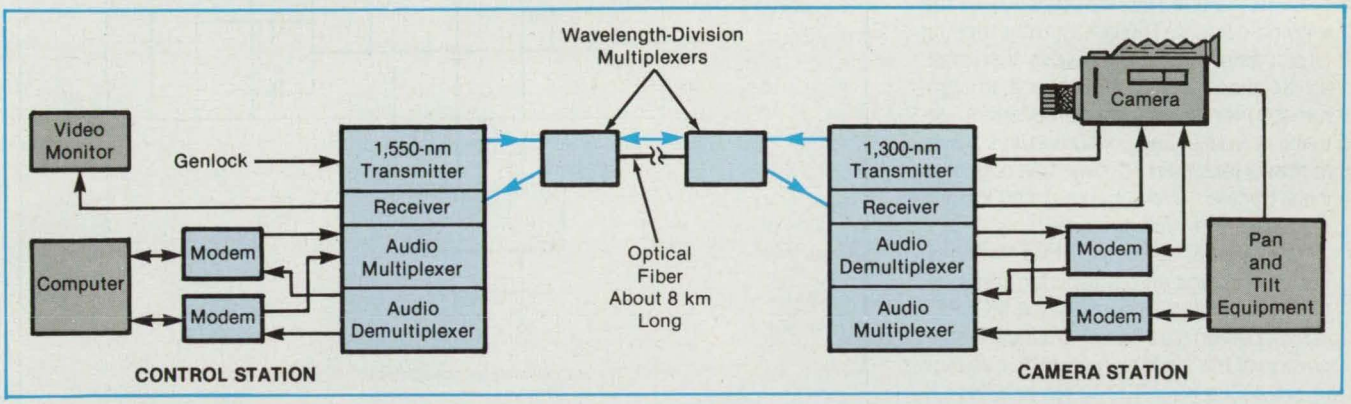
A single optical fiber carries control signals to remote television cameras and video signals from the cameras. The fiber replaces a multiconductor copper cable, with a consequent reduction in size. The nonmetallic fiber provides immunity to electromagnetic interference at suboptical frequencies and is much less vulnerable to electronic eavesdropping and lightning strikes. Its multigigahertz bandwidth is more than adequate for high-resolution television signals.

The fiber-optic link is 8 km long; unlike in the multiconductor cable, repeaters are not needed. The system will work with either multimode- or single-mode fiber types. A computer generates the feedforward control signals (pan, tilt, zoom, and focus) for eight cameras. They are multiplexed and transmitted at a wavelength of 1,550 nm on two audio subcarriers (see figure). A 4.75-MHz-wide video control signal is transmitted on the same 1,550-nm carrier.

From each camera, signals are transmitted back to the control station on another optical carrier, which has a wavelength of 1,300 nm. These signals include multiplexed feedback status signals on audio subcarriers and 8.5-MHz-wide video signals for each camera.

This work was done by F. Houston Galloway of Boeing Aerospace Operations, Inc., for **Kennedy Space Center**. *For further information, Circle 15 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Kennedy Space Center [see page 26]. Refer to KSC-11571.



Optical Signals Travel in opposite directions on the optical fiber at different wavelengths. The single fiber is used in place of a multiconductor coaxial and twisted-pair cable with repeaters.

Add/Compare/Select Circuit for Rapid Decoding

A prototype decoding system operates at 200 Mb/s.

Lewis Research Center, Cleveland, Ohio

The ACS (add/compare/select) gate array is a highly integrated emitter-coupled-logic circuit that implements arithmetic operations essential to the Viterbi decoding of convolutionally encoded data signals. The principal advantage of the circuit is speed: commercially available Viterbi decoders are limited to tens of Mb/s, but the ACS gate array can operate at rates of hundreds of Mb/s.

The computationally intensive part of the Viterbi decoding algorithm is the ACS operation, which involves additions, comparison of the sums, and selection of the smallest sum. One ACS operation is required for each state of the code. Generally, as each code symbol is received at the tth increment of time, the ACS operation is performed for each of the code states:

$$S_{i,t} = \min_j (S_{j,(t-1)} + b_{j,(t-1)})$$

where each code state is said to have j branches leading into it. Each of these ACS computations must be completed for each of the code states within the duration of one symbol. If, for example, the symbol rate is 100 MHz, then all of these ACS operations must be completed in 10 ns.

Massively parallel computation is necessary to attain such high speeds. In a typical parallel processor dedicated to this problem, one ACS module would be used for each code state. Because of the manner in which the code states interconnect, it is not feasible to partition the ACS modules into larger sets with minimal connections between them. Furthermore, all the modules must communicate with each other within one symbol period. Therefore, the high-speed ACS unit must be highly integrated to avoid the effects of delays in wired connections.

This prototype ACS gate array performs the ACS operation at over 100 MHz. (Counting each addition and each comparison as one arithmetic operation, it performs over 1.5 billion arithmetic operations per second.) The circuit includes eight 8-bit adders and a tree of comparators. The adders compute $(S_{j,(t-1)} + b_{j,(t-1)})$, while the comparators find the minimum of these sums. The minimal sum is selected and sent to the output terminals. This operation is completed in less than 10 ns, allowing for Viterbi decoding at over 200 Mb/s, the exact throughout depending on the code rate.

The ACS gate array is very flexible: it can operate as a single unit that performs eight additions and finds the minimum of the eight sums, or it can operate as two independent units, each performing four additions and finding the minimum of its four sums. This flexibility enables application to a variety of different codes. The ACS gate array includes built-in self-testing circuitry, which enables the unit to be tested at full speed with the help of only a very simple test fixture.

This work was done by James M. Budinger of **Lewis Research Center** *and Neal D. Becker and Peter N. Johnson of Communications Satellite Corp. No further documentation is available.*
LEW-15253

Fast Overcurrent Tripping Circuit

An electronic circuit breaker consumes little power.

Lewis Research Center, Cleveland, Ohio

A fast overcurrent tripping circuit is designed for incorporation into a power metal oxide/semiconductor field-effect transistor (MOSFET) switching circuit. The overcurrent tripping circuit serves as a fast electronic circuit breaker by sensing the voltage across the MOSFET's during conduction and switching the MOSFET's off within 1 μs after this voltage exceeds a reference value that corresponds to the tripping current. The overcurrent tripping circuit acts much more quickly than does a Hall-effect current sensor and, in comparison with shunt current-measuring circuits, is smaller and consumes less power (it draws less than 10 mA). It also ignores initial transient overcurrents during the first 5 μs of the switching cycle.

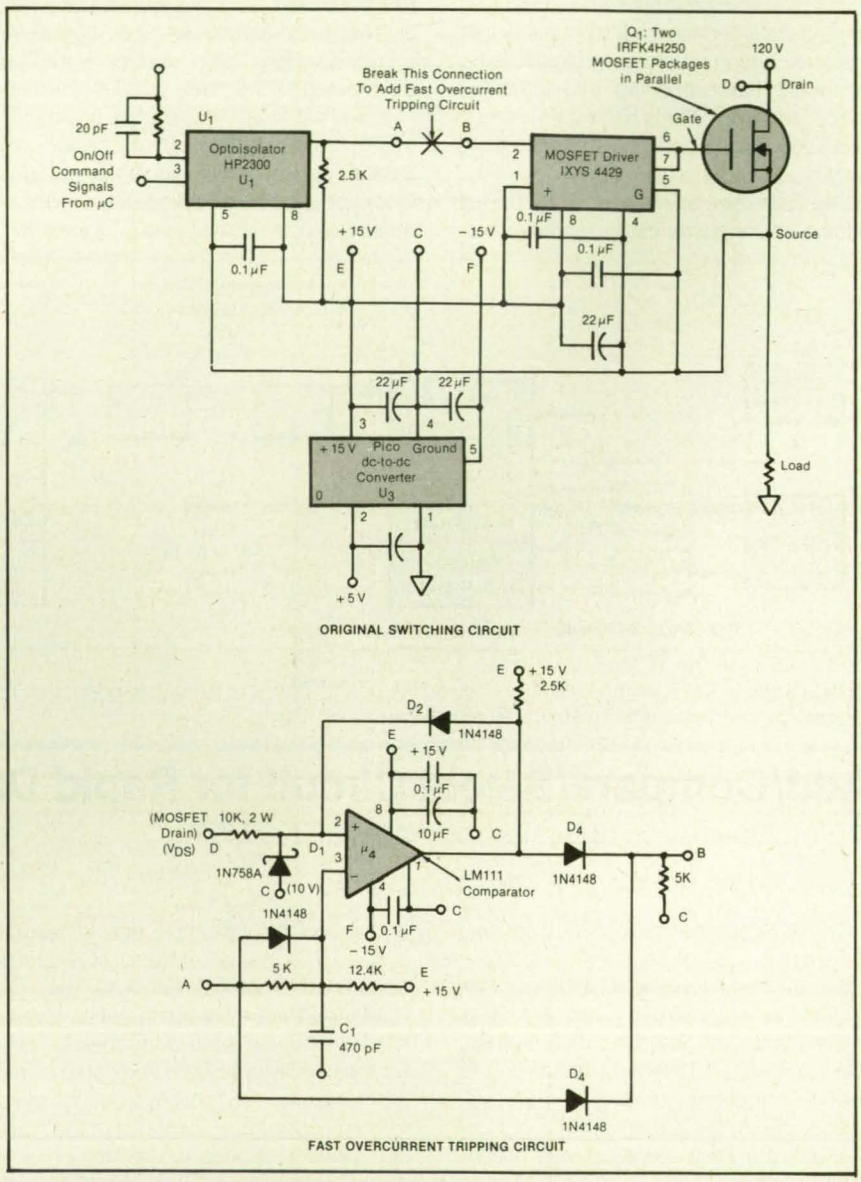
The original power-MOSFET switching circuit contains an optoisolator and a dc-to-dc converter, which isolate the MOSFET-driving portion (see figure). During the "on" portion of the switching cycle, the voltage at point C is near 120 V. No provision is made for sensing of overcurrent or quick turnoff in the original circuit. The fast overcurrent tripping circuit is added to the original circuit by connecting it at points A through F.

The drain-to-source resistance of Q_1 (the parallel combination of two IRFK4H250 power-MOSFET packages) during the "on" portion of the operating cycle is 0.01 Ω. It is desired to make the circuit trip at a drain-to-source current of 500 A, which is 10 times the normal operating current of I_{DS} = 50 A. Therefore, the overcurrent-tripping reference drain-to-source voltage is set at $V_{DS} = 0.01\ \Omega \times 500\ A = 5\ V$.

When the external control circuit, μC, sends the "on" command to the MOSFET-driving circuitry during normal operation, the voltages at points A and B go low and U_2 turns on Q_1. Immediately after Q_1 has been turned on, the output of comparator U_4 is low.

Previously, while Q_1 was off, V_{DS} was 120 V. Once Q_1 is on, V_{DS} falls to $V_{DS} = I_{DS} \times 0.01\ \Omega$ (where I_{DS} = the drain-to-source current). At first, the reference voltage at pin 3 of U_4 is kept high so that the initially high values of V_{DS} caused by initial transient surges of current do not cause false tripping. After 5 μs, C_1 has discharged to 5 V. Thereafter, if V_{DS} exceeds 5 V (signifying I_{DS} > 500 A), the output of U_4 goes high, causing the MOSFET driver to turn Q_1 off. D_2 conducts current to 10-V zener diode D_1, which keeps pin 2 of U_4 at 10 V, latching the output of U_4 high. This prevents Q_1 from turning on again after it has been turned off in response to a very short transient of excessive I_{DS}.

Once the circuit has been thus tripped, it can be reset only by an "off" command from μC to the FET-driving circuitry. When this command is received, the voltage at point A goes high, C_1 is charged up to 15 V in 1.5 μs, and the output of U_4 goes low. Then μC can command Q_1 on and off at any time.



The **Fast Overcurrent Tripping Circuit** is incorporated without modifying the original switching circuit other than making the connections at points A through F.

This work was done by Craig C. Sullender, Bryan L. Davies, and Stephen H. Osborn of Rockwell International Corp. for **Lewis Research Center**. *No further documentation is available.*
LEW-15022

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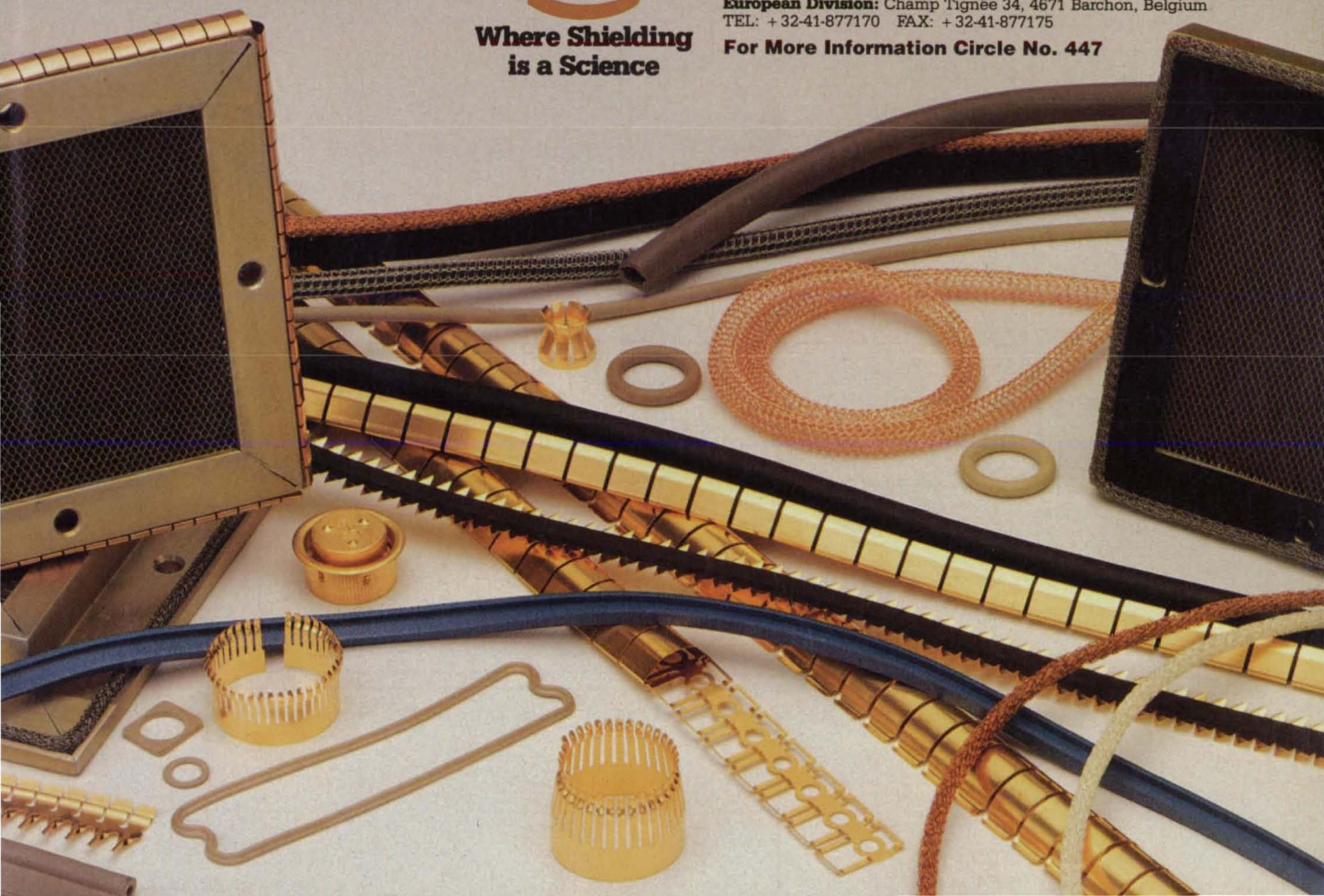
For More Information Circle No. 447



Analog-to-Digital Converter for Sum-of-Squares Measurements

Notable features include low power and fast conversion.

Lewis Research Center, Cleveland, Ohio

An analog-to-digital converter (ADC) circuit (see figure) is designed as part of a larger circuit intended to measure the root-mean-square current on a 20-kHz powerline. The ADC provides a digital output of 11 bits of data plus a 1-bit overflow signal at a sampling rate of 4 MHz. The output of the ADC is processed by multiplying-and-accumulating circuitry to obtain the sum of squares and digitized current samples accumulated during a preset number of consecutive sampling periods. One could also use the digitized current samples from the ADC directly as alternative or auxiliary output. Other ADC's on the market can provide 12 bits at a greater sampling rate, but each of them consumes more than 6 W of power. Even with the multiplying-and-accumulation circuitry, the ADC consumes less than 500 mW.

The current is sensed by a Hall-effect device, which was chosen because it can be electrically isolated from the powerline. Operational amplifier 2 compensates for the offset that occurs in a Hall-effect device operated with a monopole voltage reference. The offset input to operational amplifier 2 is taken from the output of operational amplifier 1 so that when the voltage on the Hall-effect device drifts, the value of the offset changes at the same rate. The output of operational amplifier 2 goes to operational amplifier 3, which is a 140-kHz filter. The output of operational amplifier 3 goes to the variable resistor R_2, which determines the gain of the input to the summing junction at operational amplifier 4.

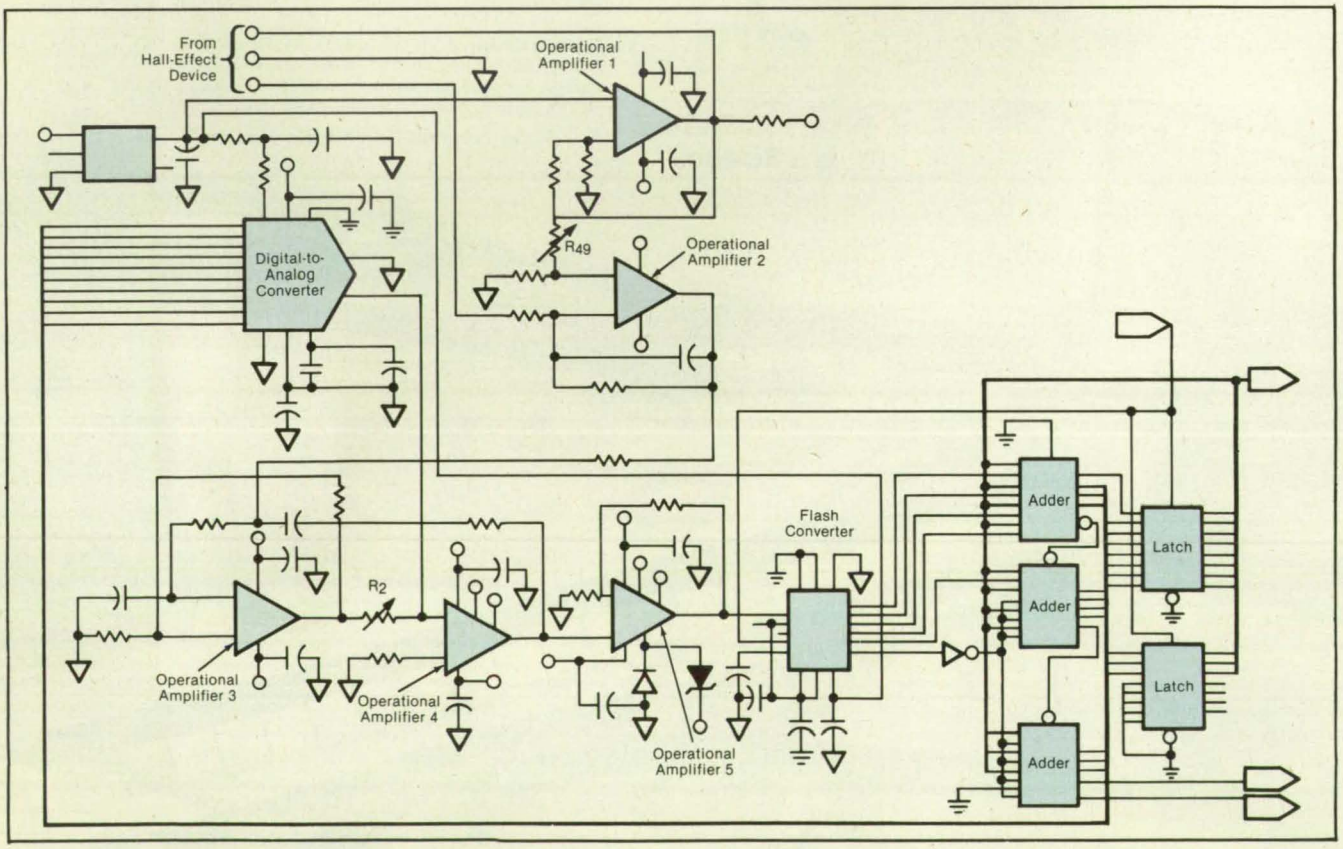
Operational amplifiers 4 and 5 act together as an error amplifier. Operational amplifier 4 acts as a summing node, and its output is proportional to the sum of the negative output of the digital-to-analog converter and the positive output of operational amplifier 3. Operational amplifier 5 has a gain of 16, which is chosen to scale the error signal to the proper amplitude for the flash converter. The input to the flash converter has an offset voltage level of 0; an input above, at, or below 2.5 V is considered positive, zero, or negative, respectively.

The positive or negative output of the flash converter is added to the previous value of current provided by the latch circuits, which also feed the output data lines. The outputs of the adders are fed back to the digital-to-analog converter, which provides input to the summing node of operational amplifier 4 to generate a new input for the flash converter.

The output can be scaled by adjusting R_2. The zero offset is adjusted by adjusting R_{49}. These two adjustments affect each other and must be performed together.

This work was done by Stephen H. Osborn, Bryan L. Davies, and Craig C. Sullender of Rockwell International Corp. for **Lewis Research Center**. *For further information, Circle 91 on the TSP Request Card.*

LEW-15025



The **Digital-to-Analog Converter** digitizes the output of a Hall-effect current sensor to 11 bits at a sampling rate of 4 MHz.

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Magnetic Direct-Current-Measuring Circuits

Current is measured via saturation/unsaturation transients in magnetic cores.

Lewis Research Center, Cleveland, Ohio

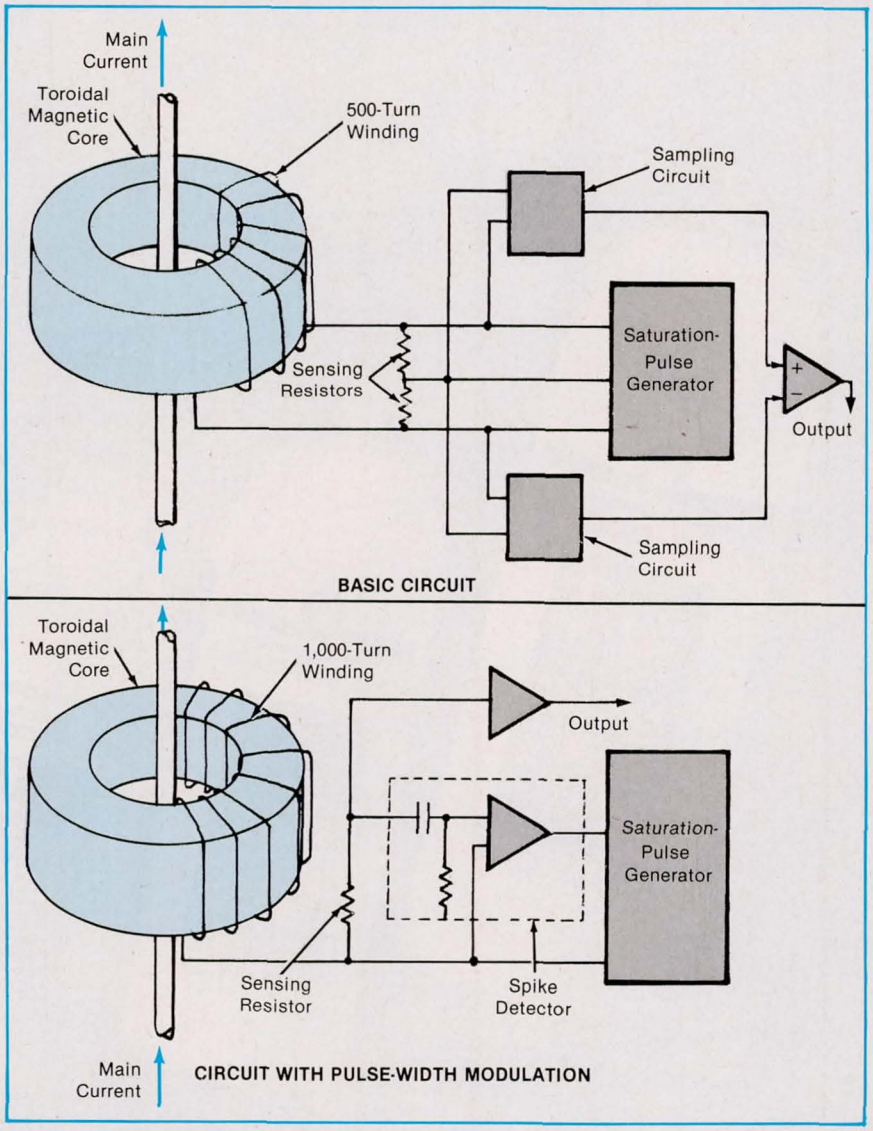
Two circuits measure large direct currents (as much as 150 A) in main conductors by use of the magnetic fields produced by these currents in glassy metal toroidal ferromagnetic cores that surround the main conductors (see figure). In both circuits, the direct currents to be measured are deduced from the transient voltages generated in multiturn windings by the transitions between the magnetic fields produced by the measured currents and the saturation magnetic fields of the cores.

The figure illustrates both circuits in greatly simplified form. In the basic circuit, pulses of alternating polarity are applied to a 500-turn winding on the core to reset the core to saturation alternately in one direction, then in the other direction. During each interval between saturating pulses, the transition from the saturation magnetic field to the magnetic field produced by the measured current generates a transient voltage in the winding. This transient voltage is applied to sensing resistors and sampled.

Depending on the polarity of the saturating current and of the current to be measured, the transient voltage during one sampling interval is approximately proportional to $I+NI_S$ (where I is the current to be measured and I_S is the magnitude of the saturation current), while the transient voltage during the next sampling interval is proportional to NI_S-I, or vice versa. A comparator subtracts samples from each other in sequential pairs to obtain an output voltage proportional to I.

In the more advanced circuit, the winding on the core consists of 1,000 turns, and the durations of the saturating pulses are repeatedly adjusted so that each pulse is terminated as soon as saturation is detected. This feature reduces the consumption of power and heating by preventing the waste of saturation current. A 10-mV spike transient across the sensing resistor indicates the moment of saturation; when the circuit senses this transient, it turns off the saturating pulse.

This circuit requires an average saturation current of 50 mA to measure a main current of 150 A, whereas the basic circuit requires about six times as much average saturation current. The use of pulse-width modulation also helps to maintain accuracy at high measured currents.



The **Magnetic Direct-Current-Measuring Circuits** measure large main currents via electromagnetic transients between pulsed saturation and dc magnetic fields in toroidal cores.

This work was done by Craig C. Sullender, Daniel D. Johnson, Dan E. Walker, Marek Gajewski, and Dale S. Krasnow of Rockwell International Corp. for **Lewis Research Center**. *For further information, Circle 44 on the TSP Request Card.* *LEW-15070*

Another Nulling Hall-Effect Current-Measuring Circuit

Features include reduced weight and increased accuracy and stability.

Lewis Research Center, Cleveland, Ohio

A lightweight, low-power circuit (see figure) provides noncontact measurement of an alternating or direct current of many amperes in a main conductor. The circuit is of the nulling Hall-effect type, which has been described previously in *NASA Tech Briefs*. To recapitulate: The current in the main conductor produces a magnetic field in a toroidal ferrite core through which it passes. A small current in a multiturn coil wound on the core (about 1/500 the main current in this case) opposes the magnetic field produced by the main current. A Hall-effect sensor in a gap in the core measures the net magnetic field, and the associated cir-

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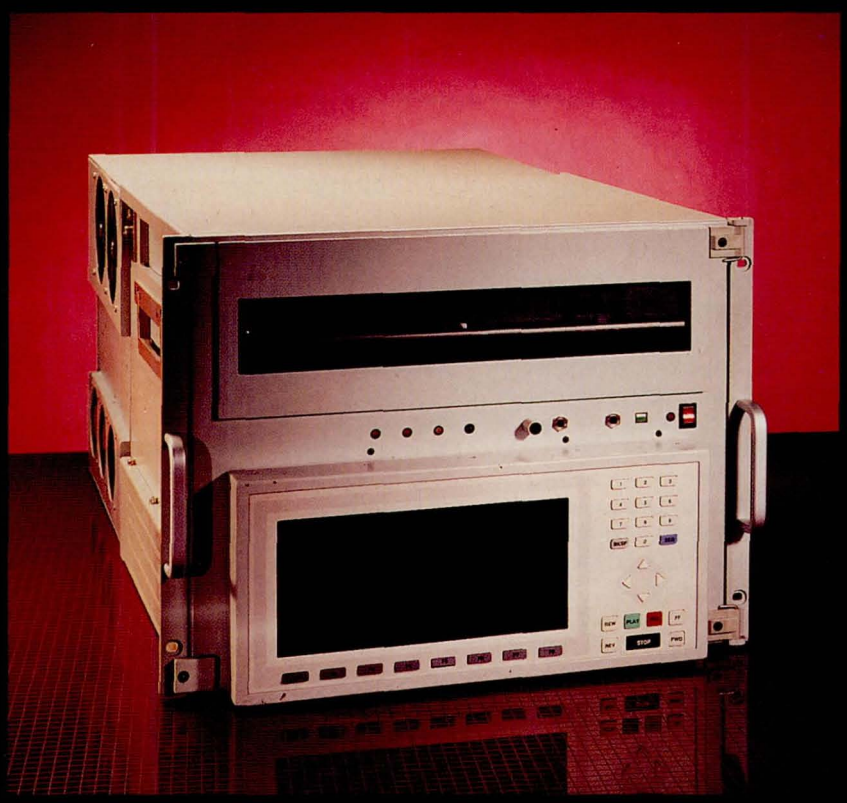

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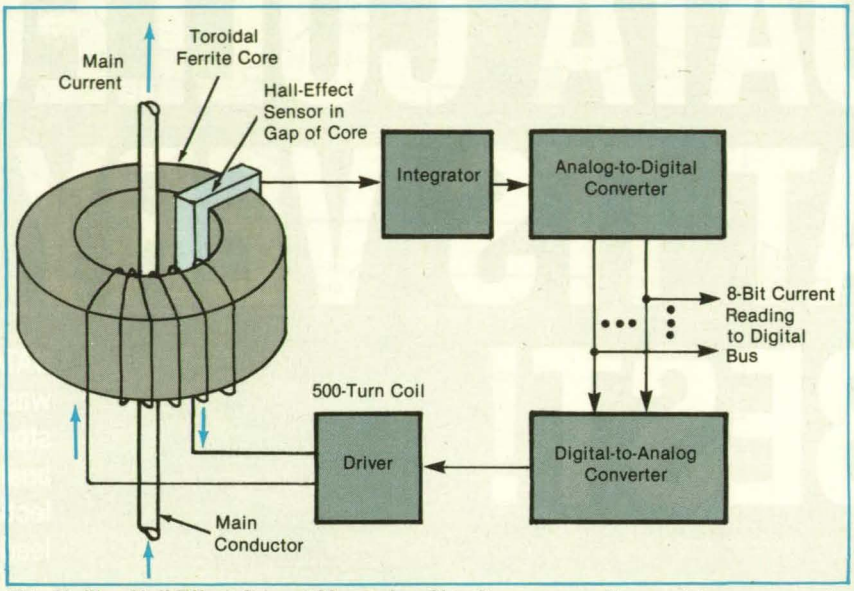
cuitry responds to this measurement by repeatedly adjusting the current in the 500-turn coil to bring the net magnetic field toward zero.

This and other nulling Hall-effect current-measuring circuits offer two important advantages over nonnulling Hall-effect current-measuring circuits: (1) the size and weight of the core can be kept low because there is no need for the large core that would otherwise be needed to prevent magnetic saturation, and (2) operation at the null point increases the linearity and temperature stability of the response of the Hall-effect sensor.

In this circuit, the output voltage of the Hall-effect sensor is integrated, amplified, and applied to an analog-to-digital converter. The output of the analog-to-digital converter is also converted back to analog, in which form it is used to drive the current in the multiturn (in this case, 500-turn) coil. The output of the Hall-voltage integrator (and the corresponding outputs of the analog-to-digital converter, digital-to-analog converter, and current in the 500-turn coil) increases until the net magnetic field in the core falls to zero, as signaled by zero Hall voltage. At this null point, the output of the analog-to-digital converter is a measure of the small current in the 500-turn coil.

The exact proportionality between the small and main currents can be determined via a calibration reading and can be adjusted by adjusting the reference voltage supplied to the digital-to-analog converter. One of the advantages of this circuit over other nulling Hall-effect current-measuring circuits is that stability and accuracy are increased by putting both the analog-to-digital and digital-to-analog converters in the nulling feedback loop. These converters and the rest of the circuit are designed for operation at a sampling rate of 100 kHz, but this rate can be changed to alter the time or frequency response of the circuit.

This work was done by Phillip E. Thibodeau and Craig C. Sullender of Rockwell International Corp. for **Lewis Research Center**. *For further information, Circle 43 on the TSP Request Card.*
LEW-15069



This **Nulling Hall-Effect Current-Measuring Circuit** uses a small current to measure a large current by canceling the magnetic field produced by the large current in what amounts to a 1-to-500 toroidal-core transformer.

Electric-Field Instrument With ac-Biased Corona Point

Measurements indicative of incipient lightning could be made to yield additional information.

John F. Kennedy Space Center, Florida

An instrument that measures the electrostatic potential of the atmosphere at a preset height (usually about 18 m) above the ground is an improved version of the old corona-point sensors that were used to measure electric fields associated with clouds capable of producing lightning. The corona-point sensors gave unreliable readings, but the new instrument gives reliable readings. There is a plan to deploy a network of the instruments along with a network of electric-field-measuring instruments called "field mills," which are mounted close to the ground.

By utilizing the measurements from both sets of instruments, one could estimate the density of the space charge of ions that have been put into the air by corona discharges in the vicinity and that have been blown into the vicinity by the wind. Knowledge of the space charge is important because it distorts the measurements of the field mills: in effect, the space charge makes the field mills less sensitive to the cloud-to-ground electric fields associated with lighting. To determine space-change density, it is necessary to measure the electric field or potential at a point well above ground level as well as the electric field at ground level. This is facilitated by the characteristic of corona systems to work best when the needle is elevated on a mast, while it is difficult to operate field mills in such locations. Thus, the improved corona-point instrument is expected to yield additional information that may assist in the safety-oriented forecasting of lighting.

The old corona-point sensors yielded unreliable readings in two respects: (1) they were so sensitive to winds that they acted more like anemometers than like the potential probes they were meant to be; (2) grounded points (like the old corona points) do not go into corona until thunderstorm electric fields rise to about 2 kV/m. Thus, even during thunderstorms, the old corona-point sensors did not function 20 to 50 percent of the time.

The new instrument overcomes both limitations. To suppress the modulation by wind, a resistance of $5 \times 10^{10}\ \Omega$ is placed in the path of the discharge current. This ensures that most of the resistive voltage drop between the ground and the atmosphere occurs across this known, stable resistance rather than across the wind-sensitive variable resistance of the cloud of ions around the corona needle.

To overcome the 2-kV deadband, the needle is kept in corona at all times by use of a 60-Hz ac high-voltage power supply, which is connected to the corona needle through a capacitor network bridging the input resistor array. The high alternating voltage maintains a cloud of ions around the point, so that current can flow, even during weak fair-weather electric fields.

The improved corona-point instrument (see figure) includes a sharply pointed stainless-steel needle 3 in. (about 8 cm) long, which protrudes from the end of a metal rod ½ in. (about 13 mm) in diameter and 8 ft (about 2.5 m) long, which extends up from a poly(methyl methacrylate) tube 10 ft (about 3 m) long and 3 in. (about 8 cm) in diameter. The tube contains the 5×10^{10}-Ω resistor and capacitor network potted in an

Low Profile 15-W DC/DC Converters

The new AHV 2800 series of 15W DC/DC converters features high power densities and ruggedized low-profile packages only 0.405 inches high. They are available in single, dual and triple output models and are fully compliant with MIL-STD-704 (A-E), MIL-STD-883 and MIL-H-38534. All AHV 2800 DC/DC converters withstand the 80-Volt surge requirement of MIL-STD-704A and operate over the full military temperature range of -55°C to +125°C with no derating of power output. These devices all have nominal 28 VDC inputs and operate over a 16 VDC—40 VDC range. The AHV 2800 series feedback design is impervious to temperature, radiation, ageing or variations in manufacture. The unique circuitry provides high control loop gain, high phase margin, and an extremely wide bandwith.

For More Information Circle Action No. 374

Low Profile 12-W DC/DC Converters

The AHF 2800 series of DC/DC converters feature single or dual outputs over the full military temperature range. No derating in output power is required, making them suitable for use in rugged military applications. The low profile, small outline package is ideally suited to the tight board space requirements of many industrial and aerospace applications. Designed for nominal 28 VDC inputs, this family of converters meets all the requirements of MIL-STD-704D.

The proprietary magnetic feedback circuit provides for an extremely wide bandwidth control loop with a high phase margin. These converters are manufactured in a facility fully qualified to MIL-STD-1772. Two temperature ranges and screening grades are available to satisfy a wide range of requirements.

For More Information Circle Action No. 375

Triple Output 30-W DC/DC Converter

The ATR 2815T triple output DC/DC converter provides 30 watts of output power over the full military temperature range with no derating. This device is pin compatible with ATO series converters but offers twice the maximum output power in a lower profile package. A custom CMOS ASIC pulse width modulator and a patented magnetic feedback circuit reduce circuit complexity and enhance reliability. This converter provides 500-Volt input to output isolation and operates in a highly efficient single forward mode.

The advanced design features an extremely wide bandwidth control loop with high gain and phase margin. The control loop is compensated to provide optimum performance over the full military temperature range and over the 16 to 40-Volt input voltage range.

For More Information Circle Action No. 376

High-power 40-W DC/DC Converter

The AFW 2805S hybrid DC/DC converter features high power density and full military temperature range operation without output power derating. The advanced feedback design provides fast loop response for superior line and load transient characteristics and offers greater reliability than devices incorporating optical feedback circuits. The basic circuit topology is a push-pull configuration operating at a nominal switching frequency of 500Khz.

This device is designed to meet MIL-STD-704A input requirements offering full performance over a 16- to 50-Volt input range and operating at 80 Volts for 100 milliseconds or 100 volts for up to 5 milliseconds. The AFW 2805S is packaged in a rugged parallel seam welded steel case using ceramic feedthrough pins to assure true long term hermeticity.

For More Information Circle 378

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Advanced Analog's high-performance DC/DC converters are now being shipped for mission-critical space applications. To meet space requirements, proven radiation-hardened components are used in all necessary areas, such as the custom integrated circuits and power MOSFETs. And, because the magnetic pulse feedback circuits do not use opto-couplers or generate spurious RF energy, they are unaffected by time, temperature or radiation. These converters are all implemented using thick film hybrid technology and are fully certified and qualified to MIL-STD-883.

For More Information Circle 379

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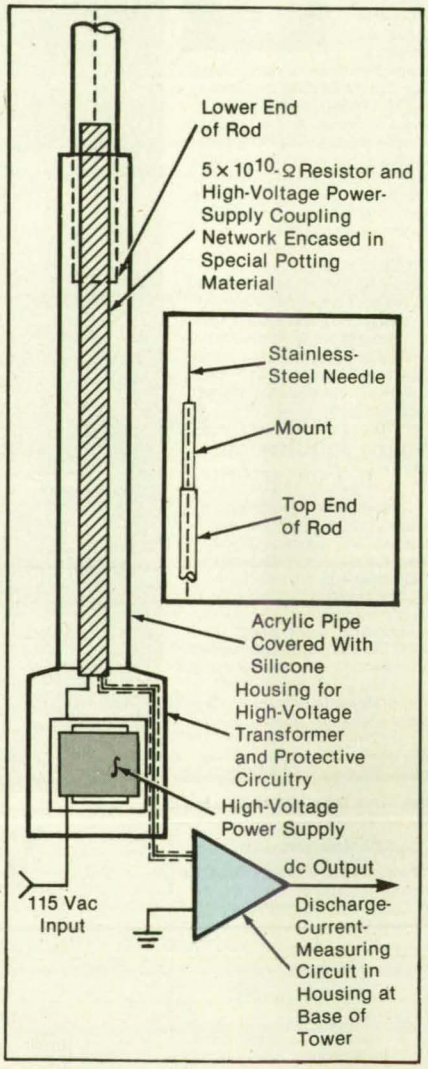
electrically insulating silicone compound. The needle is connected through this high resistance to a circuit that measures the slowly varying (at frequencies ≤ 10 Hz) component of the discharge current that in turn, is indicative of the potential of the atmosphere around the needle with respect to ground. Electric-field intensity (if desired) can be calculated by dividing the potential at the top of the pole by the height of the pole (in meters) times an experimentally determined constant.

This work was done by R. Markson, B. Anderson, and J. Govaert of Airborne Research Associates for **Kennedy Space Center**. *For further information, Circle 90 on the TSP Request Card.*
KSC-11507



High-Voltage ac Bias applied to the needle point through a high-resistance capacitance network provides a corona discharge at all times, enabling the more-slowly-varying component of electrostatic potential of the needle to come to equilibrium with that of the surrounding air. The high resistance of the high-voltage coupling makes the instrument insensitive to wind.

Nulling Hall-Effect Current-Measuring Circuit

Accuracy of measurement does not depend on linearity of the sensing components.

Lewis Research Center, Cleveland, Ohio

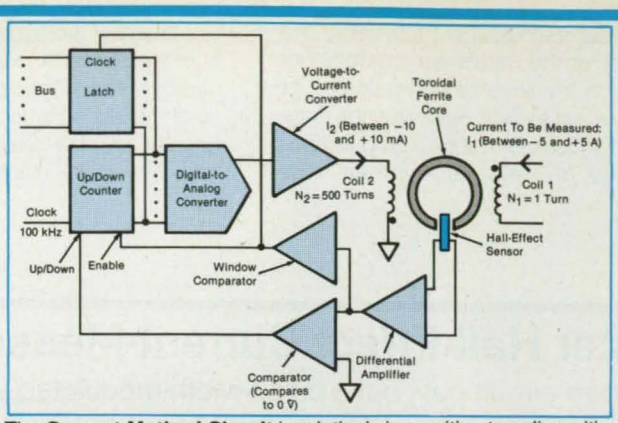
A circuit measures electrical current via a combination of Hall-effect-sensing and magnetic-field-nulling techniques. A known current generated by a feedback circuit is adjusted until it causes the cancellation or near cancellation of the magnetic field produced in a toroidal ferrite core by the current to be measured. The remaining magnetic field is measured by a Hall-effect sensor. The circuit puts out an analog signal and a digital signal proportional to the current to be measured.

The current I_1 to be measured, which lies in the range ±5 A, is carried by coil 1 (N_1 = 1 turn) wound on the core. The opposing magnetic field is generated by the feedback-controlled current I_2 in coil 2 (N_2 = 500 turns, 32-gauge wire), which is wound on the core in the opposite direction. The Hall-effect sensor is inserted in a small gap in the core, where the magnetic field is concentrated (see figure).

When $N_1I_1 = N_2I_2$, the two opposing magnetic fields cancel and the Hall-effect sensor puts out zero voltage. Otherwise, when I_1 increases above (or decreases below) this null point, the Hall voltage increases (or decreases) and causes the output of the comparator to go high (or low); this, in turn, causes the up/down counter to count up (or down). The digital output of the up/down counter is fed to the digital-to-analog converter, and the increase (or decrease) in the count causes an increase (or decrease) in the voltage applied to the voltage-to-current converter that supplies I_2 to coil 2.

By this process, I_2 continues to increase (or decrease) until $N_2I_2 \approx N_1I_1$ and the Hall voltage comes within a small range near 0 V, within which range the window comparator disables the counter and causes the clocking, into the latch, of the digital word that represents the most recent count. This count is proportional to I_2 and, therefore to I_1, the current to be measured. In a test, the circuit was found to provide accurate measurements of a ±5-A, 10-Hz sinusoidal current in coil 1. As predicted by the equation $N_1I_1 = N_2I_2$, an I_2 of only ±10 mA was sufficient to achieve the null condition.

One of the principal advantages of this circuit is that it measures the small nulling current rather than the large unknown current. Because the circuit operates at



The **Current-Method Circuit** is relatively insensitive to nolinearities in the sensing components because it maintains nearly zero net magnetic field in the core.

or near null magnetic field in the core, the accuracy of the measurement does not depend on the linearity of the core or of the Hall-effect sensor. By preventing magnetic saturation of the core, nulling extends the range of measurable current. The placement of the digital-to-analog converter in the feedback loop increases the accuracy of the measurement. The frequency of the clock that controls the up/down counter can be changed to adjust the response of the feedback loop.

This work was done by Craig C. Sullender, Juan M. Vazquez, and Robert I. Berru of Rockwell International Corp. for **Lewis Research Center**. *No further documentation is available.*
LEW-15023

Faster Hall-Effect Current-Measuring Circuit

A simpler circuit puts out a pulse-width-modulated signal.

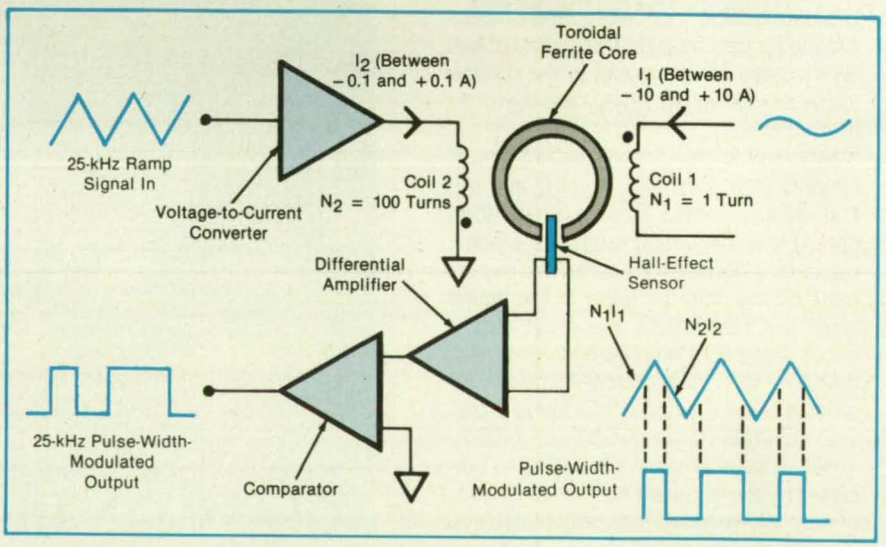
Lewis Research Center, Cleveland, Ohio

A current-measuring circuit operates on Hall-effect-sensing and magnetic-field-nulling principles similar to those described in the preceding article, "Nulling Hall-Effect Current-Measuring Circuit," but is simpler and responds faster. Usually, nulling Hall-effect circuits like the preceding one have responses slower than those of the Hall devices in them. To obtain faster response, the present circuit is designed without a feedback loop, and analog pulse-width-modulated output (instead of digital output, as in the preceding circuit) indicates the measured current. This circuit can measure current at a frequency higher than the bandwidth of its Hall-effect sensor.

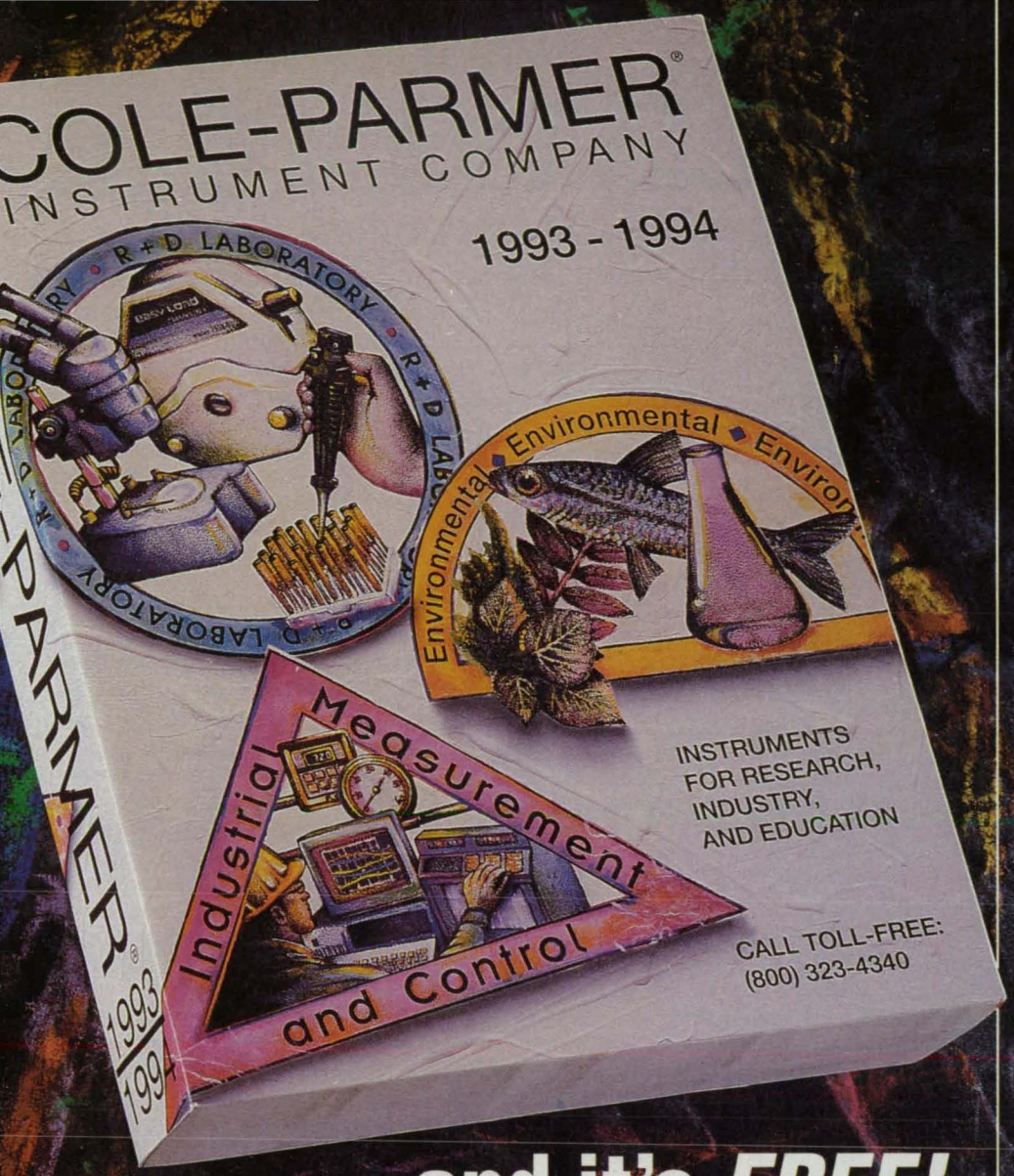
As in the preceding circuit, a small current I_2 in a coil of N_2 turns on a toroidal ferrite core generates a magnetic field in the core. This magnetic field counteracts the magnetic field generated in the core by a larger current I_1 (the current to be measured) flowing in a coil of N_1 turns wound on the core. As in the preceding circuit, when $N_1I_1 = N_2I_2$, the net magnetic field in the core is zero, and the Hall-effect sensor puts out zero voltage. Also, as in the preceding circuit, this method of comparison prevents magnetic saturation of the core, confines magnetic-flux density at the Hall-effect sensor to a very small operating range, and extends the range of measurable current.

In this circuit (see figure), I_2 is a 25-kHz triangular waveform. When $N_1I_1 > N_2I_2$, the Hall voltage is positive and the output of the comparator is low. As I_2 ramps up to make $N_1I_1 < N_2I_2$, the Hall voltage goes negative, causing the output of the comparator to go high. After I_2 reaches its peak, it ramps down again, and when N_2I_2 once again passes below N_1I_1, the output of the comparator goes low. I_2 continues to ramp down, then ramps up again, and the cycle repeats. As I_1 increases, the time during which N_2I_2 exceeds N_1I_1 (and the output of the comparator is high) grows shorter. Thus, the output of the comparator is a 25-kHz rectangular wave in which the durations of the high and low output levels are measures of the current I_1. In experiments with a prototype of this circuit, I_1 was measured at the 25-kHz sampling rate with an F. W. Bell Hall-effect device, which has a bandwidth of 6 kHz.

This work was done by Craig C. Sullender, Daniel D. Johnson, and Daniel D. Walker of Rockwell International Corp. for **Lewis Research Center**. *No further documentation is available.*
LEW-15024



This **Simple, Fast Nulling Hall-Effect Current-Measuring Circuit** puts out a pulse-width modulated signal. The leading and trailing edges of the output pulses mark the times when a known triangular measuring-current waveform nulls the magnetic field produced by the measured current. Thus, the pulse-width modulation is an indication of the measured current.



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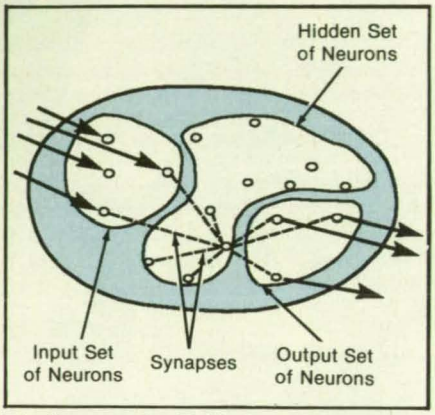
Generalized Adaptive Artificial Neural Networks

Some of the restrictions of a prior mathematical model are removed.

NASA's Jet Propulsion Laboratory, Pasadena, California

A mathematical model of supervised learning by an artificial neural network provides for simultaneous adjustments of both the temperatures of the neurons and the synaptic weights (the strengths of the synaptic connections), and can include feedback as well as feedforward synaptic connections. This is an extension of the mathematical model described in "Adaptive Neurons for Artificial Neural Networks" (NPO-17803), *NASA Tech Briefs*, Vol. 14, No. 12 (December 1990), page 25. That model included feedforward synaptic connections only. In addition, the dynamics of the neural network are represented in the new model by a less-restrictive continuous formalism, whereas in the prior model, the dynamics were represented by a more-restrictive discrete formalism.

In this as in other models, the N neurons of the network are divided into sets of input, hidden, and output neurons (see figure). The response of each neuron to the sum of its inputs is a sigmoid function. The "temperature" mentioned above is not really a temperature but is a parameter that governs the shape of the sigmoid curve. The dynamical state of the system consisting of a network of N neurons is represented by a point in the N-dimensional space of the activities (outputs) of the neurons. The trajectory of this point is described by a set of N coupled, dissipative, first-order, linear differential equations in which the synaptic weights and the temperatures are regarded as quasi-static or adiabatically varying in the sense that they vary on time scales much greater than those that characterize the relaxation of the network to a steady state.



The **Neurons Are Divided** into three sets in this model as in other mathematical models of neural networks. The parameters of the neurons and synapses are adjusted during learning to force the outputs toward the correct values.

As in the prior model, supervised learning is an iterative process in which a training set of stimulus vectors is applied to the input neurons and the responses of the output neurons are forced toward the correct responses by adjusting the temperatures and synaptic weights of all the neurons. For this purpose, the error in the responses of the output neurons is quantified as the sum-square difference between the actual and correct quasi-steady responses of the output neurons.

The gradients of this error function are computed in the vector spaces of the synaptic weights and temperatures (actually, the reciprocals of the temperatures). Then the adjustments are made in the form of motions down the gradients of the error function in the vector spaces of the synaptic weights and reciprocals of temperatures. The resulting motions traveled along the gradients on each iteration are governed by explicit characteristic time scales chosen to be much longer than the relaxation time of the network (as mentioned previously).

This work was done by Raoul Tawel of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 2 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 26]. Refer to NPO-18579.

Test-Matrix Sequencer

Repetitive tasks in laboratory tests are automated to increase productivity.

Lewis Research Center, Cleveland, Ohio

The test-matrix sequencer is a digital/analog electronic system that provides for automatic implementation of multiple interrelated sequences of test conditions in a laboratory experiment. (The system is so named because the specification of test conditions in a complicated experiment is typically given in the form of a matrixlike two-dimensional list.) By automating the repetitive tasks that would otherwise have to be performed manually to implement the test matrix, the test-matrix sequencer can increase the productivity of the laboratory. Although the test-matrix sequencer is designed for use in testing aeronautical propulsion systems in wind tunnels, it has potential for use in automated testing laboratories in general, sequencing of servo-controlled actuators, and programming of robotic manipulators.

The system (see figure) provides set points to controllers (for example, orientations of a model or positions of a probe) and contact closures to data systems (e.g., commands to record data in specified channels) during the course of a test. The system includes a microprocessor controlled by a personal computer that runs easy-to-use, special-purpose software. The software, which is the main element of the system, is interactive and menu-driven with popup windows and help screens. The software enables the technician to configure, store, and run complete test matrices from the computer keyboard. The software also enables the computer to control the digital input and output channels in the microprocessor automatically; alternatively, the technician can control the input and output channels directly from the keyboard.

At each test point, the system verifies the operation of the test-controlling equipment, turns on recorders, waits for permission from the technician to proceed with the test, and handles communications with external data-processing equipment. The microprocessor performs all of the low-level input/output tasks in parallel-processing fashion; this enables the computer to continue to run the test matrix, monitor the channels, and keep the technician informed of the status of the test.

The system includes 14 analog and 15 dig-

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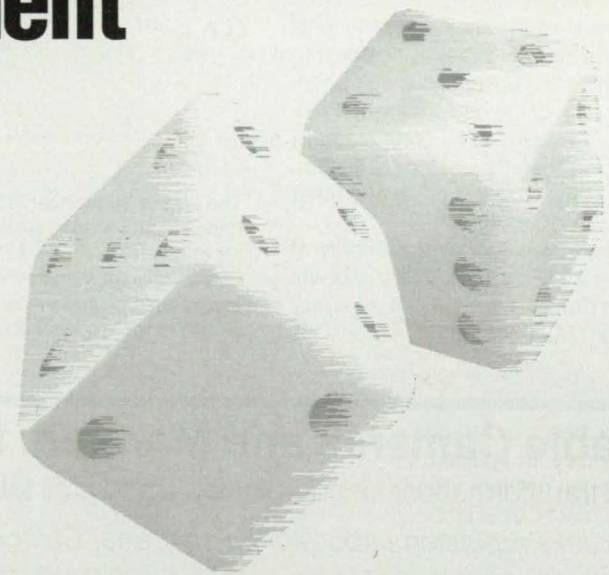

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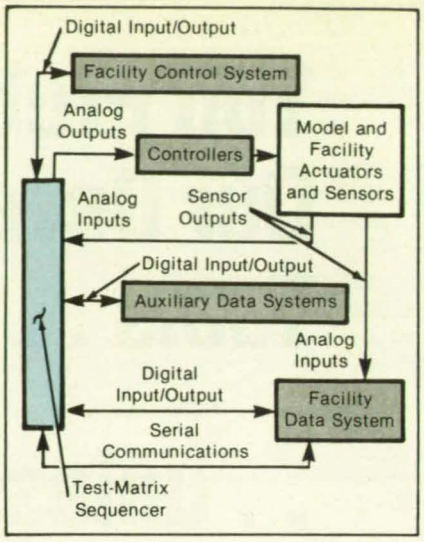
ital input/output channels that can be configured by the technician. Another 14 channels can acquire additional analog inputs from the laboratory data system. The system is fully programmable and is capable of handling 50 unique test points and multiple test sequences.

The test-matrix sequencer has been used in three of the major wind tunnels at Lewis Research Center. It has proven valuable in setting up test equipment, verifying operation of the equipment, and running tests. Because of its great success in enhancing the efficiency of operation, there are plans to use it in several other aeropropulsion facilities.

This work was done by Timothy P. McCartney and Edward F. Emery of **Lewis Research Center**. *Further information may be found in NASA TM-103108 [N90-23416], "A Test Matrix Sequencer for Research Test Facility Automation."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.
LEW-15387



The **Matrix Sequencer** is a microprocessor-based digital/analog system that automates repetitive tests in the setup and operation of a complicated experimental apparatus — for example, a wind tunnel containing a model with multiple control actuators and sensors.

Movable Cameras and Monitors for Viewing Telemanipulator

Various transformations of coordinates could facilitate remote handling.

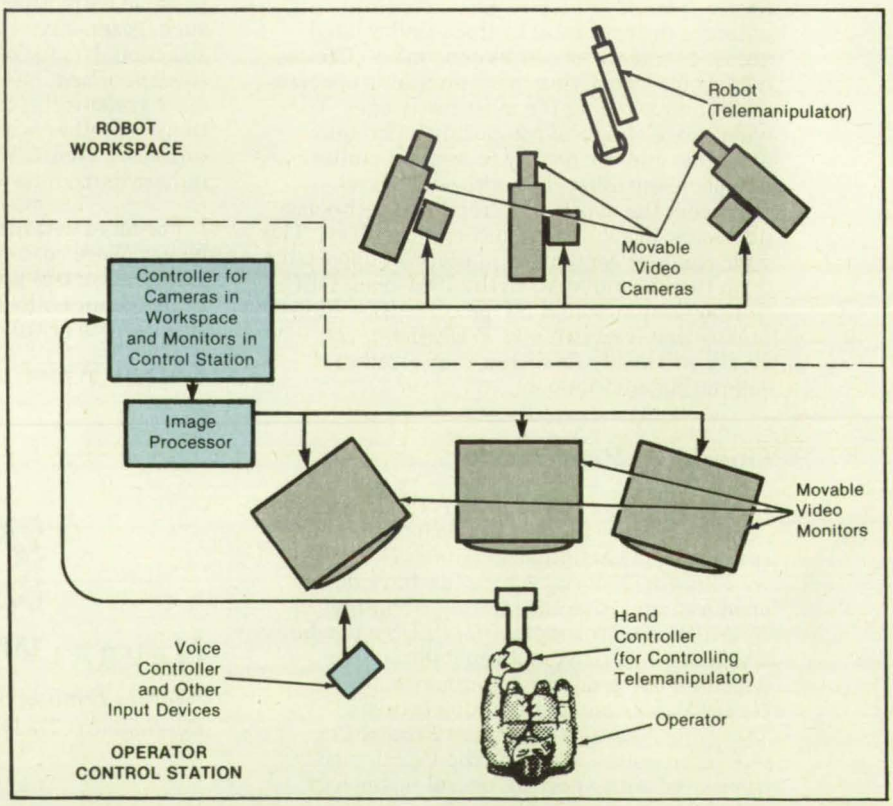
NASA's Jet Propulsion Laboratory, Pasadena, California

Three methods have been proposed to assist an operator viewing a telemanipulator on a video monitor in a control station when the video image is generated by a movable video camera in the remote workspace of the telemanipulator. These methods could reduce the operator's workload and the probability of error by obviating the need for the mental transformations of coordinates during operation. The methods could be applied in outer space, undersea, in the nuclear industry, in surgery, in entertainment, and in manufacturing.

Any panning, rolling, or tilting of the cameras in the workspace affects the relationships between the coordinate system of the camera and the coordinate system of the operator. Consequently, the operator needs to transform coordinates mentally during operation; if several movable cameras are presenting their images to several monitors (see figure), each may require a different coordinate transformation. The increase in workload and probability of operator error may well become unmanageable and dangerous.

In one of the three methods intended to overcome this difficulty, each monitor would be mounted on an automated platform that would pan, tilt, roll, and shift with the camera, the image of which it displayed. In this manner, the operator would not need to transform coordinates at all. No matter how many cameras and monitors a system might have, if the coordinates of the hand controller of the manipulator matched the workspace coordinates, then they would also always match all the camera-monitor coordinates; for example, pushing the hand controller forward (away from the operator) would show the robot arm moving away from the operator on all of the monitors.

In another of the three methods, one would minimize the required motions of the monitors by digital processing of the video images. Each monitor would display an image that had been compensated for the rotation of its corresponding camera. If, in addition, each monitor graphically displayed the location of its camera, then the operator would always know the configura-



Video Monitors at the Control Station would be rotated or shifted and/or the images in them would be transformed to adjust the coordinate systems of the scenes visible to the operator according to the motions of the cameras and/or the operator's preferences.

tion of the cameras and manipulator in the remote workspace, and all of the coordinate systems would match.

In the remaining one of the three methods, one would change the coordinates of the hand controller to match those of one of the cameras, while the monitor remained fixed. If there were more than one monitor, this method would be disadvantageous in that the coordinates of the hand controller would match those of only one of the monitor/camera pairs, and the operator would have to remember which one (or tell the system which one) to avoid making a possibly dangerous mistake. However, if the system included several movable cameras but only one monitor, this disadvantage could be eliminated by making the system match the coordinates of the hand controller to those of whichever camera is connected to the monitor at the moment.

This work was done by Daniel B. Diner and Steven C. Venema of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 3 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 26]. Refer to NPO-17837.

Robot-Control Station Would Adapt to Operator

A conceptual system would enhance the operator's performance.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed control station for a remote robot would adapt the control system to the personal characteristics and preferences of the operator. It would automatically adjust the positions and angles of video cameras and monitors, adjust the characteristics of a hand controller, process images, and provide the graphical displays that serve the particular operator best. The station would be suitable for use in nuclear, underwater, surgical, industrial, and entertainment applications.

A system of one or more video cameras, controlled by a computer, would view the workspace of the robot, as shown in the preceding article, "Movable Cameras and Monitors for Viewing Telemanipulator" (NPO-17837). The control station could include several video monitors, a hand controller, an image-processing system that would also provide graphical displays, a voice-input command system, keyboards, and a mouse.

The configuration of the system that best enhances an operator's performance would first be determined experimentally for each type of task. Thereafter, whenever that operator was identified as being in control, the system would automatically reset itself for that operator.

For operators who have anomalies of stereoscopic vision, the system would make appropriate adjustments in its stereoscopic displays. For example, if an operator had high stereoscopic acuity beyond a fixation point but was stereoscopically insensitive to positions in front of that point, the system would converge the stereo cameras to a point slightly in front of the critical area of the workspace for the particular task.

One operator may work best with perspective views of the workspace from a pair of cameras tilted at 15°. Another operator might find this presentation inadequate and want orthogonal views from three cameras — from front, top, and side. The system would readily accommodate such preferences.

Certain operators may prefer high gain in the hand controller for large robot movements and low gain for fine movements. Others may become confused by changes in gain and prefer an intermediate level at all times. The system would satisfy these preferences, too — not only for each operator, but also for each task an operator performs.

Similarly, the system would provide the type and quantity of graphical information each operator wants. It would present the information in the colors and at the repetition rate the operator likes best.

This work was done by Daniel B. Diner of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 28 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 26]. Refer to NPO-17838.

Analog Processor To Solve Optimization Problems

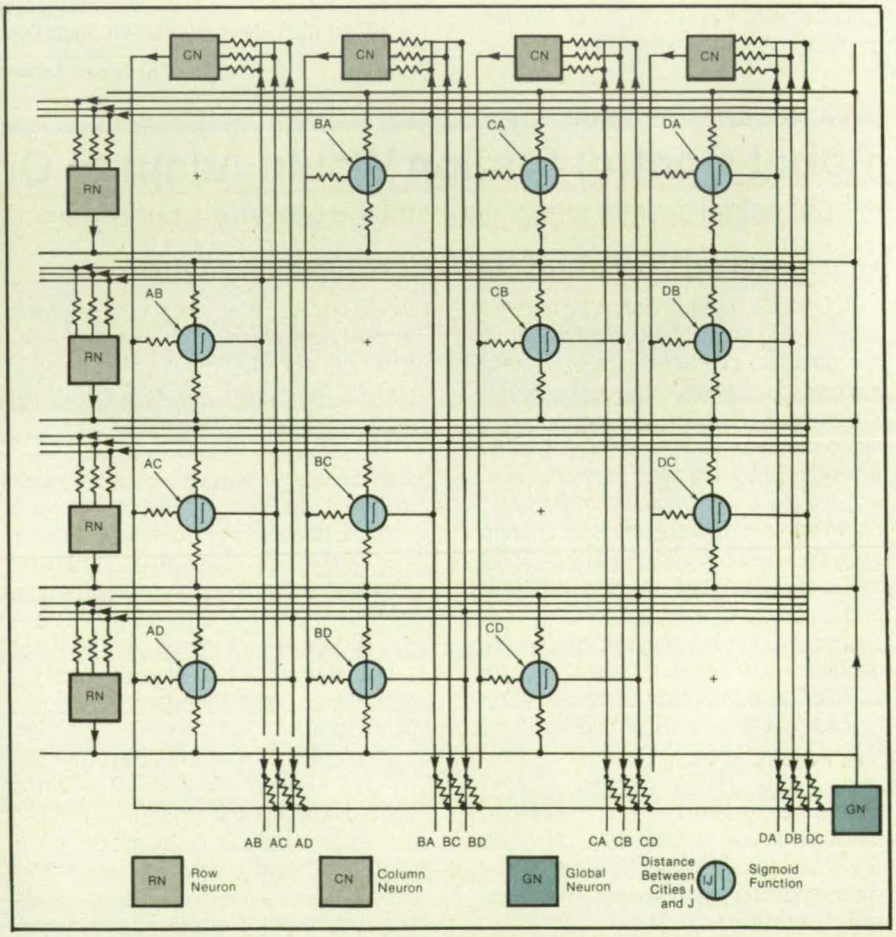
A neural network would solve the "traveling-salesman" problem.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed analog processor would solve the "traveling-salesman" problem, which is considered to be a paradigm of global-optimization problems that involve routing or the allocation of resources. The processor would include an electronic neural network and auxiliary circuitry based partly on the concepts described in "Neural-Network Processor Would Allocate Resources" (NPO-17781), *NASA Tech Briefs*, Vol. 14, No. 10 (October 1990), page 46, and "Neural Network Solves 'Traveling-Salesman' Problem" (NPO-17807), *NASA Tech Briefs*, Vol. 14, No. 12 (December 1990), page 22.

The traveling-salesman problem can be stated as follows: given N cities and knowing the distance (or the cost of travel) between any two cities, find the shortest (or cheapest) route that passes through every city once and only once. Although one could solve the problem on a digital computer by comparing the costs of all possible routes, this approach requires an impractically long computing time when N is large, because the number of routes grows factorially with the number of cities. The proposed analog processor based on highly parallel computing promises to solve the problem in significantly less time.

The processor would include a feedback neural network with analog prompting, control neurons, and a modified auxiliary circuit (which would intervene to prevent the network from settling on cheaper multiple itineraries through loops of fewer than N cities). As shown in the figure, $N(N-1)$ sigmoid-response neurons that duplicatively represent the $N(N-1)/2$ possible intercity legs of the journey would be arranged in an $N \times N$ matrix lacking the diagonal. (The network would be symmetric about the diagonal.) The outputs of the neurons in each row or column would be fed to a row (or column, respectively) control neuron, which would send an appropriate in-



This **Neural Network** would be part of an analog processor that solves the traveling-salesman problem for four cities designated A, B, C, and D.

hibitory or excitory signal back to all the neurons in the row or column to assure a valid tour with two neurons "on" and the rest of the neurons "off" in each row or column, as explained more fully below. A global control neuron would monitor the activity of all the $N(N-1)$ sigmoid-response neurons to enforce the requirement that the total number of intercity legs be N, also as explained more fully below.

Sigmoid-response neurons selected as the final solution would thus be forced to satisfy the constraints imposed by all the control neurons simultaneously, to obtain a valid solution. The symmetry across the diagonal dictates that each of the N row and N column control neurons must ensure that two and only two sigmoid neurons are "on" in each row and column. This would enforce the requirement that every city be visited once and only once in a closed tour.

After providing all the costs of the intercity travels to the matrix of sigmoid-response neurons as analog prompts, the matrix would go into action. Initially, several of the low-cost neurons would tend to come "on." If the tour were not complete, the control neurons would act on the basis of the excess or shortage in the number of the "on" neurons in each row and column, providing the desired excitation or inhibition. This process would occur simultaneously at every neuron. The global control neuron is needed to provoke the process and bring it back to within a reasonable linear region of the dynamics to enable the global exchange of information. The global control neuron would thus determine the number of sigmoid neurons that are "on" in the whole network. The global control neuron would apply an inhibitory or excitatory input to all the sigmoid-response neurons, depending on whether the number of "on" sigmoid-response neurons is greater or less, respectively, than $2N$.

The auxiliary circuit (not shown in the figure) would monitor the outputs of all sigmoid-response neurons simultaneously. Upon detecting a multiple-loop pattern in these outputs, it would send increasing cost inputs to selected neurons, thereby increasing the costs of the loops until the loops are broken, leading to the convergence of the entire network toward a global solution with a loop containing all N neurons.

This work was done by Tuan A. Duong, Silvio P. Eberhardt, and Anil P. Thakoor of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 54 on the TSP Request Card.*

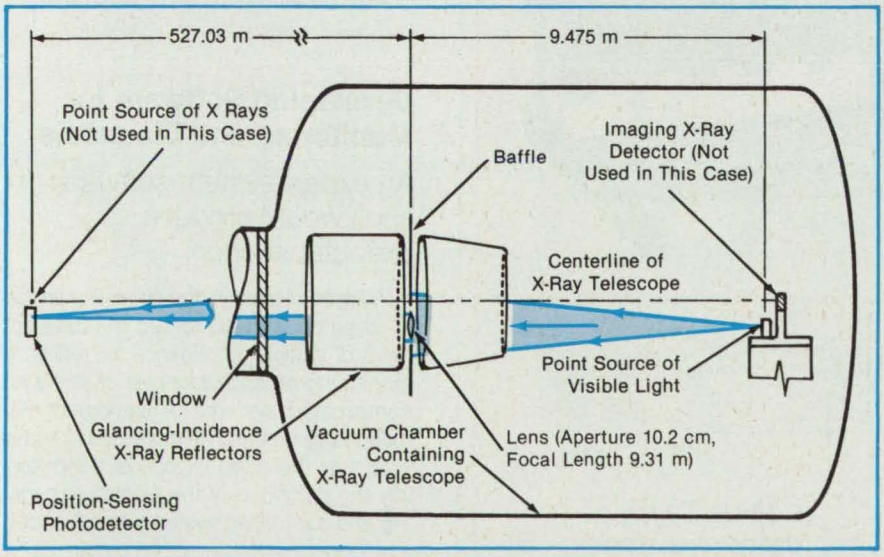
This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 26]. Refer to NPO-18390.

Measuring Small Changes in Aim of an Instrument

An x-ray telescope is operated in visible light as a projector.

Marshall Space Flight Center, Alabama

An optoelectronic system measures small changes in the direction of the line of sight of an instrument. These changes are associated with small rigid-body rotations of



The **Optical Point Source and Lens** are mounted on the x-ray telescope in reverse configuration — as a projector. The magnified relative lateral motion of the point source and lens is imaged on the position-sensing photodetector.

the instrument about axes perpendicular to the line of sight. In the specific application for which the system was designed, the instrument is an x-ray telescope in a vacuum chamber in a calibration facility; the measurements are needed to determine, among other things, to what degree small rigid-body rotations caused by seismicity affect the aim of the instrument.

The basic optical configuration is simple. A small source of visible light (regarded as a point source) is mounted in the telescope near the x-ray imaging detector, and a lens is mounted between the glancing-incidence x-ray reflectors of the telescope. The point source and lens are aligned so that they image the point source onto a position-sensing photodetector located far from the telescope, near the x-ray source (see figure). Thus, the x-ray telescope is effectively converted to a visible-light instrument and operated in reverse — as a projector. The motion of the image of the point source on the position-sensing photodetector is a magnified version of the relative lateral motions of the point source and lens; in the case of the dimensions shown in the figure, the magnification factor is 55.6. Thus, the projection configuration increases the sensitivity of the measurement.

The visible light, at a wavelength of 6,238 Å, is generated by a 47-mW helium/neon laser outside the vacuum chamber. The laser light is injected via a microscope objective lens into an assembly of fiber-optic cables. The cables conduct the light into the vacuum chamber and to the source fixture in the telescope. The ends of 19 optical fibers in the final leg of cable are held rigidly in a hexagonal-close-packed array. The array is large enough so that at least one fiber end is within view (and therefore available for use as the point source) in case of a drift or shift in alignment of the telescope.

The position-sensing photodetector puts out four currents, the normalized differences between which are approximately proportional to the coordinates of the centroid of the image relative to the center of the detector plane. The currents are fed to a four-channel transimpedance amplifier, which converts them to voltages. The voltages are digitized and fed to a computer. The motions of the centroid and the corresponding rigid-body rotations of the telescope are then computed from the digitized voltages from coordinate transformations derived from calibration of the position-sensing photodetector, and from the magnification.

This work was done by Jonathan W. Arenberg and Scott C. Texter of TRW, Inc., for **Marshall Space Flight Center**. *For further information, Circle 48 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 26]. Refer to MFS-28663.

Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

Developing Software for Monitoring and Diagnosis

An expert-system software shell would produce executable code.

A report discusses the beginning phase of research directed toward the development of artificial intelligence for real-time monitoring of, and diagnosis of faults in, complicated systems of equipment. Although this research is motivated to some extent by the need for onboard monitoring and diagnosis of the electronic sensing and controlling systems of advanced

aircraft, it takes a general approach that should also make it applicable to such equipment systems as refineries, factories, and powerplants.

The intended product of the research and development is an expert-system software shell of the knowledge-compiler type that could convert the knowledge base into programs in conventional procedural programming languages for execution by the various monitoring, controlling, and diagnosing microprocessors in a system. Here, this software concept is generalized into a rule-set-processor (RSP) method that would enable the specification of topological and procedural application knowledge for time-critical applications, the interactive development of an expert software system based on this specification, and the integration of a machine-code version of this software into a conventional application program designed to be executec in real time.

The expert-system software shell would provide for multiple hierarchical representations of a system of interconnected elemental dynamic objects. More specifically, the RSP would enable the definition of such elemental dynamic objects as integrators, actuators, and sensors and the specification of both the interconnections among these objects and the dynamic behaviors of them as they perform their intended function. In other words, the conventional state-space and transfer-functions mathematical model of the system would be extended to include a topological representation. The RSP would include an "inheritance" software mechanism by means of which a dynamic object could be defined in terms of previously defined dynamic elements. Moreover, the RSP would provide a hierarchical dynamic representation software mechanism that would enable multiple representations of a subsystem at several levels of abstraction associated with each element.

In the phase of research described in this report, a preliminary specification of the design of the RSP was completed. A prototype of the RSP was implemented in an Ada-language program. The prototype includes a specification, in the BNF language (a programming metalanguage developed by Bachus and Naur), of the User System Description Language (USDL). The USDL supports both topological knowledge (e.g., systems, blocks, paths, and external equipment) and procedural knowledge (e.g., sets of rules, declarations, and mathematical and logical operations) about dynamic systems. The prototype includes a parser that examines the USDL source code for errors, then translates it into an internal system description (ISD). The prototype also includes an interpreter that interactively interprets the set(s) of rules and declarations determined by the user's command (e.g., simulate or diagnose) by use of the error-free ISD.

This work was done by S. J. Edwards and A. K. Caglayan of Charles River Analytics Inc. for **Ames Research Center**. *Further information may be found in NASA CR-179441 [N89-23209], "Expert Systems for Real-Time Monitoring and Fault Diagnosis."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.
ARC-12636

Fiber-Optic System Would Detect Leaking Liquid H_2

The sizes and positions of leaks would be measured by optical time-domain reflectometry.

John F. Kennedy Space Center, Florida

A proposed instrument based on optical time-domain reflectometry would measure both the locations and the sizes of leaks in tanks and plumbing that store and transfer liquid hydrogen. The instrument was conceived for use in detecting leaks of hydrogen from the propulsion system of the Space Shuttle, but the underlying concept is also applicable to the detection of flammable and/or poisonous fumes in chemical-processing plants, fuel-distributing equipment, and other terrestrial applications.

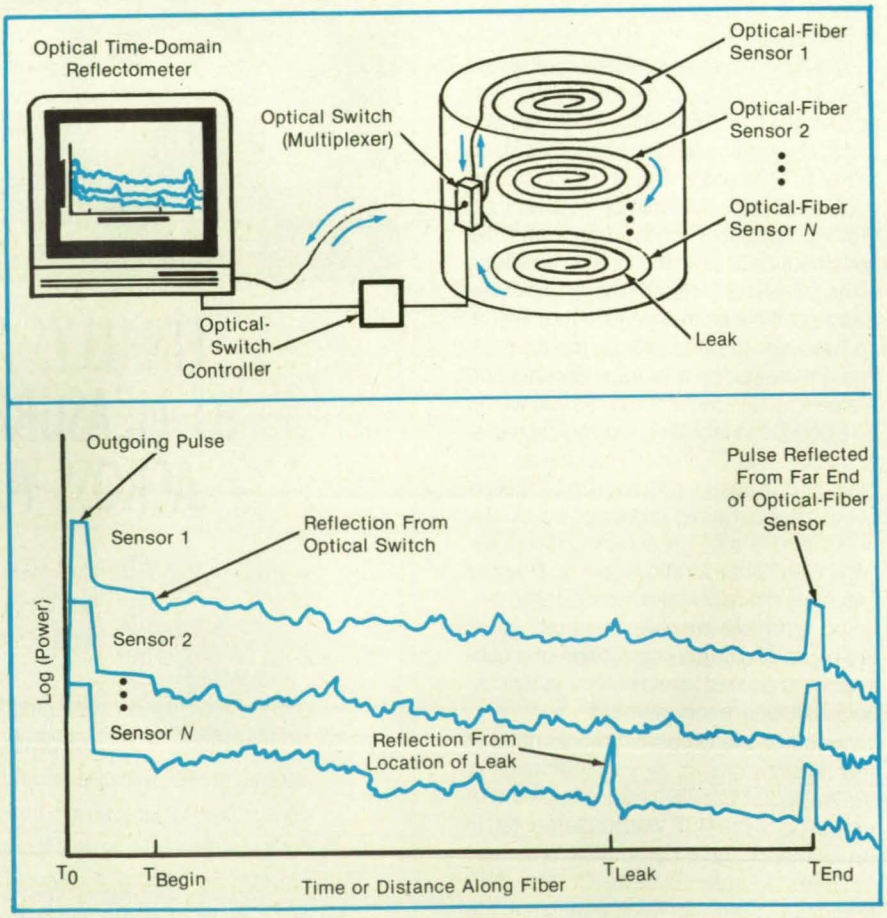
Optical time-domain reflectometry has been used before to detect chemicals. The principle of operation is simple: An optical fiber is coated and/or permeated with substances, the index of refraction of which is altered locally in response to the local concentration of the chemical to be detected. The optical time-domain reflectometer launches pulses of light periodically into the fiber at one end. As the light travels toward the far end, part of it is reflected back toward the source by local alterations in the index of refraction. The size and shape of the reflected pulse are indicative of the amount and spatial distribution of the chemical, and the round-trip time of the reflected pulse is proportional to the distance along the fiber to the reflecting location. The pulse is displayed and analyzed on the optical time-domain reflectometer to extract this information.

The optical-fiber sensing element of the proposed instrument would be tailored for the detection of hydrogen gas or liquid in the liquid-hydrogen temperature range: it would be coated and/or permeated with material(s) that impart(s) the desired optical response in this temperature range, including material(s) that undergo(es) reversible chemical reaction(s) with hydrogen, such that the change in the index of refraction of some part of the fiber is proportional to the local concentration of hydrogen.

By use of optical multiplexing, the instrument could accommodate several fiber-optic sensors (see figure). This would make it possible to construct a leak-distribution profile from data gathered along multiple paths through an area or volume. It has been estimated that the instrument could locate a pocket of leaking hydrogen within about 3 cm.

This work was done by Charles H. Grove of **Kennedy Space Center**. *For further information, Circle 18 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Kennedy Space Center *[see page 26].* *Refer to KSC-11553.*



Multiple Fiber-Optic Sensing Elements would be multiplexed to the optical time-domain reflectometer. In the hypothetical case shown here, the return signal from the *N*th sensing element includes a reflection that indicates a leak.

Germanium Resistance Thermometer for Subkelvin Temperatures

An improved design provides greater sensitivity and more-efficient removal of heat.

Goddard Space Flight Center, Greenbelt, Maryland

An improved germanium resistance thermometer measures temperatures as small as 0.01 K accurately. A typical prior germanium resistance thermometer is not useful below 0.05 K; below that temperature, the change in its resistance with temperature is too small to be practical, and even minute measurement currents cause excessive heating.

The design of the new device overcomes these deficiencies by providing a large area for electrical connections (to reduce elec-

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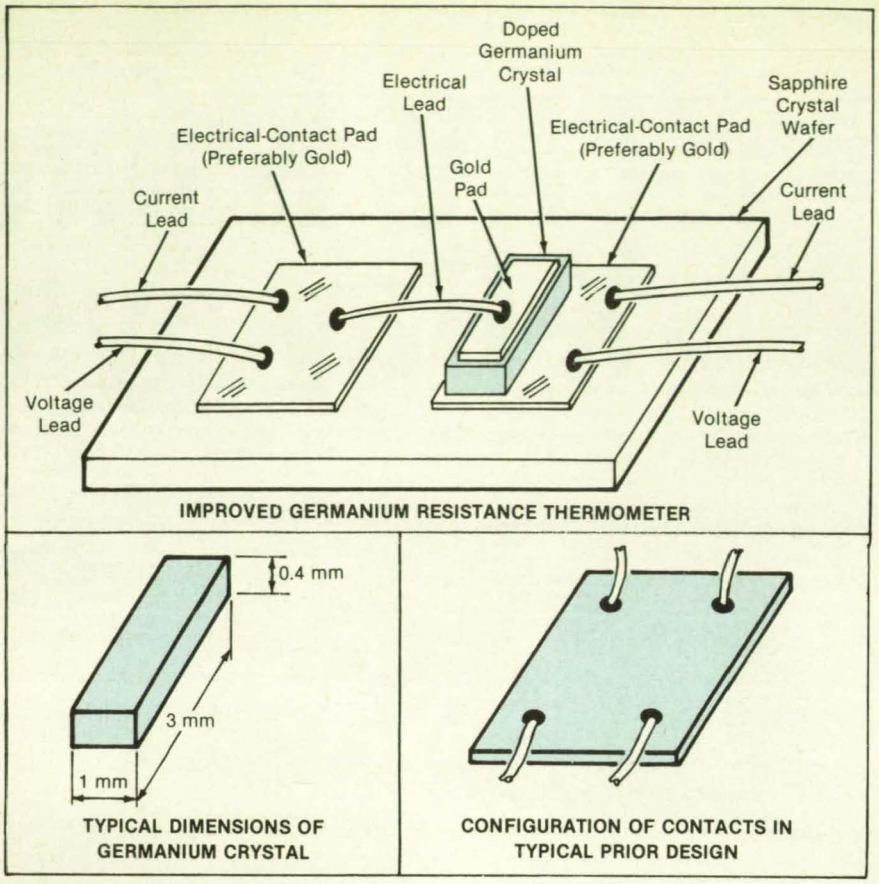
trical gradients and increase sensitivity to changes in temperature) and a large heat sink (to minimize resistance heating). The device is less expensive than are the magnetic thermometers or superconducting quantum interference devices (SQUID's) that would otherwise have to be used.

The device includes a germanium crystal and heat sink made of a wafer of sapphire crystal (see figure). The crystal is bulk-doped to have a total resistance between 100 and 100,000 Ω in the range of temperatures near 0 K in which it is to be used. The top and bottom surfaces of the germanium crystal are covered with films of gold that serve as electrical contact pads. The gold film on the bottom surface is bonded to the rightmost (in the figure) one of two electrical-contact pads on the sapphire wafer. The sapphire wafer is bonded to a copper plate that is, in turn, mounted on the object, the temperature of which is to be measured.

Pairs of current and voltage leads are bonded to the conductive pads on the sapphire wafer. These leads are connected to the external instruments that measure the electrical resistance of the germanium crystal. A single lead connects the leftmost electrical-contact pad on the germanium crystal to the contact pad on top of the germanium crystal.

The path for electrical current through the crystal is characterized by a relatively large cross-sectional area and a relatively short length. This makes it possible to obtain electrical resistances in the desired range by use of light doping, which, in turn, makes it possible to have a relatively large change of resistance with temperature — that is, high sensitivity. For example, if the dimensions of the crystal are 1×3×0.4 mm, then the sensitivity of the device (with the current flowing along the 0.4-mm dimension) is about 4.3 times that of a device made with same crystal in the older configuration (current flowing along the 3-mm dimension). Moreover, because the heat sink is larger and the thermal resistance between the germanium crystal and the heat sink is smaller than in prior germanium resistance thermometers, one can use a larger measurement current (and, thereby, increase sensitivity).



Gold Pads on the top and the bottom of the germanium crystal distribute electrical current and the flow of heat nearly uniformly across the crystal.

This work was done by Stephen H. Castles of **Goddard Space Flight Center**. *For further information, Circle 89 on the TSP Request Card.*

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, Goddard Space Flight Center [see page 26]. Refer to GSC-13406.

Improved Method for Experiments in Vertical-Flow Boiling

The frictional pressure drop and volume fraction of vapor are determined from simultaneous measurements.

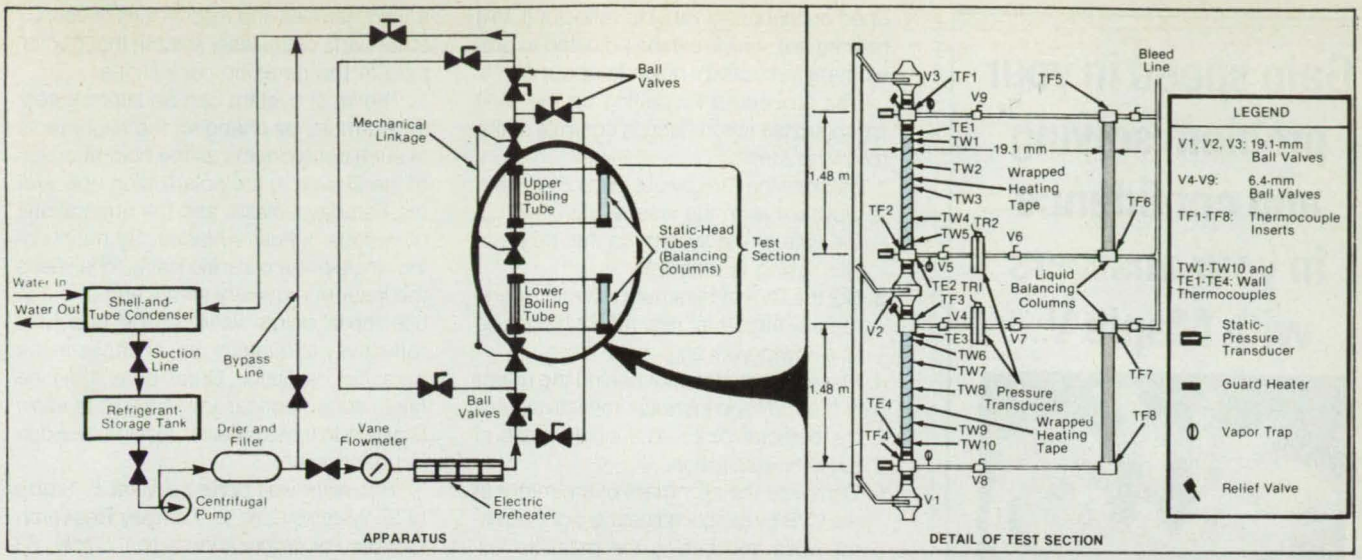
John F. Kennedy Space Center, Florida

An improved method of experimentation in boiling and adiabatic vertical flows provides for the simultaneous determination of the two-phase frictional pressure drop and the vapor-volume fraction. To determine a frictional pressure drop, it is necessary to subtract the gravitational pressure drop and the accelerational pressure drop (which is zero only in fully developed, adiabatic flows) from the total pressure drop. In the improved method, the gravitational pressure drop is determined from precise measurements of temperatures and differential pressures in conjunction with quick closure of valves. In some older methods of determining frictional pressure drops, the gravitational component of total measured pressure drop was ignored; in other methods, the gravitational component was estimated from prior information on vapor-volume fraction, which usually cannot be measured as accurately as pressures and temperatures can be.

The method has been demonstrated with the apparatus shown schematically in the figure, using $CFCl_3$ (also called "refrigerant 11") as the boiling fluid. The vertical test section consists of two subsections, each containing a copper tube wrapped with a heating tape. For vertical upflow, the lower tube is heated to produce boiling while the upper tube is not heated and becomes, in effect, an adiabatic test section. For vertical downflow, the upper tube is heated, while the lower tube remains unheated.

Two identical static-head tubes filled with $CFCl_3$ in the liquid phase serve as balancing columns for pressure-drop measurements. Valves at the upper end (V3), midheight (V2), and lower end (V1) of the test section are ganged together mechanically so that they can be closed or opened simultaneously within about 0.2 seconds. Pressure differentials are measured by magnetic-reluctance transducers.

Pressures and temperatures are measured in steady-state vertical upflow and steady-state vertical downflow. Measurements are also taken in the no-flow condition that is obtained by suddenly interrupting the upflow or downflow with the closure of V1, V2, and V3 and waiting 1



This **Vertical-Flow Boiling Apparatus** provides data from which one can calculate the frictional pressure drop and the volume fraction of vapor.

second for the flow to decay.

The measurements of pressure are analyzed by use of equations based on conservation of mass and momentum. The quality of the vapor (in the thermodynamic sense of "quality" as the mass fraction of vapor in a vapor/liquid mixture) is estimated by a heat-balance calculation. The volume-averaged volume fraction of vapor is determined from the mean density of the mixture in the test section, which, in turn, is evaluated from the differential pressure between the liquid balancing column and the test section, together with temperature measurements. The data are well correlated by a modified version of the Zuber–Finday method, in which volume-fraction data are correlated with volumetric fluxes.

This work was done by J. F. Klausner of the University of Florida and B. T. Chao and S. L. Soo of the University of Illinois for **Kennedy Space Center**. *For further information, Circle 53 on the TSP Request Card.*
KSC-11549

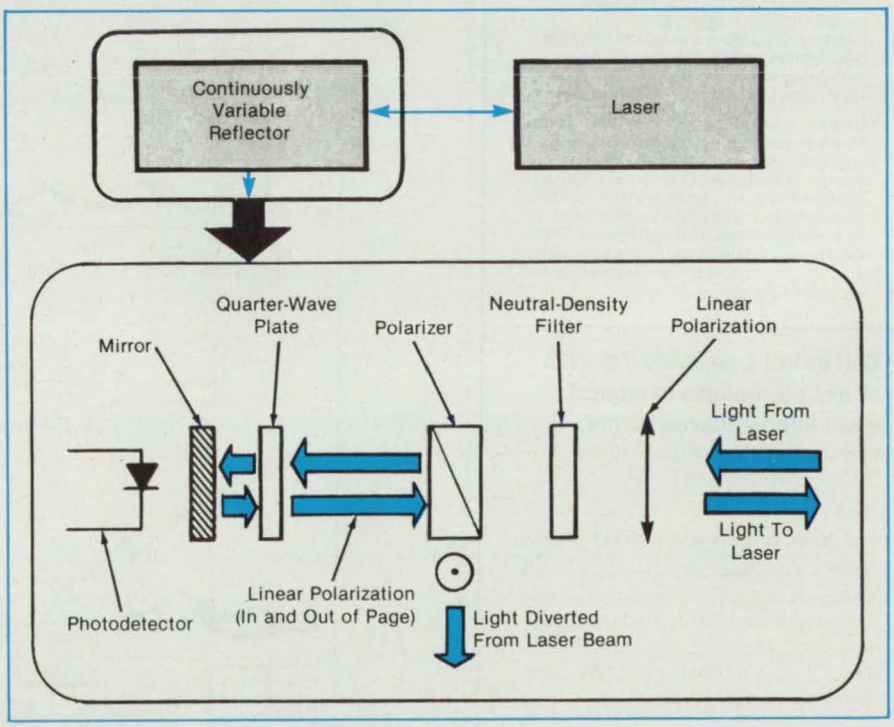
Testing for Parasitic Lasing With Controlled Retroreflection

Parasitic oscillations can be quantified and suppressed with precision.

Langley Research Center, Hampton, Virginia

The controlled-retroreflection technique provides a new capability to test safely for parasitic oscillations in a laser — particularly, in a high-gain, Q-switched laser. Parasitic lasing is unwanted stimulated emission that depletes the gain of the laser and can damage some or all of its optical components. Typically, parasitic lasing manifests itself as relaxation oscillations that occur during the buildup of gain just before the main Q-switched event. In a controlled-retroreflection test, one probes the laser system by reflecting a very small, controlled amount of light back into the laser system to initiate parasitic oscillations at a low power safely, with the Q-switch disabled, and uses the resulting measurements (1) to quantify those parameters of the design and/or adjustment of the laser that affect parasitic lasing and/or (2) to adjust the optical components of the laser system to suppress parasitic lasing.

Reflection of light back into a high-gain laser usually results in damage to the optical components. Therefore, the controlled-retroreflection technique requires great care to prevent excessive reflection; in a typical test, the energy of the parasitic oscillations should not be allowed to exceed a few microjoules. The success of the technique depends on the recently devel-



The **Continuously Variable Reflector** can be adjusted continuously over a dynamic range of about 3 decades by rotation of the quarter-wave plate about the optical axis. The neutral-density filter establishes the maximum reflectivity. Overall, by selection of neutral-density filters and continuous adjustment, the reflector can be made to have any reflectivity from about 1 down to 10^{-8}.

oped continuously variable reflector (CVR) (see figure), which can be adjusted to provide any reflectivity down to about 10^{-8}.

The procedure for setting up the CVR for controlled retroreflection consists of the following steps:

1. Calibrate the CVR by use of another laser.
2. Optically align the laser system. Adjust the gain of the system so that no parasitic lasing is detected.
3. Set the CVR at minimum reflectivity and roughly align it for retroreflection by use of a low-power alignment laser.
4. Place a photodetector behind the mirror in the CVR and increase reflectivity until the detector picks up a single pulse of parasitic oscillation.
5. Complete the alignment of the mirror in the CVR by gimbal adjustment of the mirror while maintaining the parasitic lasing near the single-pulse threshold.

Once the CVR is aligned with respect to the laser, various tests can be performed to optimize and quantify the laser system. Quantification involves the known threshold-condition relationship among the laser gain, the reflectivity of the CVR, and the transmissivities and reflectivities of various other parts of the laser system that participate in the parasitic oscillations.

The laser system can be interrogated, for example, by changing the alignments of such components as the holdoff optics of the Q-switch, the polarization optics of the Faraday isolator, and the orientations of various optical surfaces. By maintaining single-pulse parasitic lasing, one keeps the laser energy very small, and one can use the absolute value of the threshold reflectivity to quantify any changes in the parasitic oscillator. Great care must be taken during optical adjustments to allow only one to three parasitic laser pulses during each event.

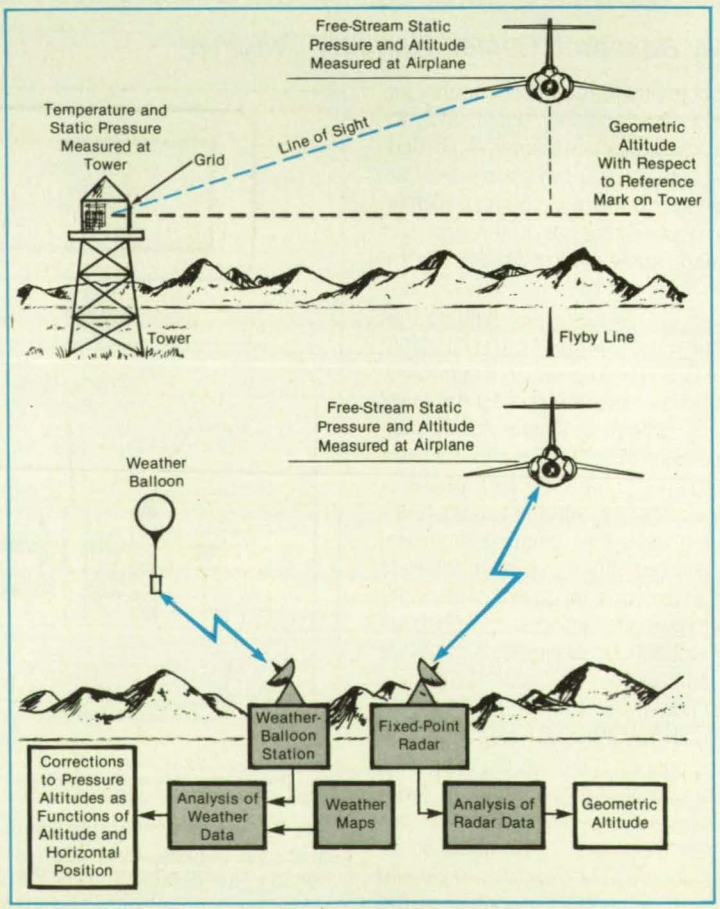
This work was done by Mark E. Storm of ST Systems Corp. for **Langley Research Center**. *For further information, Circle 63 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Langley Research Center [see page 26]. Refer to LAR-14645.

Calibrating Airplane Instrumentation To Measure Winds

Several techniques are used to obtain greater accuracy.

Ames Research Center, Moffett Field, California



The **Tower-Flyby and Radar Acceleration/Deceleration** techniques yield geometric altitude and pressure altitude data needed for calibrations.

An elaborate combination of techniques has been used to calibrate the wind-measuring instrumentation aboard an F104 airplane. The goal is to obtain wind profiles more rapidly than by tracking an instrumented rising balloon at comparable accuracies. This requires calibration accuracies greater than those previously required of airborne instrumentation. The improved method of calibration was devised to determine whether the winds aloft at and shortly after the time of measurement will allow safe launch of the Space Shuttle. This could also prove beneficial in other safety- or research-oriented applications in which wind velocities over a range of altitudes must be determined in nearly real time. In the original Space Shuttle application, guidelines were to obtain wind profiles in 10 to 15 min at altitudes up to 60,000 ft (about 18 km) in a horizontal circle of 10-mi (about 16-km) radius.

The basic principle of wind profile measurement is simple. By using pressure and temperature transducers and flow vanes, one obtains data on the velocity of wind relative to the airplane. The velocity of the airplane relative to the ground (determined by ground-based radar or an onboard inertial reference unit) is then subtracted from the velocity of the wind relative to the airplane. This gives the velocity of wind relative to the ground.

The airplane is equipped with a standard NACA research nose boom, which includes pressure probes and flow vanes that yield data on static and total pressures, angle of attack, and angle of sideslip. The airplane also has a ring-laser-gyroscope inertial reference unit, like those used in commercial airliners, which gives linear and angular velocities, linear acceleration, and orientation of the airplane. A body-mounted total-temperature sensor is also used.

These sensors must have very accurate calibrations to measure winds effectively. Two techniques are used to calibrate the mach number (from the pressure measurements) and total temperature measurements. These are tower flybys and radar acceleration/decelerations (see figure). In the tower flyby technique, the airplane flies near a tower at a steady airspeed and altitude. The airplane is sighted from the tower through an eyepiece and grid to determine its true geometric altitude, which is used to calibrate static pressure and total temperature. In the radar acceleration/deceleration technique, the airplane accelerates and decelerates while flying at a constant heading and geometric altitude (as determined by radar and fed back to the pilot) and gathers pressure and temperature correction data.

The flow angles measured by the nose boom must be corrected for various effects. Using mathematical models, the flow angles can be corrected for misalignment and bending of the nose boom, and for angular velocity of the airplane. In addition, flank angle of attack is transformed into angle of sideslip. Aerodynamic effects on the flow angles due to the nose boom and aircraft must be calibrated. A trajectory reconstruction algorithm, based on a multiple-state linear Kalman filter, blends data from the inertial reference unit, the probes, the tracking radar system, and meteorological observations to determine these effects.

This work was done by Edward A. Haering, Jr., of Dryden Flight Research Facility for **Ames Research Center**. *Further information may be found in NASA TM-101714 [N90-14228], "Airdata Calibration of a High-Performance Aircraft for Measuring Atmospheric Wind Profiles."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.
ARC-12846

Flame-Retardant Diaminobenzenes Containing Phosphorus

The diamines can be polymerized with dianhydrides or diacyl halides to produce fire-resistant polymers.

Ames Research Center, Moffett Field, California

A variety of (diorganooxyphosphonyl) methyl-2,4- and -2,6- diaminobenzenes (general compound 3 of the figure) can be synthesized, then polymerized with a variety of dianhydrides and diacyl chlorides to produce fire-resistant polymers. The properties of the polymers make them useful as matrices in laminated composite-material aircraft structural components that resist fire and exhibit such desirable mechanical properties as high tensile strength. The diamines can also be used as encapsulating or potting compounds when reacted with epoxy resins (the resulting compounds being more resistant to flames and fires than are conventional epoxy resins). Moreover, free phosphonic acids, which are byproducts of the synthesis of the diamines, can be used as complexing agents to extract metals from aqueous solutions or as corrosion inhibitors for metals.

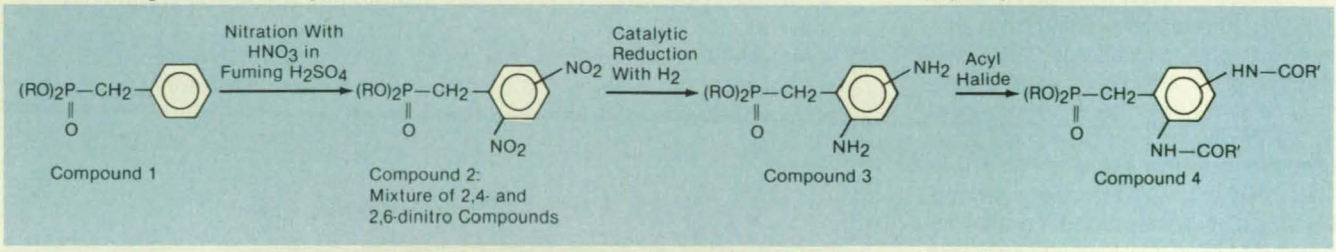
The scheme for the synthesis of the diaminobenzenes containing phosphorus is shown in the figure. The starting material, a diorganooxyphosphonyl methyl benzene (compound 1), can be produced by the Michaelis–Arbuzov reaction of benzyl bromide with a suitable trialkyl phosphite or other equivalent protected phosphate. Compound 1 is then nitrated by use of more than 2 equivalents of nitric acid in fuming sulfuric acid under anhydrous conditions at a temperature between 40 and 90 °C for 0.5 to 8 h to produce a mixture of the 2,4- and 2,6-dinitro derivatives (compound 2), which can be separated if desired but are typically reacted further as a mixture.

The mixture is then reduced — preferably by use of molecular hydrogen and a platinum or palladium catalyst supported on an inert organic oxidic support or on carbon in a nonaqueous medium such as methanol or ethanol — to produce a mixture of the 2,4- and 2,6-diamino compounds (compound 3).

The protecting groups (R) are unstable in acid and can be removed either from the dinitro compounds (compound 2) or from the diamino compounds (compound 3) by acidic hydrolysis to produce the corresponding phosphonyl acids. This hydrolysis is carried out in concentrated aqueous HCl, HBr, or H_2SO_4 at a temperature between 50 and 150 °C for 0.5 to 8 h. The diamines (compound 3) can be reacted with acyl halides to produce amides (compound 4) or with dianhydrides or diacyl chlorides to produce fire-resistant polymers or copolymers.

This work was done by Demetrius A. Kourtides of **Ames Research Center** *and John A. Midroyannidis of the University of Patras. For further information, Circle 34 on the TSP Request Card.*

This invention has been patented by NASA (U.S. Patent No. 4,886,896). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Ames Research Center [see page 26]. Refer to ARC-11425.



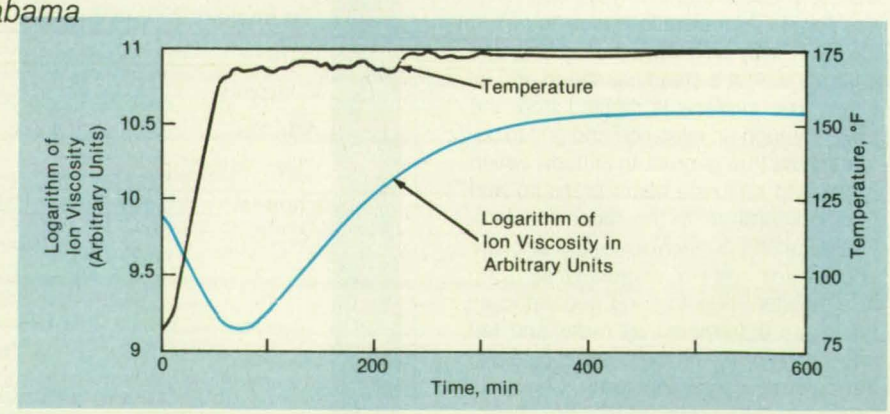
(Diorganooxyphosphonyl)methyl-2,4- and -2,6-Diaminobenzenes, which can be used to produce fire-resistant polymers and copolymers, are synthesized in this sequence of reactions and products.

Conductivity as a Measure of Degree of Polymerization

Conductivity is a better indicator of cure than permittivity is.

Marshall Space Flight Center, Alabama

In an improved method of dielectric monitoring of the process of polymerization ("curing") of the mixed ingredients of a polymeric material, emphasis is placed on measurement of conductivity rather than permittivity. Typically, in preparation for dielectric monitoring, electrodes that amount, in effect, to plates of a capacitor are placed on or in the material, which is thereby made to serve as the dielectric of the capacitor. Monitoring then consists of measurement of the capacitance and conductance of the capacitor as a function of time at a given frequency or frequencies. From these measurements, one computes the electrical permittivity, the electrical conductivity, and possibly other properties of the



The **Ion Viscosity** of a curing polymer was computed from its conductivity as measured in dielectric monitoring at a frequency of 10 Hz. (Frequencies from 0.1 Hz to 100 kHz were tried, and the 10-Hz measurements were found to provide the most sensitive indication of the progress of the cure.)

material as a function of time.

The improved method is based on the observation that, typically, the conductivity tends to change more during the curing process than the permittivity does, and the conductivity is less dependent on frequency. This means that, in comparison with the permittivity, the conductivity is a more-sensitive and more-reliable indicator of the progress of the cure. The conductivity can be used to compute a quantity called "ion viscosity." This quantity is related to the classical viscosity of a fluid. During the cure of a typical polymer, the ion viscosity varies over a wide range, eventually rising to a plateau toward the end of the cure.

In a demonstration, the method was applied to an isophorone di-isocyanate-cured, hydroxyl-terminated polybutadiene filled with a carbon black and some other ingredients. The ingredients were mixed; then the mixture was subjected to dielectric monitoring as it was heated to and then held at the curing temperature. As shown in the figure, the ion viscosity decreased during the initial increase in temperature, then increased (signifing the onset of the curing reaction), then leveled off at a plateau (signifying completion of the cure).

The validity of the ion viscosity as an indicator of the degree of cure was verified by correlation with measurements from differential scanning calorimetry, dynamic mechanical spectroscopy, thermography, chemical analysis, Fourier-transform infrared fiber-optic spectroscopy, and mechanical-strength tests.

This work was done by David L. Dean and Robert K. Walsh of Science Applications International Co. for **Marshall Space Flight Center**. *For further information, Circle 30 on the TSP Request Card.*
MFS-28613

Microsheet Glass in Solar Concentrators

Desirable properties include durability and smoothness.

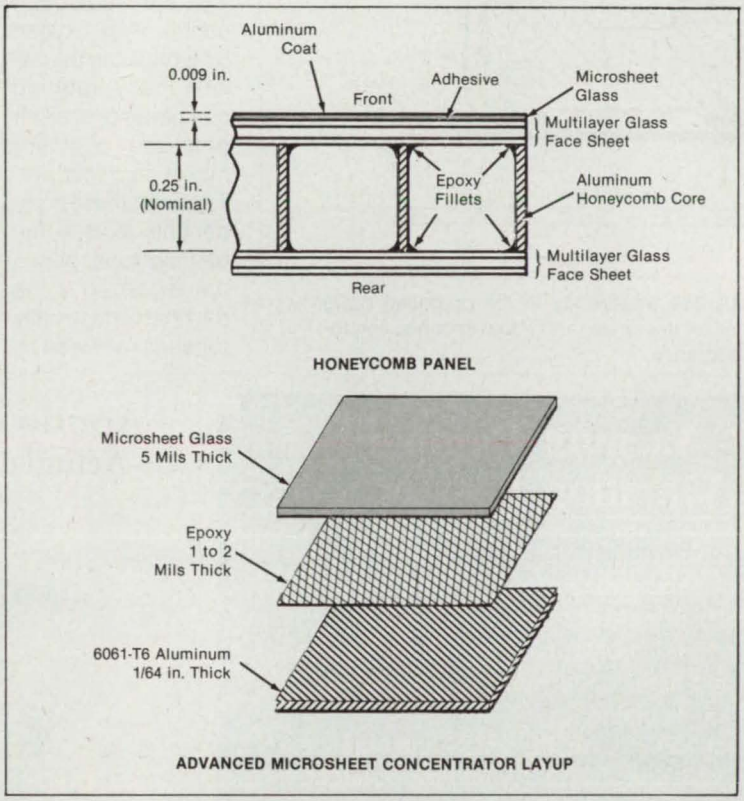
Lewis Research Center, Cleveland, Ohio

Microsheet glass is being used as a highly protective covering material for developmental concentrating reflectors for solar power systems. Together with other materials, the glass is expected to make it possible to fabricate lightweight, highly reflective, accurate, and long-lived concentrators. "Microsheet glass" is the name given to a family of soda-lime glasses ranging in thickness from 1 to 20 mils (0.025 to 0.51 mm). It is well-suited to use in solar concentrators because, like glasses in general, it is not affected by ultraviolet radiation. It is also not degraded by atomic oxygen, which is found in low orbits around the Earth. Although the developmental concentrators are intended for use in outer space, it is noteworthy that a terrestrial concentrator has been fabricated with glass sheet 0.7 mm thick.

In the construction of a concentrator according to one of several concepts, microsheet glass is bonded to an aluminum facesheet on one side of an aluminum honeycomb core. A reflective film of aluminum is evaporated onto the microsheet. A second face sheet is bonded to the other side of the core. In another concept, the microsheet is bonded with epoxy to an aluminum sheet supported in a framework (see figure).

The microsheet glass is cut by scoring it with a diamond scribe dipped in motor oil. The scribe is moved around a template to obtain the required shape. Even pressure is applied on both sides of the scribe line to make the final cut. The edge is then polished to remove microcracks.

It is necessary to remove the oil and other contaminants to ensure a void-free joint with the overlying aluminum film and the underlying glass face sheet. The microsheet is degreased in a solvent, immersed in an alkaline solution, rinsed, immersed in an acid solution, rinsed again, and dried in an oven.



These **Concentrator Panels** represent two major solar-reflector concepts undergoing development.

The microsheet can be given a paraboloidal contour required for a concentrating reflector by heating it in an argon atmosphere to just below its softening temperature of 720 °C in a Pyrex (or equivalent)-lined graphite mold that has the desired shape of the concentrator. During about 30 minutes, it gradually slumps, assuming the contour of the mold. It is then cooled to just above its annealing temperature of 550 °C and held there for 1 hour. It is then cooled at a rate of 3 to 5 °C per minute to a temperature just below its strain point of 508 °C. Finally, the heat is turned off and the glass is cooled to room temperature in argon.

This work was done by Scott W. Richter of Sverdrup Technology, Inc. in support of **Lewis Research Center**. *Further information may be found in NASA TM-102406 [N90-14678], "Technology Development Program for an Advanced Microsheet Glass Concentrator."*

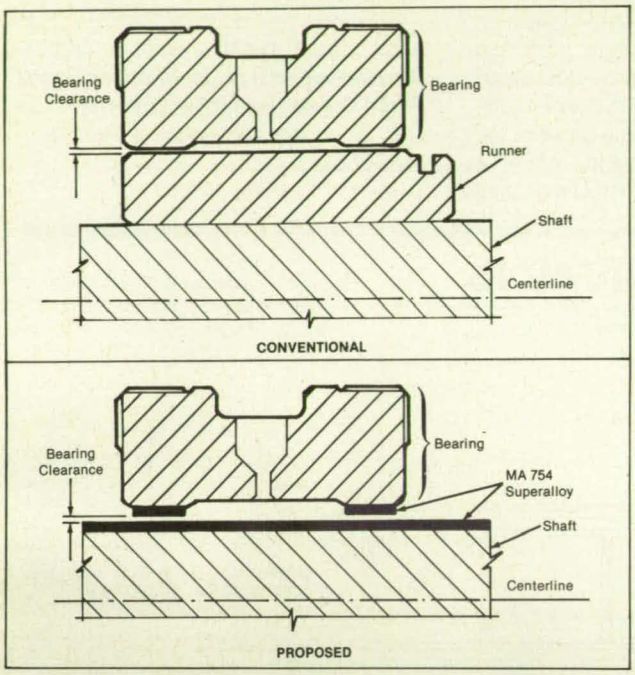
Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.
LEW-15105

Coating Hydrostatic Bearings To Resist Ignition in Oxygen

A superalloy is plasma-sprayed onto rubbing surfaces.

Marshall Space Flight Center, Alabama

Coats of the superalloy MA 754 would be plasma-sprayed onto the occasionally rubbing surfaces of hydrostatic journal bearings that operate in liquid and/or gaseous oxygen, according to a proposal. These coats would prevent the ignition and combustion that occur when components made of stainless steels or other conventional bearing alloys rub against each other in oxygen.



The Coat of MA 754 Superalloy in the proposed design would eliminate the need for the runner and would enhance control over the critical bearing clearance.

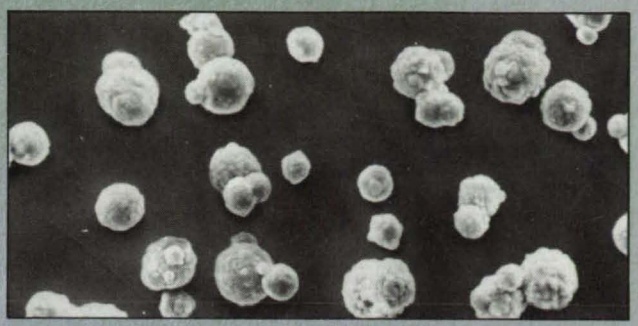
At present, bearings are made compatible with oxygen by fabricating the occasionally rubbing components of silver or an alloy of mostly nickel and copper. Typically, these components include the bearing itself, plus a runner, which is the part that occasionally rubs against the bearing. The runner is press-fit or otherwise attached to the shaft, as shown at the top of the figure. Because the coefficient of thermal expansion of the bearing and runner differ from that of the shaft, it is difficult to maintain the tight control of the bearing clearance that is necessary for proper operation.

If the occasionally rubbing surfaces were coated with MA 754 superalloy as proposed, the bulk of the bearing could be made of the same material as that of the shaft, and the runner could be eliminated, as shown in the lower part of the figure. Because the combined thicknesses of the superalloy coats would be less than the overall radial thickness of the bearing, the different thermal expansion of the coats would have negligible effect. Essentially, the shaft and bearing would thermally expand and contract together, and the thermal error in the bearing clearance would be eliminated.

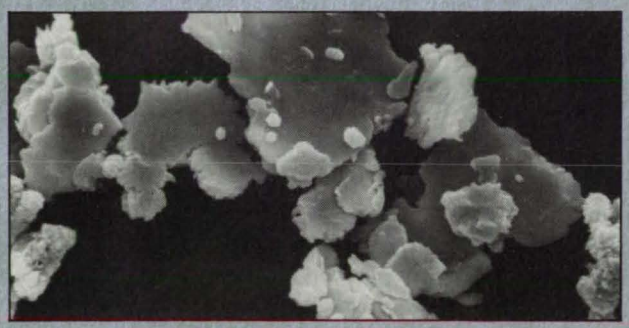
The composition of MA 754 in weight percentages is nickel $77.6+x$ (where $x \leq 1.0$), chromium 20, titanium 0.5, aluminum, 0.3, yttria 0.6, and iron $1.0-x$. The alloy

SPECIFY INCO SPECIALTY POWDERS FOR WIDE RANGE OF ELECTRONIC APPLICATIONS

Inco Type T 287 Filamentary Powder, particle size (FSSS) 2.6-3.3 microns, apparent density 0.75-0.95 g/cc, relative surface resistivity 0.30 ohms per square (□).



Novamet Silver Coated Nickel Spheres, 15% Ag, 2.5 g/cc apparent density, particle size 10 microns, screen mesh 99%-250, surface resistivity 0.03 Ω/□.



Novamet HCA-1 Flake, screen mesh 98% minus 400, apparent density 0.90 g/cc, thickness 1.0-1.1 microns, surface resistivity 0.25 Ω/□.

Novamet Nickel Coated Graphite, 60% fully encapsulated Ni, apparent density 1.6 g/cc, particle size (FSSS) 100 microns, screen mesh 63% −150/+250, surface resistivity 0.3 Ω/□.

Inco Specialty Powder Products now has a wide range of nickel and coated powders with exceptional conductive and magnetic properties. These properties make them ideal for a spectrum of electronic applications such as conducting film technology, coatings, adhesives, gaskets and EMI shielding.

EXTENSIVE PRODUCT RANGE

The development of computer processed control coupled with the continuous powder production improvements enables us to meet your most stringent powder specifications for electronic applications.

In addition to the products pictured above, INCO SPP has available the following high performance powder products. Novamet Conductive Nickel Spheres, particle size (FSSS) 8-9 microns, apparent density 3.2-3.5 g/cc, surface resistivity 1.0 ohms per square. Novamet 525 Conductive Nickel Pigment, screen mesh 100% minus 400, particle size 3.2 microns, 0.65 BET surface area m^2/g, surface resistivity 0.35 ohms per square. Silver Coated Nickel Flake, 15% Ag, 2.6 g/cc apparent density, particle size (FSSS) 15 microns, screen mesh 99% minus 200, surface resistivity 0.04 ohms per square.

Magnetic ferrites and surge arrestor applications also use our specialized range of nickel oxides. High Purity Black Nickel Oxide, 77.2% Ni, BET 75 (m^2/g) particle size (FSSS) 5.2 microns, minus 325 mesh 99% plus. Green Nickel Oxide, 78.5% Ni, BET 3 (m^2/g) particle size 1.6 microns, −325 mesh 100%.

Inco Specialty Powder Products is your unique source for custom fitting high performance powders into electronic applications. Our customer focused, world-wide marketing service group is ready to help you with your current and future needs.

For more information write INCO Specialty Powder Products, Dept. 1-90, Park 80 West-Plaza Two, Saddle Brook, NJ 07662

INCO SPP

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Shin-Muromachi Building, 4-3 Nihonbashi-Muromachi 2-Chome, Chuo-ku, Tokyo 103 Japan
1-3 Grosvenor Place, London SW1X7EA England
15/Fl Wilson House, 19-27 Wyndham Street Central, Hong Kong

For More Information Circle No. 652

is made by powder metallurgy, and the yttria imparts additional strength. This material has been shown to be compatible with liquid and gaseous oxygen at high pressure in promoted-combustion and frictional-heating tests. Because the material has a low coefficient of friction and high mechanical strength, it would undergo little deformation during a rub.

This work was done by Merle E. Funkhouser of United Technologies Corp. for **Marshall Space Flight Center**. *For further information, Circle 36 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 26]. Refer to MFS-28636.

Polyimides Containing Amide and Perfluoroisopropyl Links

Flexible linkage yields polyimides with improved solubilities, strengths, and thermo-oxidative stabilities.

Langley Research Center, Hampton, Virginia

Polyimides are condensation-type polymers commonly synthesized by the reaction of aromatic diamines with aromatic dianhydrides. The intermediate polyamide-acids are either thermally or chemically dehydrated to form the polyimides. Polyimides are generally insoluble after conversion from the polyamide-acid form to the polyimide form. Soluble polyimides are extremely useful in that they can be used to make polyimide films and coatings. In a new synthesis, a flexible linkage, the perfluoroisopropyl group, was incorporated into the dianhydride portion of the polymer to improve the solubility characteristics of the polyimides.

More specifically, new polyimides were synthesized from the reactions of aromatic hexafluoroisopropyl dianhydrides with asymmetric amide diamines. The polyimides were found to be soluble to the extent of at least 10 percent by weight at a temperature of about 25 °C in common amide solvents such as N-methylpyrrolidone, N,N-dimethylacetamide, and N,N-dimethylformamide. These polyimides were found to form tough, flexible films, coatings, and moldings. Glass-transition temperatures ranged from 300 to 365 °C, and crystalline melting temperatures were observed between 543 and 603 °C.

Films of several of these polyimides were shown to be semicrystalline, as evidenced by wide-angle x-ray scattering and differential scanning calorimetry. In comparison with prior state-of-the-art polyimide films, these films are more soluble in polar solvents and exhibit less color. At a temperature of 25 °C, the average values of tensile strength, tensile modulus, and elongation at break were found to be 16.3 kpsi (112 MPa), 506.8, kpsi (3.494 GPa), and 4.58 percent, respectively. Mechanical properties at 204 °C were also found to be good. The thermo-oxidative stabilities of the new polyimide films were found to be as good as or better than those of prior state-of-the-art polyimides.

The new soluble polyimides display excellent physical, chemical, and electrical properties, which render them useful as adhesives, laminating resins, fibers, coatings for electrical and decorative purposes, films, wire enamels, and molding compounds.

This work was done by James F. Dezern of **Langley Research Center**. *For further information, Circle 4 on the TSP Request Card.*

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, Langley Research Center [see page 26]. Refer to LAR-14608.

Computer Programs

COSMIC: Transferring NASA Software

COSMIC, NASA'S Computer Software Management and Information Center, distributes software developed with NASA funding to industry, other government agencies and academia.

COSMIC's inventory is updated regularly; new programs are reported in *Tech Briefs*. For additional information on any of the programs described here, circle the appropriate TSP number.

If you don't find a program in this issue that meets your needs, call COSMIC directly for a free review of programs in your area of interest. You can also purchase the annual *COSMIC Software Catalog*, containing descriptions and ordering information for available software.

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Computer Programs

These programs may be obtained at a very reasonable cost from COSMIC, a facility sponsored by NASA to make computer programs available on program price, size and availability, circle the reference number on

Materials

Preprocessing Program for Finite-Element Analyses

COMGEN generates finite-element models of composite materials at the micromechanical level.

A significant percentage of time spent in a typical finite-element analysis is taken up in the modeling process and assignment of loads and constraints. The analyst must be both well-versed in the art of finite-element modeling and familiar with some sort of preprocessing software to perform the task expeditiously.

COMGEN (COmposite Model GENerator) is an interactive FORTRAN program that can be used to create a wide variety of finite-element models of continuous-fiber composite materials at the microscopic level. It quickly generates batch or "session" files to be submitted to the finite-element pre- and post-processor program, PATRAN, from PDA Engineering, Costa Mesa, CA.

COMGEN reflects the assumption that the constituents of a composite material to be geometrically modeled, can be represented by a "unit cell" of a fiber surrounded by matrix material. Two basic types of cells are available. Those of the first type are arranged in a square packing arrangement, in which each fiber is positioned in the center of a square matrix cell. Cells of the second type are packed hexagonally, each fiber being centered in its hexagonal matrix cell. Different models can be created by use of combinations of square and hexagonal packing schemes. Variations include two- and three dimensional cases, models with fiber/matrix interfaces, and different constructions of unit cells.

Inputs from the user include the diameter of the fibers and the percent of volume occupied by fibers. In addition, various mesh densities, boundary conditions, and loads can be assigned to the models within COMGEN. The PATRAN program then uses a COMGEN session file to generate finite-element models and their associated loads, which can then be translated to virtually any finite-element analysis code; e.g., NASTRAN or MARC.

COMGEN is written in FORTRAN 77. It has been implemented on DEC VAX computers running VMS and requires about 124 Kb of main memory on these computers. The program is available on a 5.25-in. (13.3-cm) MS-DOS format diskette (standard medium); in VAX FILES-11 format on a 9-track, 1,600-bit/in. (630-bit/cm) magnetic tape; or on a TK50 tape cartridge.

COMGEN was developed in 1990. DEC, VAX, and VMS are trademarks of Digital Equipment Corp. PATRAN is a registered trademark of PDA Engineering.

This work was written by M. E. Melis of **Lewis Research Center**. *For further information, Circle 79 on the TSP Request Card. LEW-15171*

Mechanics

Program Computes Flows of Fluids and Heat

SINDA'85/FLUINT incorporates lumped-parameter-network and one-dimensional-flow mathematical models.

SINDA, the Systems Improved Numerical Differencing Analyzer, is a software system for solving problems that involve lumped-parameter representations of physical problems governed by diffusion-type equations. SINDA was originally designed

for the analysis of thermal systems represented in electrical-analog, lumped-parameter form, although its use can be extended to include other classes of physical systems that can be modeled in this form. As a thermal analyzer, SINDA can handle such interrelated phenomena as sublimation, diffuse radiation within enclosures, transport delay effects, and sensitivity analysis. FLUINT, the FLUid INTegrator, is an advanced one-dimensional fluid-analysis program that solves problems that involve the flows of fluids in arbitrary networks. The working fluids can be of single phase (vapor or liquid) or two phases (vapor and liquid). The SINDA'85/FLUINT system enables the analysis of the mutual influences of thermal and flow phenomena.

The SINDA program consists of a programming language, a preprocessor, and a subroutine library. The SINDA language is designed for working with lumped-parameter representations and finite-difference solution techniques. The preprocessor accepts programs written in the SINDA language and converts them into standard FORTRAN. The SINDA library consists of a large number of FORTRAN subroutines that perform a variety of commonly needed actions. The use of these subroutines can greatly reduce the programming effort required to solve many problems.

A complete run of a SINDA'85/FLUINT mathematical model is a four-step process. First, the user's desired mathematical model is run through the preprocessor, which writes out data files for the processor to read and translates the user's program code. Then the translated code is compiled. In the third step, the user's code is linked with the processor library. Finally, the processor is executed.

The features of the SINDA'85/FLUINT program include 20,000 nodes, 100,000 conductors, 100 thermal submodels, 10 fluid submodels, two-phase flow, capillary devices, fluids defined by the user, gravitational and accelerational body forces on a fluid, and variable volumes. SINDA'85/FLUINT offers two finite-difference numerical solution techniques: the forward-difference explicit approximation and the Crank–Nicholson approximation (which is implicit).

The program enables the simulation of nonuniform heating and facilitates mathematical modeling of thin-walled heat exchangers. The ability to model nonequilibrium behavior within two-phase volumes is included. Recent changes in the program improve the modeling of real evaporator pumps and other capillary-assist evaporators.

SINDA'85/FLUINT is available by license for a period of 10 years to approved licensees. The licensed program product includes the source code and one copy of the supporting documentation. Additional copies of the documentation may be purchased separately at any time.

SINDA'85/FLUINT is written in FORTRAN 77. Version 2.3 has been implemented on DEC VAX-series computers running VMS, Sun-3 and Sun-4 computers running SunOS, and Cray-series computers running UNICOS. The CONVEX version is a port of the 1988 version (version 2.2). Binaries are included with the Sun and Cray versions only. The VAX and Sun versions contain a graphical display program called EXPLOT. The VAX version of EXPLOT requires the DISSPLA graphics package, while the Sun version requires TEMPLATE. The VAX and Cray versions of SINDA'85/FLUINT also contain SINGE, an additional graphics program developed at Johnson Space Center. Both source and executable codes are provided for SINGE. Users who wish to create their own SINGE executable codes will also need the NASA Device Independent Graphics Library (NASADIG, previously known as SMDDIG; VAX version, MSC-21801; UNIX version, MSC-22001). The VAX version of SINDA'85/FLUINT is available in DEC VAX BACKUP format on a 9-track, 1,600-bit/in. (630-bit/cm) magnetic tape (standard distribution medium) or TK50 tape cartridge. The Sun version is available on a 0.25-in. (6.35-mm) streaming-magnetic-tape cartridge in UNIX TAR format. The Cray and CONVEX versions are available on 9-track, 1,600-bit/in. (630-bit/m) magnetic tapes in UNIX TAR format. SINDA was developed in 1971, and

fluid capability was first added in 1975. Version 2.3 of SINDA'85/FLUINT was released in 1990.

DEC, VAX, and VMS are trademarks of Digital Equipment Corp. Sun, Sun-3, Sun-4, and SunOS are trademarks of Sun Microsystems, Inc. TEMPLATE is a registered trademark of Template Graphics Software. CONVEX is a trademark of Convex Computer Corp. Cray and UNICOS are registered trademarks of Cray Research Inc.

This program was written by Brent Cullimore and Steven Ring of Martin Marietta Corp. and Mark Welch of Lockheed Engineering and Sciences Co. for **Johnson Space Center**. *For further information, Circle 11 on the TSP Request Card. MSC-21778*

Analyzing Transonic Flow Over a Wing and Fuselage

TAWFIVE is computationally efficient, yet accurate enough for use in design.

The TAWFIVE computer program calculates transonic flow over a transport-type wing and fuselage. Although more-complicated programs that implement Euler and Navier–Stokes methods are available, TAWFIVE combines a multigrid acceleration technique in the iterative solution of the potential equation with the use of integral-form boundary-layer equations to provide a software tool that is computationally efficient, yet accurate enough for use in design.

TAWFIVE simplifies the solution process by breaking the problem into a loosely coupled set of modified equations. The inviscid-flow method, using standard inviscid-flow equations (nonlinear full potential), is valid in the "outer" region away from the wing, whereas the boundary-layer equations are valid in the thin region near the solid surface of the wing.

The two types of equations are coupled by a technique of modifying surface boundary conditions for the equations of inviscid flow. The coupling process starts with a solution of the equations of the outer flow field. Pressures are computed at the surface of the wing and are used to calculate the boundary-layer flow. The properties of the boundary layer and wake are then computed by use of a three-dimensional integral method, and a fictitious layer with the computed displacement thickness is added onto the solid surface.

The resulting new fictitious displaced wing surface is then regridded and the inviscid-flow field is recomputed. New values of the inviscid pressures are then used in the boundary-layer method to predict a new distribution of displacement thicknesses. An underrelaxed update of the previously predicted displacement thicknesses is then made to obtain a new displacement-thickness correction that is added to the thickness of the fictitious layer on the solid surface. These global iterations are continued until suitable convergence is obtained.

Input to TAWFIVE is limited to geometric definition of the configuration, free-stream flow quantities, and iteration-control parameters. The geometric input consists of the specification of a series of airfoil sections to define the wing and a series of fuselage cross sections to model the fuselage mathematically. High-aspect-ratio wings are modeled more accurately than low-aspect-ratio wings are because no special provisions are made to mathematically model the wing/fuselage juncture or the wing-tip region accurately. The user can specify the solution either in terms of lift or in terms of angle of attack. TAWFIVE can produce tabular output and input files for PLOT3D (COSMIC program number ARC-12779).

TAWFIVE is written in FORTRAN 77 for CRAY-series computers running UNICOS. The size of main memory required for execution is 2.7 Mb. This program is available on a 9-track, 1,600-bit/in. (630-bit/cm) UNIX tar format magnetic tape. TAWFIVE was under development from 1979 to 1989 and first released by COSMIC in 1991.

CRAY and UNICOS are registered trademarks of Cray Research, Inc.

This program was written by N. Duane Melson and Craig L. Streett of **Langley Research Center**. *For further information, Circle 60 on the TSP Request Card. LAR-14722*

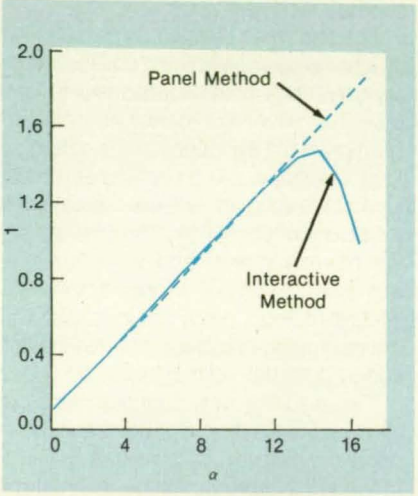
Interactive-Boundary-Layer Computations for Oscillating Airfoil

A method of computation based on quasi-steady flow works satisfactorily.

Ames Research Center, Moffett Field, California

An interactive-boundary-layer method, developed previously for computations of steady flow, has been extended, under the assumption of quasi-steady flow, to computations of the evolution of two-dimensional flow about an oscillating airfoil under light-dynamic-stall conditions (i.e., at angles of attack slightly above the angle at which the airfoil would stall in steady flow). The success of this application represents an advance toward the eventual ability to compute unsteady flows at even greater angles of attack with solutions of the equations normally used for description of boundary-layer flows on airfoils prior to stall. The ability to compute the effect of the unsteady motion of an airfoil on its stall behavior is important in practical studies of the flow on the blades of helicopter rotors, axial compressors, and turbines.

In this interactive-boundary-layer method, a set of equations, describing viscous flow in the boundary layer and another set of equations for the inviscid flow in the bulk of the fluid are solved and made to interact with each other in an iterative scheme. An unsteady-potential-flow panel method that includes wake modeling is used to represent the inviscid flow. The shape of the airfoil is represented by a large number of straight-line segments called panels (forming an inscribed polygon). Each panel has a constant source strength, which differs from panel to panel, and a constant vorticity strength, which is the same for all panels. The wake is represented by a series of free vortices, one shed from the trailing edge at each instant of time. Each shed vortex has a strength that differs from the strengths of the other vortices in the wake; this strength is a function of position along the wake and is dictated by the time history of the circulation around the airfoil.



Lift predicted by the inviscid panel method is compared with lift predicted by the viscous-inviscid interaction method for an airfoil pitching rapidly past the angle at which the airfoil would stall statically.

The boundary-layer part of the present method is based on the solution of the two-dimensional boundary-layer equations, using an eddy-viscosity model. To avoid the breakdown of the solution that usually occurs at separation, the outer, viscous boundary condition expresses the velocity as the sum of an inviscid free-stream velocity and perturbation velocity computed from a Hilbert integral. A discrete approximation of this integral enables the expression of the perturbation velocity in terms of the geometric coefficients of the airfoil, and the expression of the edge boundary condition in a form that provides a relationship with the external velocity and displacement thickness. The boundary-layer equations for flow on the airfoil and in the wake are solved by a finite-difference technique. The boundary-layer solution provides updated boundary conditions for the inviscid solution and vice versa, and the computations are repeated until the solutions converge.

The results of these interactive-boundary-layer computations of flow about an oscillating airfoil clearly show the effects of the viscous layer on the variation of lift with the angle of attack under unsteady condition (see figure). They also show that the quasi-steady interactive-boundary-layer method satisfactorily represents the flow over the airfoil at these angles of attack.

This work was done by L. W. Carr of **Ames Research Center**, *T. Cebeci of Douglas Aircraft Co., and Hong-Ming Jang of the University of Michigan. Further information may be found in AIAA paper 89A-25016, "An Interactive Boundary Layer Procedure for Oscillating Airfoils Including Transition Effects."*

Copies may be purchased [prepayment required] from AIAA Technical Information Service Library, 555 West 57th Street, New York, New York 10019, Telephone No. (212) 2476500. ARC-12466

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Ceramic-fibers brush and an integral spring clip would block hot, engine flows.

Lewis Research Center, Cleveland, Ohio

A proposed high-temperature brush seal would include a bundle of ceramic fibers or bristles packed tightly together to minimize leakage. The ceramic brush seal would withstand operating temperatures much higher than those of metal-brush shaft seals found on some of today's turbojet engines. The ceramic brush seal is designed to block the leakage of gases through gaps between panels in advanced aerospace vehicles. The primary use would be in the gaps between movable panels and adjacent sidewall panels in advanced ramjet and scramjet engines. Other potential applications include sealing gaps in variable-geometry two-dimensional turbojet exhaust nozzles or sealing control surface gaps of hypersonic vehicles. The ceramic brush seals could also be used as structural seals in high-temperature furnaces or advanced ceramic heat exchangers.

In the intended engine application, the seal (see figure) would include the ceramic brush packing and a secondary spring clip mounted in a closely mating seal channel in the movable panel. To increase the density of packing of the fibers or bristles in the brush and thereby decrease the permeability and leakage, the fibers or bristles could be tied together or interleaved with other fibers along the length of the seal. This type of hybrid or braided construction would increase the ability of the seal to withstand the high engine pressures and the supersonic flow of hot gas tangent to the exposed edge of the seal. It would also minimize the damage caused by the sliding of the seal on the stationary panel.

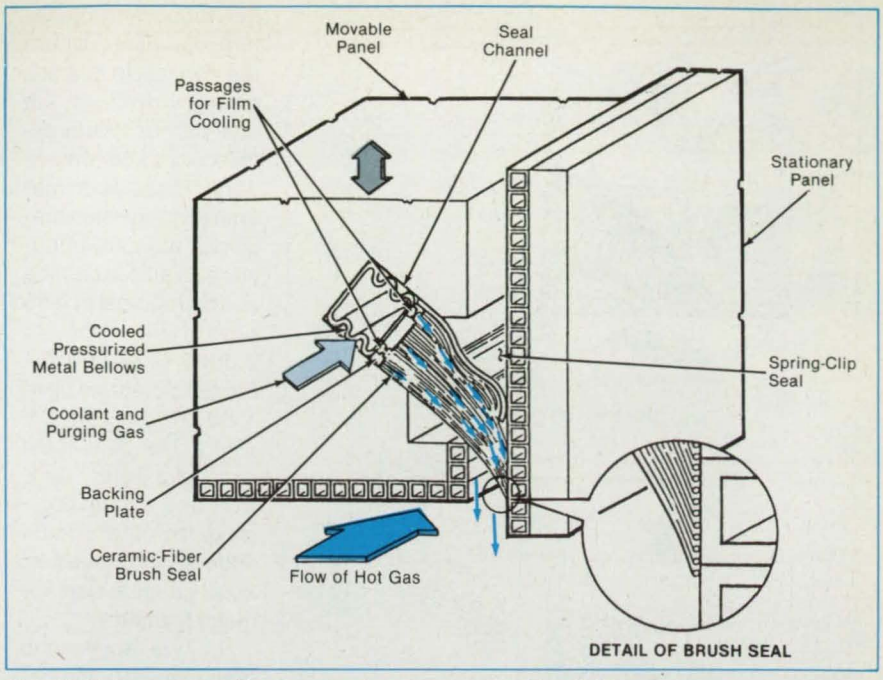
The bristles would be mounted and secured with a backing plate in the seal channel. The brush would extend out from the movable panel and make contact with the stationary panel. The angle between the seal and the stationary panel would be such that the pressure would act to improve the sealing contact between them.

In engine applications requiring significant seal travel or "stroke," an optional cooled pressurized metals bellows could be used to preload the seal against the adjacent sidewall.

The brush seal and the metal spring clip work synergistically to improve the overall performance of the seal system. The low-conductivity ceramic brush functions as an excellent insulator or first line of defense against the >2,000 °F (1,100 °C) engine flow gases. The integral metal spring clip located on the "cooler" [<1,500 °F (820 °C)] side of the ceramic brush provides a virtually leak-tight seal.

The angle between the clip and the stationary panel would be nominally the same as the angle between the brush seal and the stationary panel. The engine pressure would also act to improve the sealing contact between the spring clip and the stationary panel. To accommodate the distortions of the stationary panel, the spring clip could be segmented along its length, with adjacent spring clips overlapping.

The fibers of the brush packing could be made of materials such as alumina-silica, alumina-boria-silica or silicon carbide. Such fibers remain flexible when hot, and should function at high operating temperatures [up to 2,300 °F (1,260 °C)]. The permeability of the brush packing could be reduced significantly by the use of fibers with square cross sections in place of fibers with circular cross sections, so as to achieve a nearly ideal 100-percent packing density instead of the more typical 60-percent packing density. The backing plate and spring clip could be made of either nickel- or cobalt-based superalloys.



The **High-Temperature, Pressure-Assisted Brush Seal** would be installed in a movable panel in an advanced hypersonic engine. The seal would prevent the flow of hot engine gas from penetrating the gap between the movable panel and the adjacent stationary panel.

This work was done by Bruce M. Steinetz of **Lewis Research Center** *and Paul J. Sirocky of Sverdrup Technology, Inc. For further information, Circle 92 on the TSP Request Card.*

This invention has been patented by NASA (U. S. Patent No. 5,076,590). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Lewis Research Center [see page 26]. Refer to LEW-15086.

High-Temperature, Flexible, Fiber-Preform Seals

Seals can be tailored to service in a variety of environments.

Lewis Research Center, Cleveland, Ohio

High-temperature seals of a new type consist of preforms of multiple layers of fibers wound in configurations that minimize gas leakage while maintaining flexibility. The seals withstand operating temperatures much greater than those of prior fiber-preform or fiber-reinforced seals. The proposed fiber-preform seals are intended primarily to block hypersonic flows of air and engine gases through gaps between movable panels and adjacent stationary sidewall panels in advanced aircraft engines.

As shown in Figure 1, a representative seal includes a core of straight uniaxial (0°) fibers covered by various right-hand and left-hand spiral-wound fibers. The volume fractions of the various types of fibers are selected to optimize the seal for a given application to meet the competing requirements to minimize leakage and to enable the preform to conform to small bend radii. Increasing the fraction of uniaxial fibers decreases leakage but increases the bending stiffness. To resist abrasion damage, a sheath is braided over the seal. The sheath can be constructed of either 2- or 3-dimensional braid-architectures.

The addition of helical wraps of fibers increases the shear strength of the seal, helping minimize damage by abrasion as the seal slides on a highly distorted stationary wall. These inner helical wraps also reduce leakage by increasing seal packing density, thereby providing a more tortuous flow path. Materials selected for the seal are dependent on the application. For

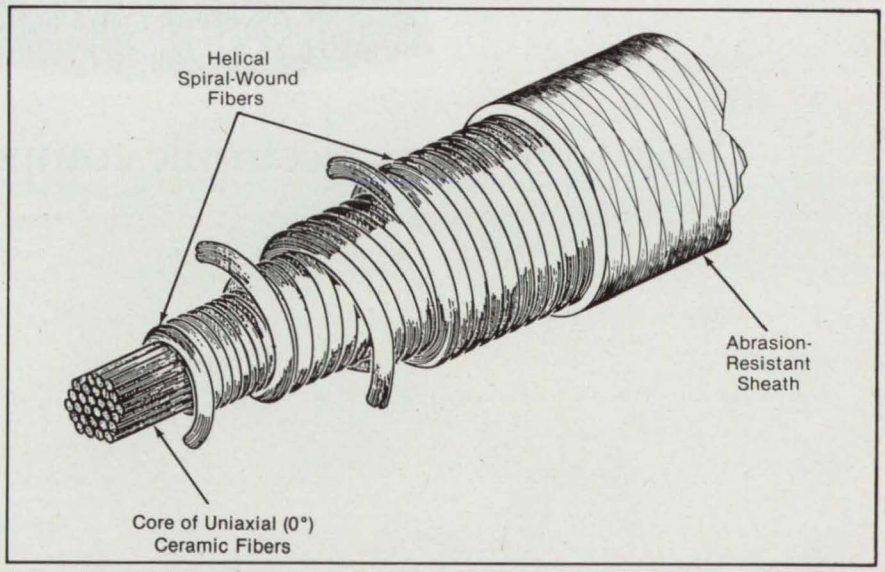
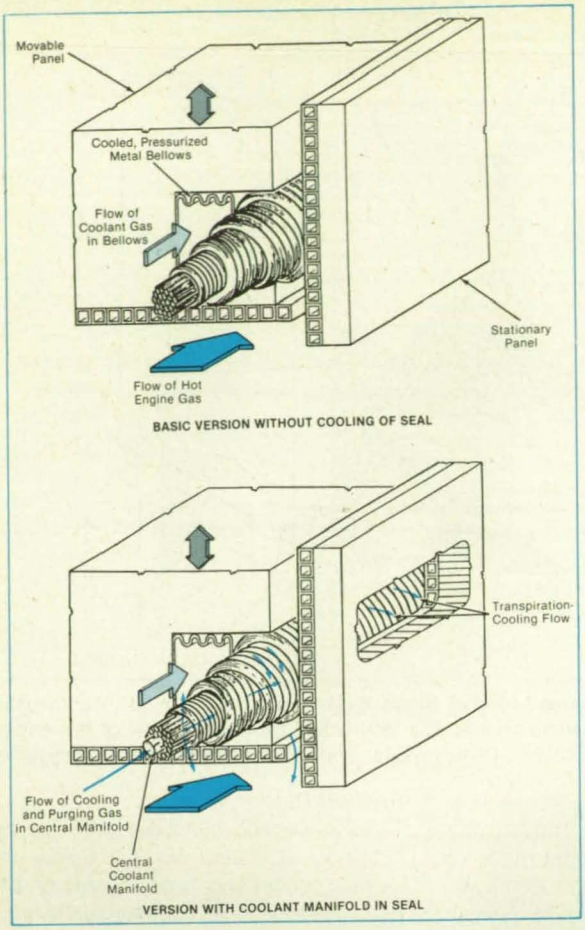


Figure 1. The **High-Temperature, Flexible, Fiber-Preform Seal** includes axial core and helical windings, and an abrasion-resistant sheath.



the highest temperature operation, where the duty cycle is static or mildly dynamic, the seal can be made exclusively of ceramic fibers. These fiber materials include alumina-silica, alumina-boria-silica, or silicon carbide and can operate at temperatures up to 2,3000°F (1,260°C). For temperatures up to 1,800°F (980°C), where the seal must resist significant abrasion and dynamic cycling, the outer sheath should be braided of small-gauge superalloy metal filaments.

In one application (see Figure 2), the device seals the sliding interface between movable and stationary engine panels of advanced hypersonic engines. The seal is mounted in a close-tolerance seal channel in the movable panel. To maintain good contact between the seal and the possibly distorted stationary wall, the seal would be preloaded by a cooled, pressurized metal bellows. Optionally, a central superalloy tube could be incorporated into the preform to carry purge cooling gas through the seal. This tube would also serve as a manifold to meter coolant gas to engine stations where the temperatures and pressures are higher. An inert gas, such as helium, flowing radially outward through the seal, would cool the seal and purge the cavity behind the seal of potentially explosive hydrogen/oxygen mixtures.

Figure 2. The **Fiber-Preform Seals** would be used between movable and stationary panels in advanced aircraft engines or to seal gaps of high-temperature furnaces.

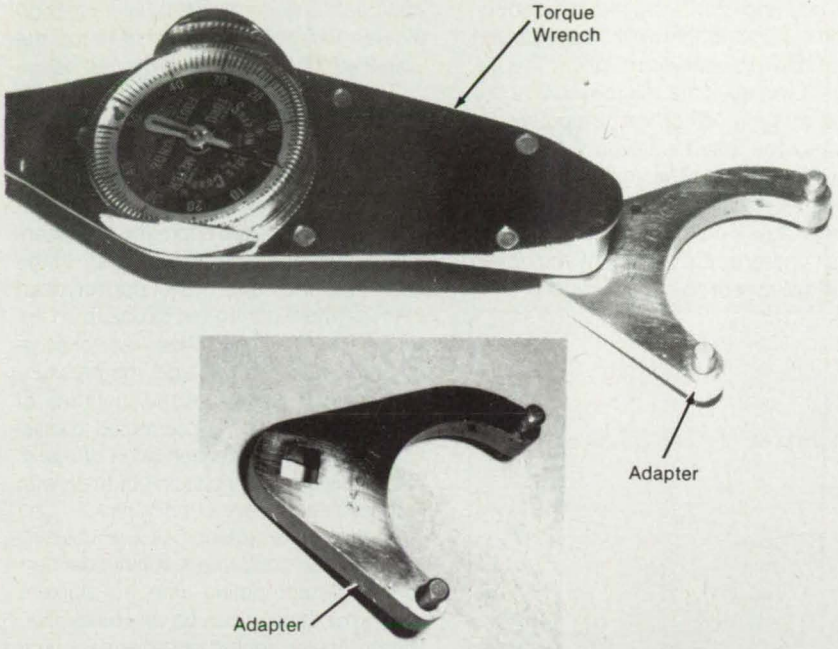
This work was done by Bruce M. Steinetz of **Lewis Research Center** *and Paul J. Sirocky of Sverdrup Technology, Inc. For further information, Circle 93 on the TSP Request Card.*

This invention has been patented by NASA (U. S. Patent No. 5,082,293). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Lewis Research Center [see page 26]. Refer to LEW-15085.

Torque-Wrench Adapter for Confined Spaces

A simple, durable tool can torque nuts that are difficult to reach.

John F. Kennedy Space Center, Florida



The **Spanner-Type Adapter** fits a standard torque wrench.

An adapter for a torque wrench enables it to tighten nuts in a confined space. The adapter allows full rotation of nuts with minimum clearance of the wrench.

The adapter is a spanner-type attachment that fits on the end of a standard torque wrench (see figure). A pair of dowel pins centers and locks the wrench onto a nut.

The adapter is fabricated from type 304 stainless-steel plate. It has been made in 2- and 2½-in. (5.1- and 6.4-cm) sizes but can readily be made in smaller and larger versions. The dowel pins, each 1 in. (2.5 cm) long and ¼ in. (0.64 cm) in diameter, are also made of 304 stainless steel.

In the original application for which it was designed, the adapter is used to apply a torque of 40 lb-in. (4.5 N-m). However, it can withstand torques up to 100 lb-ft (136 N-m).

This work was done by Alan Littlefield of **Kennedy Space Center**. *For further information, Circle 16 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Kennedy Space Center [see page 26]. Refer to KSC-11508.

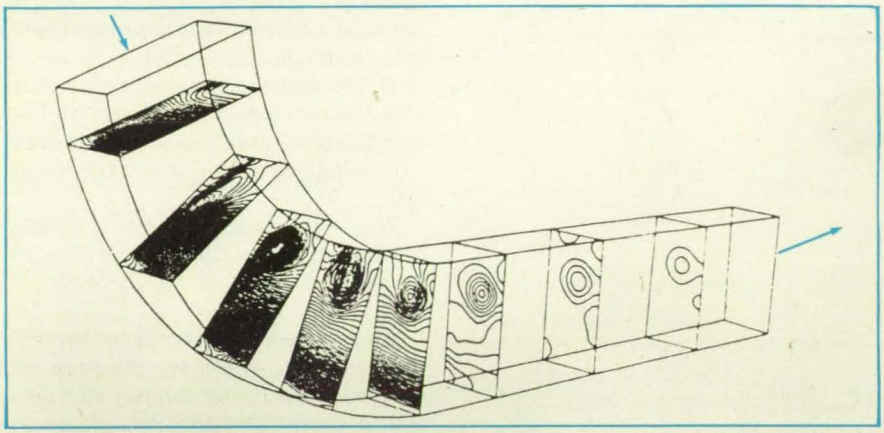
A Fractional-Step Method of Computing Incompressible Flow

Volume fluxes replace velocities as dependent variables.

Ames Research Center, Moffett Field, California

A method of computing the time-dependent flow of an incompressible, viscous fluid involves the numerical solution of the Navier–Stokes equations on a two- or three-dimensional computational grid that is based on generalized curvilinear coordinates. Like a number of such methods that have been reported in *NASA Tech Briefs* in recent years, this one is an intermediate product of a continuing effort to satisfy the competing requirements for accuracy and computational efficiency.

The equations of this method are derived in a primitive-variable formulation. The dependent variables are the pressure at the center of each cell of the computational grid and the volume fluxes across the faces of each cell. The volume fluxes replace the Cartesian components of velocity; these fluxes correspond to the contravariant components of velocity multiplied by the volume of the computational cell, in a staggered grid. This choice of dependent variables enables a simple extension of the previously developed staggered-grid approach to generalized curvilinear coordinates and facilitates enforcement of the conservation of mass as explained below.



These **Pressure Contours** at several cross sections of a duct with a 90° bend were obtained from computations of flow by the method described in the text.

The Navier–Stokes equations are discretized by finite volumes on the staggered grid. The resulting discrete approximation of the equations is accurate to second order in space and time. The solution follows a fractional-step approach, which entails two stages at each time step. In the first stage, the equations of conservation of momentum are solved to obtain an approximate flow field that does not conserve mass. In the second stage, the pressure and velocity (as expressed in terms of volume fluxes) fields are corrected to satisfy the equation of conservation of mass; this step leads to a Poisson equation with Neumann boundary conditions.

Because the solution of the Poisson equation can consume a substantial portion of the computing time, an efficient method of solution can be very beneficial. The particular choice of dependent variables and staggered grid facilitates the development of a computer program that solves the Poisson equation efficiently in nonorthogonal curvilinear coordinates. This

program implements an iterative scheme in which the solution is obtained at all the grid points along one coordinate line at a time, and the sequence of lines selected for solution is determined by a four-"color" ordering scheme that assures the decoupling of the implicit solution for each line from the implicit solution of any other line of the same "color."

The method has been tested on several two- and three-dimensional laminar flows: lid-driven flow in a cavity, symmetric and asymmetric flows about a circular cylinder, and flow in a rectangular duct with a 90° bend (see figure). In all cases, the results were in substantial agreement with those of other computational methods and with data from experiments.

This work was done by Dochan Kwak of **Ames Research Center**, *Moshe Rosenfeld of MCAT Institute, and Marcel Vinokur of Sterling Zero One. For further information, Circle 74 on the TSP Request Card. ARC-13154*

Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

Study of Compressibility Corrections to Turbulence Models

Effects on shear layers in simulated confined and unconfined flows are studied.

A report presents a comparative study of some terms that correct for the effects of compressibility in the standard k–ϵ mathematical model of turbulence (where k denotes the turbulence kinetic energy and ϵ denotes the rate of dissipation of turbulence kinetic energy. The classical k–ϵ model and various higher-order versions of it do not predict accurately the rates of spread of free shear layers in compressible flows, and the correction terms in question represent attempts to overcome this deficiency.

The study involved the simulation of flows by numerical solution of the Reynolds-averaged Navier–Stokes equations. In each simulated flow, two streams of air flowing at different speeds along a common streamwise direction were mingled at the trailing edge of a splitter plate, forming a free shear layer. Both unconfined streams and streams confined in a channel were considered. The mach numbers ranged from subsonic on the slow-stream side to hypersonic on the fast-stream side.

In the cases of unconfined flows, the rates of spread computed by use of k–ϵ models that incorporated the correction

terms were compared with rates of spread determined in experiments. In the case of confined flow, the velocity profiles and surface pressures computed with the help of the models and correction terms were compared with the corresponding experimental values.

The comparison showed that the compressibility-correction terms increase the accuracies of computed spread rates, but further improvements are warranted. The results in the case of the confined flow computed with all the models agreed well with data from experiments upstream of the station where the low-speed side of the shear layer merged with the boundary layer on the wall; downstream of this station, the results of computations with all the models diverged from the experimental data.

This work was done by J. R. Viegas of **Ames Research Center** *and M. W. Rubesin of MCAT Institute. Further information may be found in AIAA paper A91-42590, "A Comparative Study of Several Compressibility Corrections to Turbulence Models Applied to High-Speed Shear Layers."*

Copies may be purchased [prepayment required] from AIAA Technical Information Service Library, 555 West 57th Street, New York, New York 10019, Telephone No. (212) 247-6500.

ARC-13157

Deployable Debris Shields for Space Station

Primary debris shields would be augmented by deployable ones.

Multilayer shields made of lightweight sheet materials could be deployed from the proposed Space Station *Freedom* for additional protection against orbiting debris, according to a report. The deployment system could be a modified version of the system used to deploy blankets of solar photovoltaic cells during the Solar Array Flight Experiment aboard the Space Shuttle in 1984. The equipment in that experiment included a retractable-boom mast, a canister in which the mast was stored, a box that contained the solar-cell blanket, and associated equipment to deploy the blankets.

A deployment mechanism would be attached at each location on the exterior of the Space Station where extra protection was needed. Most such locations would likely be on the forward or "upwind" side. The shielding material could be stored on rolls in cylinders or folded in accordionlike fashion in flat cassettes, for example. The deployment equipment would withdraw a layer of this material from storage in a manner similar to unfurling a sail or extending a window shade. The number of layers to be deployed would depend on the required degree of protection, and could be as large as five. As in the blankets in the solar-array experiment, tensioning cables within each shielding layer could help maintain its shape.

This concept for augmentation of shielding offers five main advantages: One is compact storage of the shielding material. Another is the use of proven mechanisms (the solar-array-deployment system) to reduce the cost of development. The third advantage is that the deployment sequence can be simplified greatly (e.g., automatic or remotely controlled deployment and simultaneous deployment of multiple shields), thereby reducing or eliminating the need to send astronauts outside to deploy the shields. The fourth advantage is that the deployment equipment can be integrated into a small, self-contained system that can be handled without undue difficulty and possibly installed remotely. The fifth advantage is the ability to retract the boom to provide access to the shielded surface for inspection and/or maintenance.

This work was done by Eric L. Christiansen, Burton G. Cour-Palais, and Jeanne Crews of **Johnson Space Center**. *To obtain a copy of the report, "Deployable Debris-Shield Augmentation Element," Circle 22 on the TSP Request Card.*

MSC-21796

Configuration-Control Scheme Copes With Singularities

Joint velocities near singularities are reduced at the expense of small trajectory errors.

NASA's Jet Propulsion Laboratory, Pasadena, California

An improved configuration-control scheme for a robotic manipulator that has redundant degrees of freedom suppresses large joint velocities near singularities, at the expense of small trajectory errors. The scheme provides means to enforce the order of priority of tasks assigned to the robot.

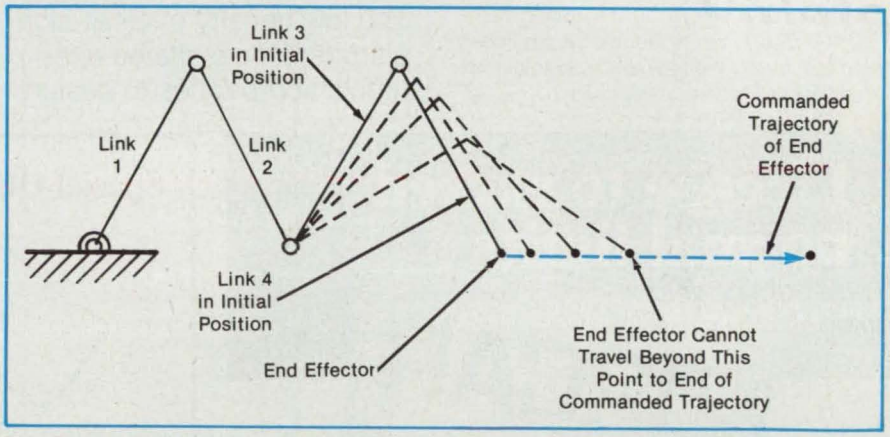
The basic concept of configuration control of a redundant robot was described in "Increasing the Dexterity of Redundant Robots" (NPO-17801), *NASA Tech Briefs*, Vol. 14, No. 10 (October 1990), page 88. To recapitulate: in configuration control, one takes advantage of the redundant degrees of freedom to superimpose an additional task or tasks on the basic task, which is to make the end effector of the manipulator follow a prescribed trajectory. Examples of additional tasks include reaching around obstacles to avoid collisions and maintaining one or more links of the manipulator arm in a desired posture.

In basic configuration control, the manipulator arm is made to track the desired trajectory as closely as possible, regardless of what velocities may be required of the manipulator joints. For a typical redundant manipulator, this kind of tracking may require impractically high joint velocities in the vicinity of one or more augmented Jacobian singularities, which are the joint configurations at which the determinant of the augmented Jacobian matrix relating joint velocities to task velocities goes to zero. These singularities can be caused by features of the basic task, the additional task(s), or by conflicts between the basic and additional tasks (see figure). The augmented Jacobian singularities are often too complicated to be determined in advance and can therefore be encountered unexpectedly during the motion of the manipulator arm.

The improved configuration-control scheme is a kinematic scheme and is said to be "singularity robust," meaning that in the vicinity of a Jacobian singularity, the control action is modified optimally in the sense that a positive quadratic cost function is minimized. The singularity-robust approach is known in the mathematical literature as the Levenberg–Marquardt-stabilization approach and perhaps more familiarly as the damped-least-squares approach. The cost function is a weighted sum of squares of trajectory (basic-task) velocity errors, additional-task-velocity errors, and joint velocities. By setting the gradient of this cost function in joint-velocity space to zero, one can find the optimal joint velocities, which now result in task coordinates and velocity that are slightly erroneous with respect to the commanded task. Of course, at coordinates far from singularities, the task coordinates and velocity are closer to the commanded trajectory.

The weights in the cost function can be chosen to express the relative desirability or undesirability of adhering strictly to the desired task trajectory vs. keeping the joint velocities within bounds, and the optimal joint-velocity solution automatically incorporates this tradeoff. As an extension of this concept, the weights can be chosen to enforce, via the cost function, the order of priority of multiple additional tasks.

This work was done by Homayoun Seraji of Caltech and Richard D. Colbaugh of New Mexico State University for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 55 on the TSP Request Card.*
NPO-18556



This **Planar Four-Link Robotic Manipulator** is assigned the basic task of moving the end effector horizontally to the right, and the additional task of keeping the distal end of link 2 at the initial position. An end-effector singularity and a conflict between the basic link additional tasks occur when links 3 and 4 both become horizontal; thereafter, links 3 and 4 cannot move the end effector farther to the right to reach the commanded position, but the control scheme will keep links 3 and 4 in a configuration such that the end effector is near the rightward limit of travel.

Membrane Separation of Nitrogen Tetroxide

A pilot plant reduces N_2O_4 content to one-hundredth of the inlet value.

John F. Kennedy Space Center, Florida

A permeable-membrane process removes nitrogen tetroxide (which is toxic) from a stream of nitrogen or helium gas. This process operates in conjunction with a scrubbing process that removes N_2O_4 from He or N_2 after the He or N_2 has been used as a gas blanket in an N_2O_4-storage tank. In a demonstration pilot apparatus, the process reduces the concentration of N_2O_4 in a 10-ft^3/min (283-L/min) helium stream from 1,000 parts per million (ppm) to 10 ppm. The selection of He, rather than N_2, as the medium for the pilot system results in a more stringent test of the concept because the membrane separation of other gases from He is more difficult than is separation from N_2.

The process is effected by a two-stage, two-step separator (see figure), with three banks of membrane modules. The membrane passes N_2O_4 preferentially over He, so that the gas on the higher-pressure side of the membrane is partially depleted of N_2O_4, while the gas on the other side is enriched in N_2O_4.

The first-step modules in the first stage contain 30 m^2 of membrane area. They are fed with helium containing about 1,000 ppm N_2O_4. The residue (the main stream,

partially depleted of N_2O_4) from these modules contains 330 ppm N_2O_4 and is fed to the second-step modules, which contain 58 m^2 of membrane area. The residue from this step contains 10 ppm N_2O_4 and is vented to the atmosphere.

The permeate (the side stream enriched in N_2O_4) from the first step contains 5,600 ppm N_2O_4. It is fed to the second stage, which contains 18 m^2 of membrane area. The residue from the second stage contains 1,000 ppm N_2O_4 and is recycled to the inlet of the first stage. The permeate from the second stage contains 19,000 ppm N_2O_4 and is returned to the scrubbing tower. (The amount of returned N_2O_4 is small in comparison with the total scrubber load.)

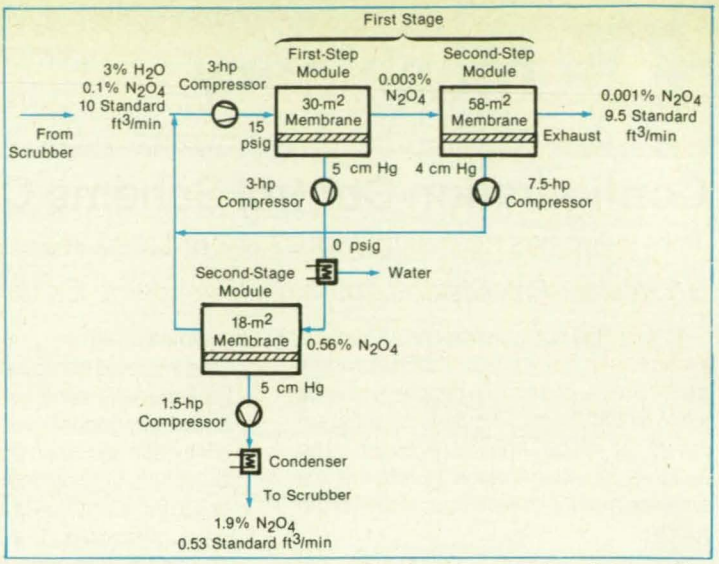
The membrane material is a polyamide copolymer that has a relatively low permeability to nitrogen and helium and high permeability to N_2O_4. Sheets of the membrane material are wrapped with spacer sheets around a perforated central tube to form a module. N_2O_4-depleted residue leaves through the ends of the spacers at the outlet end of the tube. N_2O_4-enriched permeate leaves through the central tube.

This work was done by R.C. Castro, J. Kaschemekat, V.D. Helm, P.H. Shrock, and J.G. Wijmans of Membrane Technology and Research, Inc., for **Kennedy Space Center.** *For further information, Circle 10 on the TSP Request Card.*

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

Janet Sarrant
Membrane Technology & Research, Inc.
1360 Willow Road, Suite 103
Menlo Park, CA 94025-1516

Refer to KSC-11519, volume and number of the NASA Tech Briefs issue, and the page number.



The **First Stage of the Separator** is divided into two steps for efficiency. The permeate from the second step of the first stage and the residue from the second stage are returned to the inlet of the first stage. Each module contains spiral-wound interleaved permeable membranes and spacer sheets.

Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

Subsonic Airplane for High-Altitude Research

The low density of air at high altitudes necessitates alternative approaches to design.

A report discusses the engineering issues that would be considered in the design of a conceptual subsonic airplane intended to cruise at altitudes of 100,000 ft (about 30 km) or higher. The airplane would carry scientific instruments for research

in the chemistry and physics of the atmosphere — particularly, for studies of the "ozone hole," "greenhouse" gases, and climatic effects. It is necessary to develop a new subsonic airplane for this purpose because (1) the increases in temperatures and pressures caused by the shock fronts that surround supersonic airplanes could distort the scientific measurements and (2) at present, the maximum cruising altitude achievable by any currently available subsonic airplane is about 70,000 ft (about 21 km).

The basic mission of the proposed airplane is to carry 3,000 lb (1,400 kg) of scientific instrumentation along a path 6,000 mi (9,700 km) long at the specified high altitude. The usual airplane-engineering considerations of weight, engine power, strength and rigidity of structure, cost, and duration of flight impose greater and more severely conflicting demands in this case than in the case of ordinary commercial airplanes because the low density of air at higher altitudes results in lower wing lift and lower engine thrust. Consequently, alternatives to the usual approaches to design must be considered.

The report identifies the following four major technological issues that would affect the design:

- Airfoils and propellers must be designed for operation at low Reynolds numbers and high mach numbers.
- A new propulsion system must be designed for efficient operation at the 100,000-ft (30-km) altitude.
- Lightweight materials and techniques of fabrication must be selected to keep the structural portion of the weight of the airplane low.
- Special considerations apply in the design and operation of this and other lightly loaded [5- to 7-lb-load per square foot of wing area (24- to 34-kg-load per square meter of wing area)] airplanes near the ground in the presence of wind.

Design features that would address some of these issues may include some or all of the following:

- Innovative airframe-and-wing designs, most featuring wings with high aspect ratios;
- Large propellers — as much as 30 ft (10 m) in diameter;
- A triple-supercharged reciprocating engine or engines;
- Structural components of graphite/epoxy, aromatic polyamide, and/or other lightweight materials in honeycomb and sandwich construction.

One of the most important design questions is whether the airplane should be operated by remote control or by a pilot aboard. This issue arises not only because of the obvious considerations regarding safety and the ability of a pilot to withstand long flights but also because elimination of the pilot and life-support equipment could reduce the total weight of the airplane by 600 to 800 lb (270 to 360 kg). The report concludes tentatively that about 80 percent of all flights would be conducted with a pilot aboard. However, the cockpit and life-support equipment could be modular so that they could be removed to reduce weight on remotely controlled flights.

One issue that affects the operation and, to some extent, the design of the airplane is the method of launch. Alternatives to conventional takeoffs may be preferable to reduce the weight and range penalties associated with ascents through the lower altitudes. Candidate alternative launching techniques include rocket launch or boost, drop from a carrier aircraft, and towed ascent.

This work was done by Alan Chambers of **Ames Research Center** *and R. Dale Reed of PRC System Services. To obtain a copy of the report, "NASA Studies the RPV Role: A Very High Altitude Aircraft for Global Climate Research," Circle 5 on the TSP Request Card.*
ARC-12822

Welding Wires to Thin Thermocouple Films

Parallel-gap resistance welding yields joints that should survive temperatures of about 1,000 °C.

Lewis Research Center, Cleveland, Ohio

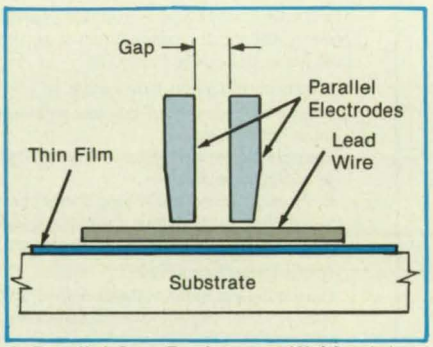
Parallel-gap resistance welding has been shown to be effective in attaching lead wires to thin-film thermocouples for high-temperature service. Temperature sensors made by this method have been tested at temperatures up to 1,000 °C.

The tested sensors consisted of platinum and 87 percent platinum/13 percent rhodium thin films; and each lead wire, 76 μm in diameter, had the same composition as that of the sensor film to which it was welded. Sensor films were deposited on various substrates, including superalloys, aluminum oxide, silicon carbide, and silicon nitride. Sensors of this type are used to measure temperatures and heat fluxes in advanced aircraft engines.

Parallel-gap resistance welding has important advantages over other methods of attaching wires to thin films. It is much faster than is thermocompression bonding, which takes at least 4 hours at high temperature and high clamping pressure to produce a diffusion-bonded junction strong enough to survive on the rotor of a jet engine. The speed of parallel-gap resistance welding also exceeds that of such techniques as conductive-paste bonding and sputtering thin films through porous flame-sprayed insulation on prewelded lead wires. Unlike conductive paste, parallel-gap welding introduces no foreign material into the thermocouple circuit and, unlike the flame spraying/sputtering process, does not require careful control of the thickness of the flame-sprayed material.

The welder has a pair of parallel electrodes (see figure). A lead wire is positioned on the thin film. The electrodes press the wire against the film with a preselected force. Welding current passes from one electrode through the wire and film to the other electrode.

The surface finishes of the substrates used in this investigation varied from 0.1 to 1 μm. The thicknesses of the platinum and platinum/rhodium films ranged from 1 to 7 μm; the most-consistent results were obtained at thicknesses from 3 to 7 μm. Welding parameters were found experimentally for each combination of wire, film, and substrate. The best welding voltages were found to range from 1 to 1.9 V, increasing with the thermal conductivities of the substrates. The best welding times ranged from 20 to 80 ms. The best welding forces ranged from weights of 400 to 850 g for platinum and from 600 to 1,000 g for 87 percent platinum/13 percent rhodium and increased with the hardnesses of the wires.



A **Parallel-Gap Resistance Welder** joins a lead wire to a thin-film thermocouple element.

Placement of the wire in relation to the electrodes is crucial. The wire should be centered under the electrodes and perpendicular to the gap. Otherwise, the pivoting motion of the electrodes as they make contact with the wire causes the wire to roll. This, in turn, damages the thin film. The use of preflattened wire eliminates rolling, but the preflattening operation cold-works the wire, making it brittle. An additional annealing step after flattening would be beneficial.

This work was done by Raymond Holanda Walter S. Kim, and Gerald A. Danzey of **Lewis Research Center** *and Eric Pencil and Mary Wadel of the University of Cincinnati. Further information may be found in NASA TM-102442 [N90-21361], "Attachment of Lead Wires to Thin Film Thermocouples Mounted on High Temperature Materials Using the Parallel Gap Welding Process."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.
LEW-15100

Oxygen-Free Welding Contact Tips

Electrical erosion is greatly reduced in gas/metal arc welding.

Langley Research Center, Hampton, Virginia

Contact tips for gas/metal arc welding (GMAW) have been fabricated from an oxygen-free copper, significantly reducing the electrical-erosion wear rate. Standard GMAW contact tips, which are manufactured from a low-grade, oxygen-impregnated copper, are considered to be expendable. Problems associated with electrical erosion in robotic welding of heavy weldments include the need to align joints for the deposition of filler metal and the need to spend excessive amounts of time in the removal and replacement of contact tips.

Twelve prototypes of the new tips were made from ASTM F-68-82 oxygen-free copper, which, heretofore, has been used to make electron devices. The prototype tips are being tested in robotic welding, for which application they are primarily intended. The use of the new tip material should reduce electrical erosion, increase electrical conductivity, and reduce mechanical wear. The productivity of robotic welding should increase while the time during which welding has to be interrupted for the removal and replacement of contact tips should be minimal. The prototype contact tips should greatly improve the alignment of joints and filler metal, thereby reducing the rate of rejection and repair of unacceptable weldments. Utility extends beyond the aerospace industry to the mass production of various types of hardware, including heavy off-highway construction equipment.

This work was done by James F. Pike of **Langley Research Center**. *For further information, Circle 38 on the TSP Request Card.*

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, Langley Research Center [see page 26]. Refer to LAR-14169

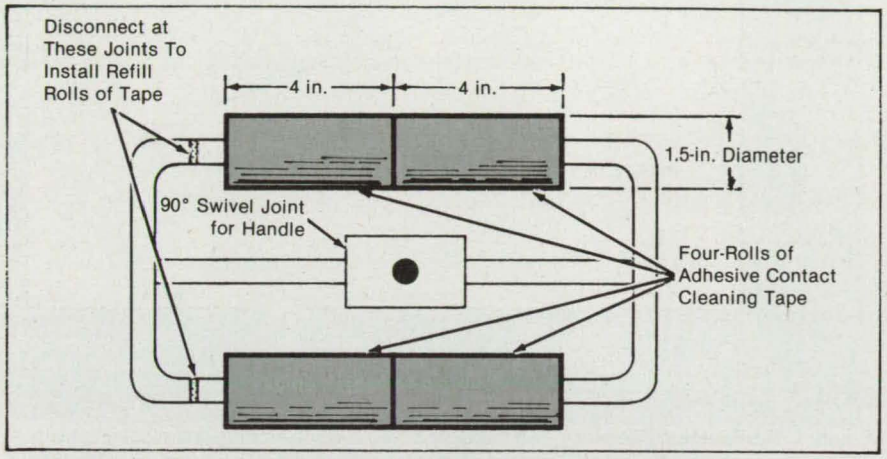
Adhesive Contact Sweeper

Sweeper cleans thoroughly without raising dust.

Marshall Space Flight Center, Alabama

An adhesive contact sweeper removes hair and particles that a vacuum cleaner leaves behind, without stirring up dust as a broom does. It can also clean loose rugs, which tend to be drawn into and clog vacuum cleaners.

The sweeper includes a frame and two spindles. Each spindle holds two spools of inverted adhesive tape — that is, with the sticky side out (see figure). The spools are commercially available products used on lint brushes. A broom handle is connected to the middle bar of the frame by a swivel joint, which provides 90° of pivotal freedom so that a user can easily move the sweeper back and forth over a surface while keeping it in contact with the surface.



The **Sweeper** holds commercially available spools of inverted adhesive tape.

The sweeper is suitable for use in environments in which air must be kept free of dust; for example, optics laboratories, computer rooms, and areas inhabited by people allergic to dust. For carpets, it is best used in tandem with a vacuum cleaner; a first pass with the vacuum cleaner removes coarse particles, and a second pass with the sweeper extracts fine particles. This practice extends the useful life of the adhesive spools.

The user sweeps a conveniently sized section of the surface, first in one direction, then in the perpendicular direction. The user then moves on to adjacent sections until the surface is completely clean. When the exposed layer of adhesive tape becomes too dirty to be effective, the user tears the layer off to expose fresh underlying tape. When the spools are empty, the user removes a side of the frame and replaces them with new spools.

This work was done by Jonathan D. Patterson of **Marshall Space Flight Center.** *No further documentation is available.*
MFS-28637

Softened-Stainless-Steel O-Rings

These O-rings seal over a wide range of temperatures.

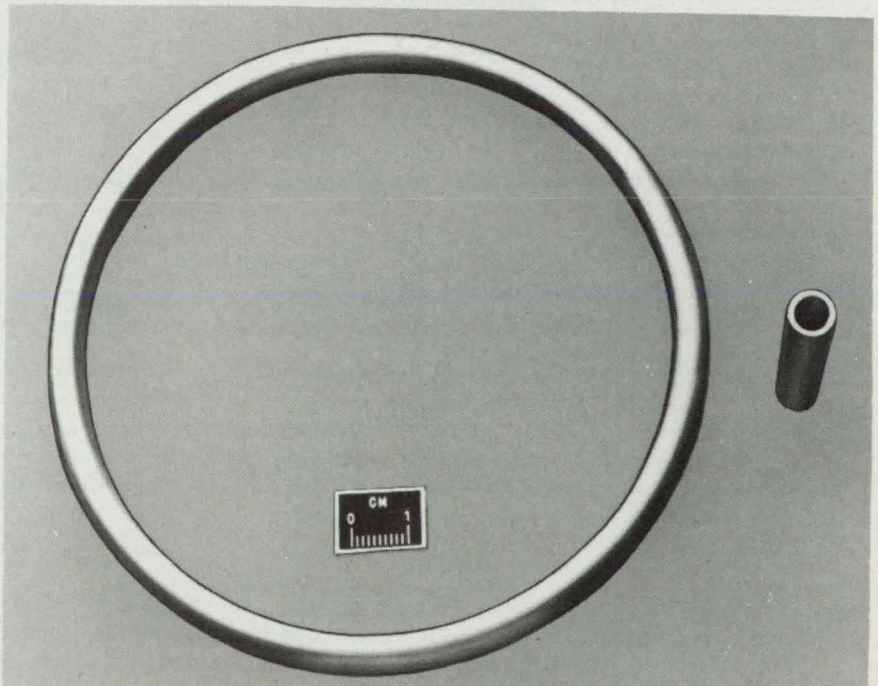
Lewis Research Center, Cleveland, Ohio

Work at the Lewis Research Center has led to the development and fabrication of novel, inexpensive O-rings that are suitable for use over a wide range of temperatures. Sections of pipe are commonly joined together by use of flanges and O-ring adapters. O-rings made of organic materials are unusable for pipe assemblies that are exposed to high temperatures. Asbestos, fiberglass, and stamped metal seals can be used to replace O-rings in joints exposed to high temperatures, but the use of such replacements is limited by environmental or production-related considerations.

In the fabrication of an O-ring of the new type, a tube of 304 stainless steel is bent around a mandril into a circle and welded closed into a ring (see figure). The ring is then annealed in a furnace to make it soft and highly ductile. In this condition, it can be used as a crushable, deformable O-ring seal.

O-ring replacements of this type offer several advantages. They can be used in a variety of atmospheres and temperatures, are relatively inexpensive, can be fabricated with a minimum amount of work, are amenable to one-of-a-kind production, are reusable, and are environmentally benign.

This work was done by G. A. Marquis of **Lewis Research Center** *and William I. Waters of Sverdrup Technology, Inc. No further documentation is available.*
LEW-15344



This **O-Ring** was made from a 304-stainless-steel tube of 5/16-in. (7.94-mm) outside diameter and 1/4-in. (6.35-mm) inside diameter.

Energetic Atoms Would Etch Photoresists Anisotropically

Directed kinetic energy enhances reactivity.

Lyndon B. Johnson Space Center, Houston, Texas

Directed beams of single oxygen atoms that have kinetic energies between 1 and 5 eV have been successfully used in the anisotropic etching of oxygen-labile photoresist patterns on silicon wafers. Anisotropic etching of photoresist is a key step in the manufacture of integrated circuits on semiconductor wafers. The use of high-kinetic-energy, neutral-oxygen atom beams in the lithographic (pattern-transfer) processing of integrated circuits has important potential advantages over such state-of-the-art methods as reactive ion etching. Most significantly, damage to the semiconductor material under a photoresist layer is reduced or eliminated when a 1- to 5-eV oxygen-atom beam is used simply because offending high-energy ions and photons are no longer part of the processing environment. The 1- to 5-eV-atom-beam method might be incorporated into lithographic processes for the fabrication of integrated circuits.

The anisotropic-etching technique is based on the discovery that the reactivity of oxygen atoms with organic solids depends strongly on the kinetic energy of the atoms (see Figure 1), and, in particular, the

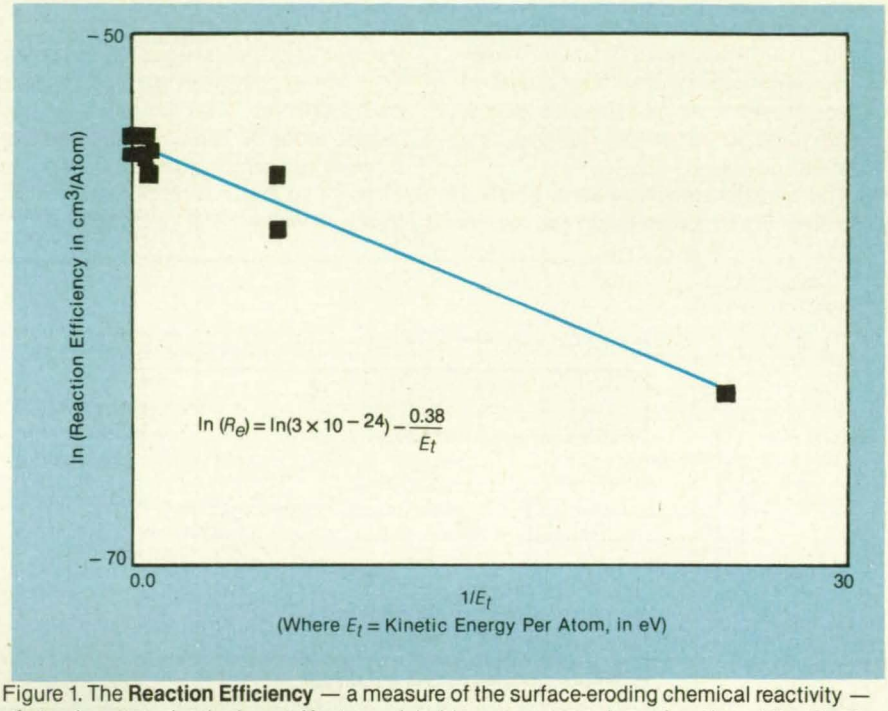


Figure 1. The **Reaction Efficiency** — a measure of the surface-eroding chemical reactivity — of atomic oxygen impinging on Kapton polyimide was measured as a function of the kinetic energy of the oxygen atoms. The measurements agree fairly well with the theoretical curve, which represents a modified Arrhenius function in which the thermal-energy term is replaced by the average kinetic energy of the atoms.

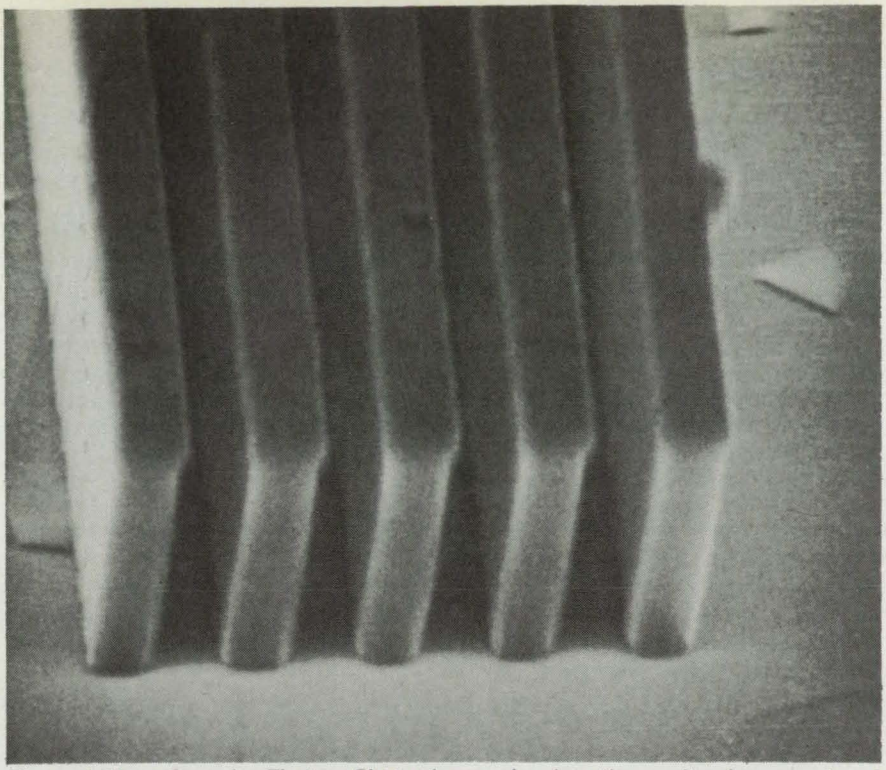


Figure 2. These **Scanning-Electron Photomicrographs** show the results of an experiment in anisotrophic etching.

reactivity of 1- to 5-eV (hyperthermal) atoms is thousands of times as great as that of 0.04-eV (thermal) atoms. As a result, a directed beam of hyperthermal atoms rapidly attacks the photoresist polymer, producing a sharp anisotropic etch. Atoms that scatter from the photoresist without reacting lose most of their kinetic energy in inelastic collisions and show greatly reduced reactivity as a result. In a fabrication process, the beam would be turned off after etching through the photoresist and before the thermalized atoms produced by inelastic collision with the substrate could undercut the pattern significantly.

In a demonstration of this method, samples of a trilayer photoresist pattern on a silicon substrate were etched by a beam of neutral atoms at a kinetic energy of 2 eV per atom, with a total dose of 3×10^{19} atoms/cm^2. The results of the experiment are shown in Figure 2. While some undercutting caused by an excessive dose is evident, the results clearly demonstrate the potential of hyperthermal neutral atom beams for anisotropic etching in the manufacture of integrated circuits or in other photolithographic processes in which precise micropatterns are etched in polymer surfaces.

This work was done by Steven Koontz of **Johnson Space Center** *and Jon Cross of Los Alamos National Laboratories. For further information, Circle 1on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center [see page 26]. Refer to MSC-21631.

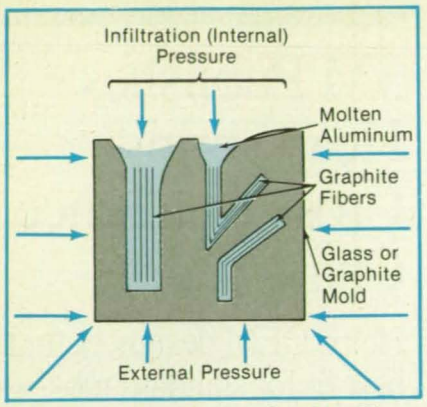
Pressurized Shell Molds for Metal-Matrix Composites

Balancing of internal and external pressures simplifies fabrication and reduces costs.

Lyndon B. Johnson Space Center, Houston, Texas

Balanced-pressure molds are used to make parts in complex shapes from fiber-reinforced metal-matrix composite materials. In a single step, the balanced-pressure molding process makes parts in nearly their final shapes; only minor finishing is needed. Because the molding pressure is the same on the inside and outside, a mold does not have to be especially strong and can be made of a cheap, nonstructural material like glass or graphite.

In the balanced-pressure molding method, fibers do not have to be cut to conform to molds. The method produces parts with



A **Preform of Continuous Graphite Fibers** rests in a glass or graphite mold. Molten aluminum is poured into the mold and pressurized. An equal opposing pressure is applied to the outside of the mold.

a high content of continuous fibers — greater than 55 percent by volume. The parts are stiff but light in weight, and their coefficients of thermal expansion can be adjusted. The parts have resistances to mechanical and thermal fatigue superior to those of similar parts made by prior fabrication methods.

The new method is based on the prior liquid-metal-infiltration method, in which a matrix metal in liquid form is poured into a mold that contains a preform composed of the reinforcing fiber in a mold. Ordinarily, to ensure that the liquid wets the surfaces of the fibers, the inside of the mold must be pressurized to more than 500 lb/in.^{2} (3.4 MPa). This means that the mold must be made of a strong structural material. Liquid-metal infiltration is therefore costly, especially for a one-of-a-kind casting.

In the new method, however, a gas outside the mold exerts a pressure equal to the internal pressure (see figure). High molding pressures can be used without resorting to structural shapes and materials for the mold. For example, a pressure of 1,000 lb/in.^{2} (6.9 MPa) has been used with glass and graphite molds to make aluminum parts reinforced by graphite fibers.

This work was done by Uday K. Kashalikar and Richard N. Lusignea of Foster-Miller, Inc., and James Cornie of Massachusetts Institute of Technology for **Johnson Space Center**. *For further information, Circle 39 on the TSP Request Card.*
MSC-21452

Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

Pulsed-Current Welding of Nickel-Based Alloy

Joints are as strong as (or stronger than) joints made with constant current.

Pulsed-current gas/tungsten arc welding produces joints at least as strong as those made by constant-current gas/tungsten arc welding, a report shows. The report is based on a study of pulsed-current versus constant-current gas/tungsten arc welding of butt joints between panels of nickel-based alloy 718.

In pulsed-current welding, the arc current is alternated between a high and a low value, typically at a repetition frequency between 0 and 10 Hz. In comparison with constant-current welding, pulsed-current welding enables greater control of the freezing and depth of penetration of the weld puddle at a given heat input. Thicker sections [thicker than 0.125 inch (3.175 millimeters)] can be joined. In addition, pulsed-current welding can readily be incorporated into an automated welding system, with resultant greater uniformity and reproducibility of welds than can be attained in manual welding.

In the study, evaluations were conducted on two base-metal lots of 0.125-in.-thick panels, two filler-metal lots, two heat-input levels, and pulsed and nonpulsed welding processes. Before welding, each panel was heat-treated to one of two conditions. After welding, panels were left as-welded or heat-treated again. Statistical analyses, including analysis of variance, were per-

formed on yield strength, ultimate tensile strength, and high-cycle-fatigue properties.

In addition to showing that the pulsed-current welds were at least as strong as constant-current welds, the analysis also showed the following:

- There was no difference between the room-temperature high-cycle-fatigue lives of welds produced by constant and by pulsed current.
- The ultimate tensile strengths and fatigue lives were affected by differences among the heat lots of the parent and filler metals and by differences in heat inputs, but the magnitudes of these effects were not significant.

This work was done by W. R. Gamwell, C. Kurgan, and T. W. Malone of **Marshall Space Flight Center**. *Further information may be found in NASA TM-103529 [N91-21287], "An Evaluation of GTAW-P Versus GTA Welding of Alloy 718."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.
MFS-27266

Ultrasonic Inspection of Thick Sections

Transmission through the thickness can reveal flaws in all-metal and composite structures.

Contrary to previous thinking, ultrasonics can be used to inspect large, relatively thick vessels for hidden defects, a report contends. The report is based on experiments in through-the-thickness transmission of ultrasonic waves in both steel and filament-wound composite cases of solid-fuel rocket motors.

In the experiments, the optimum frequency of sound was found to be 50 kHz or slightly less. The customary arguments about the detectability of flaws as a function of frequency were found not to hold in the experiments, probably because the distances from bond lines to image planes were small. In addition, resonances in through-the-thickness transmission may make certain frequencies better than others, depending on the thicknesses of cases to be inspected.

Filament-wound composite cases were found to be easier to examine by through-the-thickness transmission than steel cases were. This is because resonances and mode conversions are more pronounced in steel, and the acoustic impedances of composite cases are better matched to those of acoustic-transducer interfaces.

The most effective acoustic excitation was found to be gated bursts, with detection and processing of only the first few cycles of each burst. A clear measure of attenuation can be made by sending out a short burst of energy, then waiting for reflections to die out before sending another burst. Detecting only the first few cycles then excludes energy arriving by any path other than a direct one. This helps to eliminate resonance and mode-conversion problems in steel.

Heretofore, it has usually been regarded as necessary to use ultrasonic transducers of greater diameter as the frequency decreases. This consideration does not apply in situations like those considered in this study, because a focused, collimated beam is not necessary. Instead, the transducers — a fixed transmitter on the inside of the case and a movable receiver on the outside — can have diameters much less than half a wavelength. Indeed, the receiver should be small to locate flaws as precisely as possible.

This work was done by C. L. Friant, B. B. Djordjevic, C. V. O'Keefe, W. Ferrell, and T. Klutz of Science Applications International Co. for **Marshall Space Flight Center**. *To obtain a copy of the report, "Early Focus Ultrasonic Evaluation of Steel and Composite Case Shuttle Segments," Circle 29 on the TSP Request Card.*
MFS-28616

Planning Robot-Control Parameters With Qualitative Reasoning

Planning is treated as a search in the multidimensional space of control parameters.

NASA's Jet Propulsion Laboratory, Pasadena, California

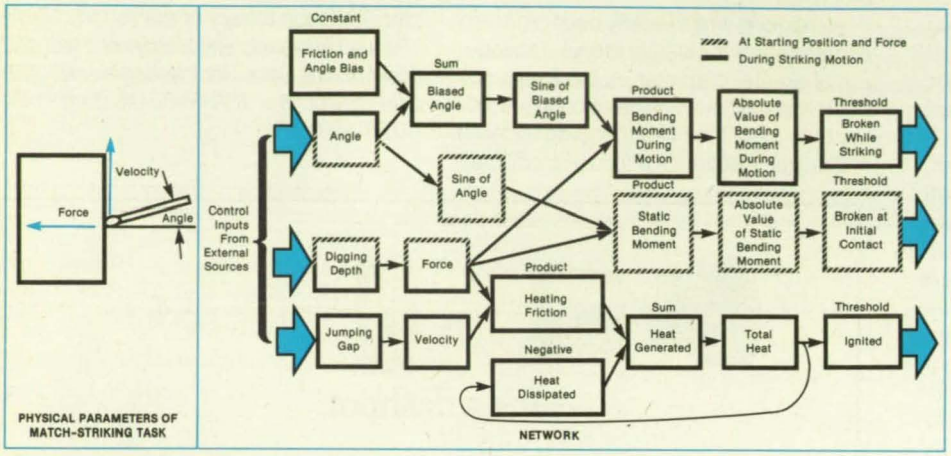


Figure 1. The **Planning Algorithm** makes use of a qualitative-reasoning directed graph in its search for parameters to control a robot in a match-striking task.

A qualitative-reasoning planning algorithm helps to determine the quantitative parameters that control the motion of a robot. The algorithm can be regarded as performing a search in the multidimensional space of control parameters from a starting point to a goal region in which a desired result of the robotic manipulation is achieved. It makes use of a directed graph representing the qualitative physical equations describing the task, and interacts, at each sampling period, with the history of quantitative control parameters and sensory data, to narrow the search for reliable values of the quantitative control parameters.

The algorithm is applied to the specific robotic task of striking a match on a matchbox. The physical parameters to be controlled are the force perpendicular to the striking surface, the velocity along the striking surface, and the angle of inclination of the match with respect to the striking surface (see Figure 1). In practice, the match-striking action is so brief (with respect to the sampling period) that the control subsystem cannot exert servocontrol over the perpendicular force and velocity. Therefore, the corresponding control parameters that are used instead are the digging depth (the depth of penetration of the nominal trajectory of the matchhead into the matchbox) and the jumping gap (the distance between sample positions), respectively.

The desired result of the robotic manipulation is ignition of the match; the undesired results include failure to ignite and breakage of the match. For the purpose of mathematical modeling, ignition is represented by the accumulation of sufficient frictionally generated heat in the matchhead, and breakage is deemed to occur when the absolute value of the bending moment in the matchstick exceeds the maximum allowable value.

The qualitative values represented in the algorithm are **+**, **0**, **−**, and **?**. For example, with respect to a given quantitative parameter, these values could mean that the actual value of the parameter minus the desired or control value is positive, zero, negative, or unknown, respectively. The heart of the qualitative mathematics is the concept of the likelihood potential, which is a measure of the number of different combinations of qualitative inputs, to each node of the network, that satisfy the known constraints, including a given qualitative output. The likelihood potentials are used to propagate qualitative values through the nodes of the network and as aids in selecting alternatives during the planning process.

The most important feature of the algorithm is the way it coordinates qualitative and quantitative information in planning. Qualitative information is embedded within the numerical history in the form of a qualitative vector at a point in the numerical search space that indicates the qualitative direction of the goal region from that point. Numerical information influences the qualitative search via the assertion of constraints on qualitative motions when numerical limits are exceeded. The key is the use of limits. In the two-dimensional example of Figure 2, the limits visible from a most recent trial are the physical limits above, below, and to the right. To the left, however, an earlier trial has given rise to a tighter limit. Only the region in white is considered for the next trial. When limits overlap, another direction must be considered. The qualitative-reasoning part of the algorithm easily handles limits by zeroing out the likelihood potentials for changes in nodes that would attempt to exceed limits.

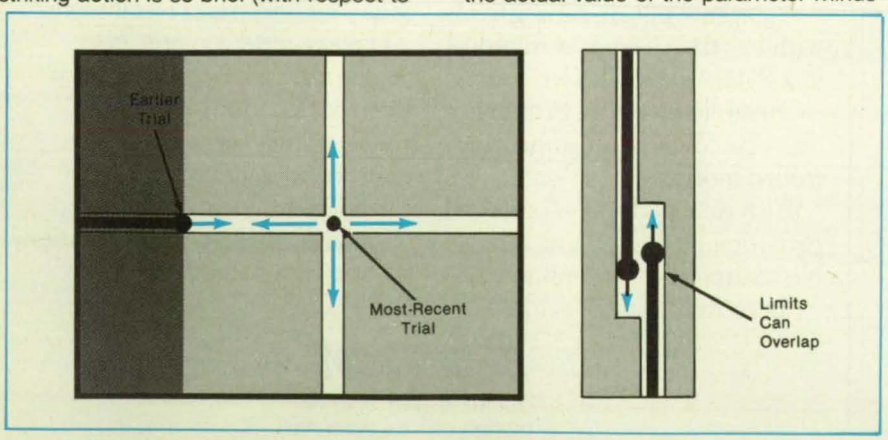


Figure 2. The **Search Region** is limited in response to quantitative data acquired during previous trials.

This work was done by Stephen F. Peters of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 8 on the TSP Request Card.*
NPO-18544

Registration of SAR Images With Multisensor Images

SAR data are resampled automatically via coordinates based on manually chosen tie points.

NASA's Jet Propulsion Laboratory, Pasadena, California

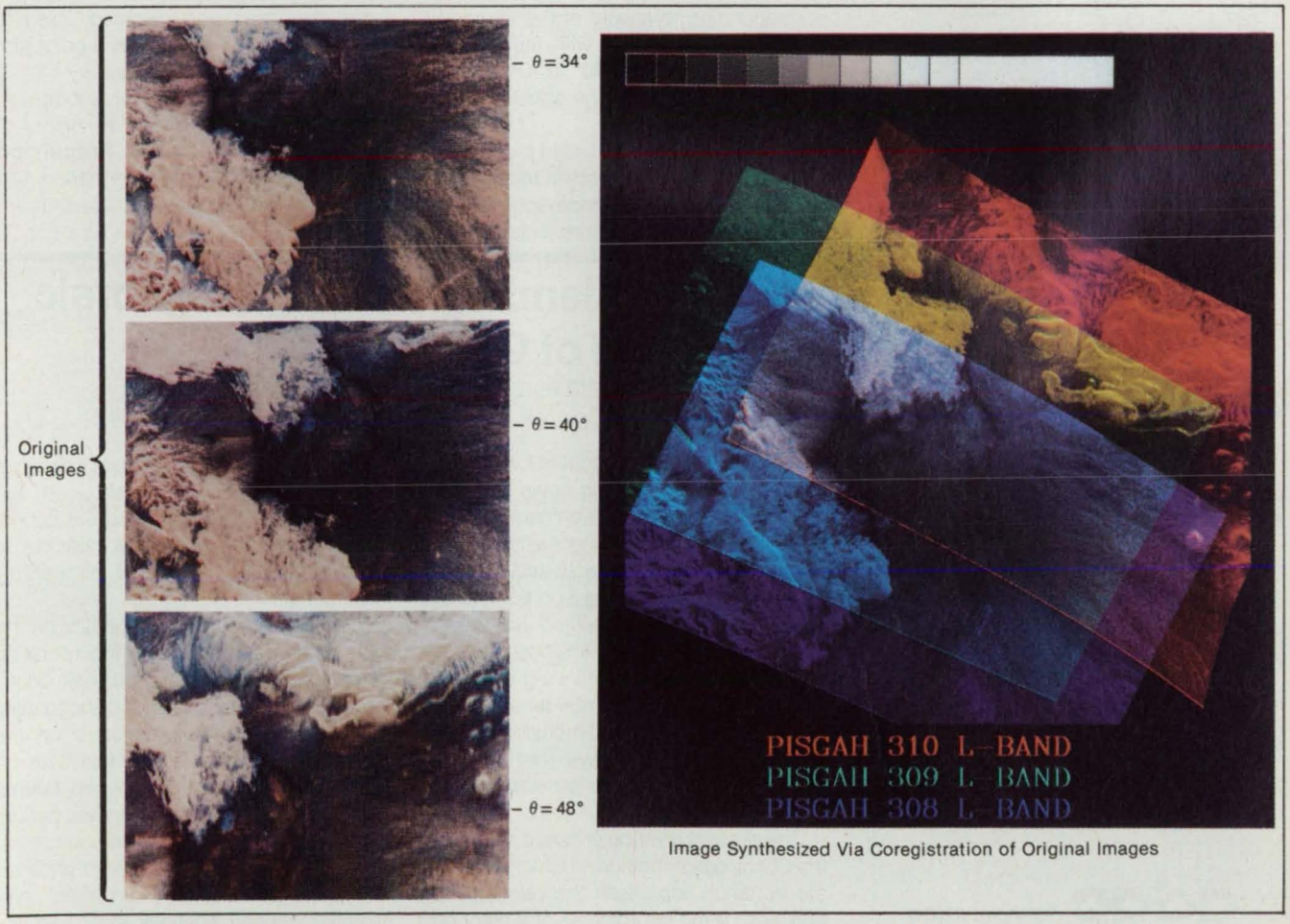
A semiautomated technique is intended primarily to facilitate the registration of polarimetric synthetic-aperture-radar (SAR) images with other images of the same or partly overlapping terrain while preserving the polarization information conveyed by the SAR data (see figure). The technique is also more generally applicable in the sense that one or both of the images to be registered with each other can have been generated by polarimetric or nonpolarimetric SAR, infrared radiometry, conventional photography, or any other applicable sensing method.

The SAR image to be registered with another image is called the "original" image; the other image with which it is to be registered is called the "reference" image. The heart of the registration technique is an algorithm that resamples the standard preprocessed original image data, in which the polarimetric radar backscattering properties of each picture element are represented by the ten elements of a Stokes matrix. The algorithm resamples each element of each Stokes matrix independently, and new Stokes matrices for all the picture elements are constructed. The new Stokes matrices can then be used to compute an SAR image in any specified combination of transmitting and receiving polarizations.

In preparation for resampling, corresponding tie points in the original and reference images are chosen manually by use of a split-screen video display and a mouse-driven cursor. The locations of picture elements in the reference and original images are expressed in x, y and x', y' Cartesian coordinates, respectively. The coordinates are assumed to be related by 2 third-order polynomial equations, each of which contains 10 unknown coefficients.

Each pair of tie points represents an instance of each of the two equations. Provided that there are at least 10 pairs of tie points, the equations can be solved by a least-squares method, yielding coefficients that minimize the distances between the x', y' of tie points computed by use of the equations and the actual x', y' of the tie points in the original image. Once the algorithm has computed these coefficients, it computes the x', y' of the point in the original image that corresponds to each picture element of the reference image. Then the resampled Stokes-matrix elements for this picture element of the reference image are computed by interpolation from the corresponding Stokes-matrix elements of those four picture elements in the original image that surround the calculated x', y' position.

This work was done by Diane L. Evans, Charles F. Burnette, and Jakob J. Van Zyl of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 7 on the TSP Request Card.*
NPO-18060



Three Partly Overlapping SAR Images made at different angles of incidence (θ) in the center of overlap were coregistered and melded by use of the technique described in the text.

Computer-Aided Plotting of Fields of View

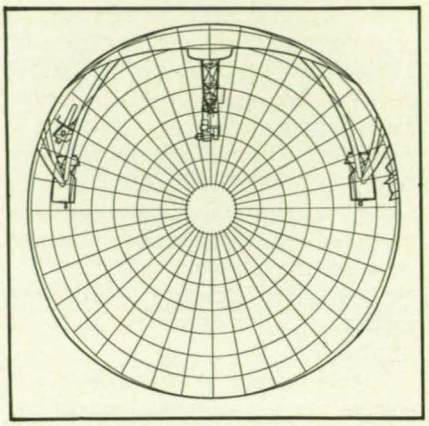
Plots are computed from data in computer-aided-design files.

NASA's Jet Propulsion Laboratory, Pasadena, California

The field of view and/or the field of obscuration of an optical or other instrument that has not been built yet can be illustrated by use of a computer-aided-plotting method. The method is based on the assumption that the structure in which the instrument is to be mounted, any nearby equipment that might also block part of the view, and possibly the instrument itself are the objects of a computer-aided-design effort, so that computer files of all relevant design data are available.

The method builds on the ability of a typical computer-aided-design program to construct perspective projections of solid objects that are specified in the associated design-data files. The user specifies the line of sight and the point of view of the instrument (called the "view vector," and "eyepoint," respectively, in this method). The computer program that implements this method superimposes part of a reference sphere centered on the eyepoint, marked with latitude and longitude lines corresponding to a pole at the intersection of the view vector with the sphere. (The latitudes run from 90° to 10°; that is, the half cone angle of the spherical grid is 80°.)

The computer-aided-design program is used to project the objects in the design-data file onto the reference sphere. The resulting perspective picture, including the latitude-and-longitude grid, is then mapped into a picture file in one of three projection formats: standard equal distance, equal area, or cosine weighted. This picture file is then used to make a polar plot of the field of view (see figure).



Structures in the Field of View of an instrument are plotted by a computer program after the user selects the point of view and the line of sight. The center of the polar grid represents the line of sight.

This work was done by Taras Kiceniuk, David F. Braun, and David W. Risher of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 12 on the TSP Request Card.*
NPO-18546

Improved Blending-Function Algebraic Generation of Grids

Orthogonality is relaxed by use of blending functions.

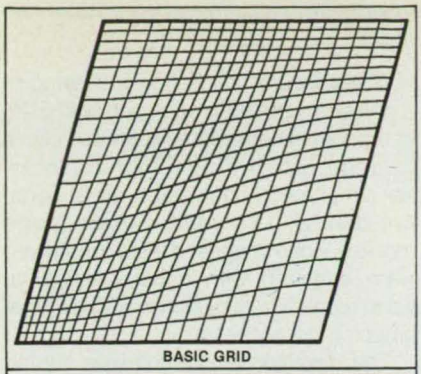
Ames Research Center, Moffett Field, California

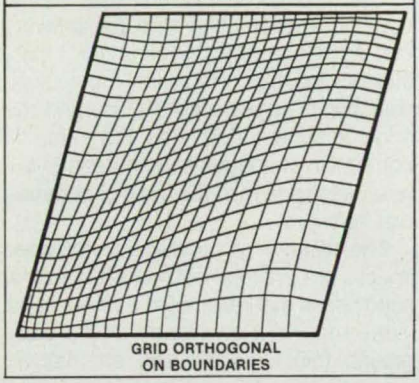
A method of algebraic generation of grids to be used in computing flows incorporates blending-function techniques to obtain a high degree of orthogonality of each grid on its bounding surfaces and to blend the grid smoothly, making it conform to all the boundaries. The method has been demonstrated in two dimensions, and it is being applied in the continuing development of software for the real-time interactive generation of three-dimensional grids with color graphical displays. That software would be used routinely in generating grids for computing flows of practical interest.

The present method is based partly on the Coons patch method, in which a bivariate equation expresses the relationship between (1) the coordinates of a point on a patch of surface and (2) the distances, along two coordinate axes on the edge of the patch, of the gridlines that intersect at the point in question. The basic Coons surface equation blends among the boundaries, generating grids that conform to the boundaries but are not necessarily orthogonal.

One can enforce orthogonality on the boundaries (see figure) by incorporating slope-correction terms into the basic Coons equation. In some cases, if orthogonality is enforced strictly everywhere on the boundaries, the grids can fold over on themselves in regions between boundaries. The present method involves parameter-controlled boundary slope corrections, which vary the angles between gridlines along the boundaries — in effect, providing controlled, spatially varying relaxation of orthogonality to prevent foldovers.

The method is implemented in the fol-





The Basic Grid conforms to the boundaries but is not orthogonal. Orthogonality can be enforced at the boundaries by use of slope-correction terms in the grid-generating equation.

lowing procedure: First, a flow domain is specified in terms of equations that define its boundaries. If necessary, the flow domain is decomposed into smaller four-sided patches (in two dimensions) or hexahedrons (in three dimensions). The boundaries of each patch or hexahedron are then discretized or redistributed by use of a suitable interpolation scheme; e.g., a piecewise cubic blending function. The resulting discrete points are then parameterized, initially to normalized arc lengths, and then parameter space is filled accordingly. The resulting distributions are substituted into the basic Coons surface equation (without slope corrections).

If orthogonality at the boundaries is desired, it is then incorporated by iterative application of a blending-function combination of intrinsic-slope (as in the basic Coons equation) and orthogonal-slope terms, which include parameters that control the relative contributions of the terms. The equations for the boundaries are reparameterized, if necessary. The process is repeated until a satisfactory grid is obtained.

This work was done by Raymond Ching-Chung Luh of MCAT Institute for **Ames Research Center**. *Further information may be found in AIAA paper A90-22198, "Algebraic Grid Generation with Boundary Orthogonality Control."*

Copies may be purchased [prepayment required] from AIAA Technical Information Service Library, 555 West 57th Street, New York, New York 10019, Telephone No. (212) 247-6500. ARC-13126

Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

Development of Software To Recognize Parts of Plants

A robotic system would differentiate among the seed heads, stems, and leaves of wheat plants.

A report describes the first phase in the development of a digital image-processing subsystem that would recognize parts of plants. The image-processing subsystem would be part of a robotic system that would tend and harvest plants in an automated plant-growth chamber. In the initial work described in the report, the focus was on image-processing software that would distinguish among the seed heads, stems, and leaves of wheat plants and would further distinguish between these parts and the background. The software was also intended to be adaptable to other types of plants.

The software was written and tested on a personal computer equipped with 512K of random-access memory, a video circuit card and monitor, mouse, math-coprocessor circuit chip, printer, four serial ports, two parallel ports, and a video image monitor. Video images to test the software were acquired with a black-and-white video camera in conjunction with a frame-grabbing coprocessor.

The development of software started from a collection of commercial software that implements algorithms for binary thresholding, binary-threshold morphology, detection of edges, gray-level morphology, and subtraction of images. Programs for correlation of images and analysis of textures were added to the base of commercial software.

The tests were conducted with video images of a single wheat head and of other seed heads that resembled a wheat head, viewed against a low-intensity neutral background (black paper) and alternatively against a noisy background (black painted lines simulating wood grain). Images of a wheat field were also used. Binary thresholding was found to segment mature and immature wheat from the neutral background but was unable to differentiate between mature wheat and the noisy background. Binary threshold morphology was found to be a good candidate for segmenting wheat heads from stems on the neutral background but not on the noisy background.

The edge-detection technique was applied in the effort to overcome the sensitivity to the noisy background in binary thresholding. Next, both gray-level morphology and edge detection were applied, but the combination was not successful in overcoming the background noise. Subtraction of images proved unsuitable as a technique for the recognition of the wheat head. Correlation of images proved successful in the recognition of both a single wheat stem and of wheat stems in a field of wheat. The texture-analyzing algorithm was found to be successful in locating heads of wheat in a wheat field but became confused when attempting to find heads among the stems near the bottom.

This work was done by Ronald R. DeSpain and Roy Tharpe, Jr., of McDonnell Douglas Corp., Leon Davis, Sharon Hauss, and Larry Shawaga of **Kennedy Space Center**, *and Ron Biro of Bionetics Corp. To obtain a copy of the report, "Plant Growth Machine Development Phase I Final Report," Circle 23 on the TSP Request Card.*
KSC-11488

Bioconvective Assay as Alternative to Draize Test

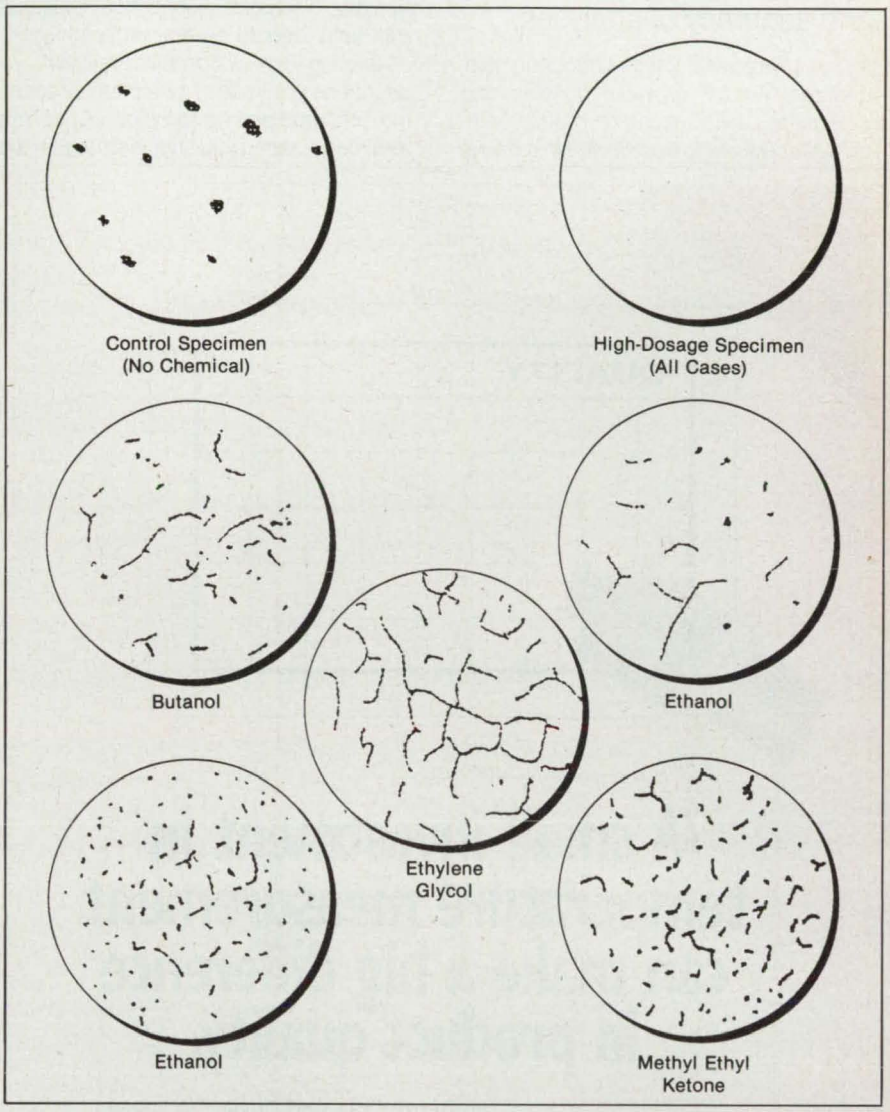
Toxicity can be assessed with greater sensitivity and at lower cost.

Marshall Space Flight Center, Alabama

A protocol to determine the toxicities of chemicals can now be implemented relatively cheaply by use of equipment and materials that can be packaged in convenient kit form. Tests according to this protocol involve the observation of macroscopic patterns that are formed at high concentrations of the free-swimming protozoan species *Tetrahymena pyriformis* in liquid media (bioconvective patterns). A test of this type provides a more-sensitive indication of toxicity and costs less than do either the Draize test (in which the toxicity of a substance is measured by its effect on the eyes of living rabbits) or tests in which the toxicity of a substance is measured by microscopic assessment of the motility of *Tetrahymena pyriformis* organisms exposed to it. Given that there are no data on the toxicities of 70 to 80 percent of commercial chemicals and given the high cost of, and the current opposition to, testing on higher animals, the new protocol could help meet a pressing need.

A bioconvective pattern is formed when organisms like *Tetrahymena pyriformis*, which have mass densities greater than that of the medium, accumulate in large numbers at the top of the medium. The resulting, relatively dense, top layer is unstable and evolves into a typical pattern as the organisms repeatedly swim upward, crowd together at the top, then fall in clumps to again repeat the cycle. This up-and-down motion involves many millions of organisms, and the resulting pattern has proven to be a reliable monitor of a variety of changes in the one-celled animals — most notably, changes in motility.

Each unit of the bioconvective-assay kit includes a sterile poly(methyl methacrylate) ampoule with syringe inserts. Initially, the ampoule contains a slant culture of about 100 of the *Tetrahymena pyriformis* protozoa that has a refrigerated life of 12 months. In preparation for a test, the remaining empty volume of an accompanying graduated syringe that has been partly filled with a proteose peptone medium is filled with distilled water; then the contents of the syringe are discharged into the ampoule. The ampoule is allowed to stand for three days while the organisms grow and multiply. No further lighting or sterile procedures are required to promote growth. For testing at the end of growth, the syringe is filled with a chemical diluent, which is similar to the water/medium mixture that was used to initiate growth except that it also includes a small quantity of the chemical to be tested. A complete kit includes multiple ampoule/syringe units for replication and varying dilutions.



These **Bioconvective Patterns** were formed at inhibitory dosages of the indicated chemicals.

To obtain quantitative indications of the toxicity of the chemical under test, the following are measured: (1) the maximum dilution at which the chemical inhibits the formation of bioconvective patterns, (2) formation times of the patterns, and (3) the numbers of nodal points in the patterns (see figure). Two additional quantities are measured to bracket the highest tolerated dose: (1) the minimum dilution at which the chemical permits patterns to form and (2) the maximum dilution at which the chemical prevents the formation of patterns.

This work was done by David A. Noever and Helen C. Matsos of **Marshall Space Flight Center**. *For further information, Circle 19 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 26]. Refer to MFS-26162.

Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

Procedures for Microbial-Ecology Laboratory

A manual prescribes routine procedures to ensure safety and accuracy of analyses.

The Microbial Ecology Laboratory Procedures Manual provides concise and well-defined instructions on routine technical procedures to be followed in a microbiological laboratory to ensure safety, analytical control, and validity of results. The manual comprises 10 sections and 2 appendices.

A brief introductory section is followed by a section entitled "Classification and Identification of Microorganisms (Bacteria)." This section discusses a procedure for observing the structures of colonies, as well as staining and other procedures for determining the structures of cells. This section also discusses biochemical tests that can help identify several organisms.

Section 3 — "Sample Analysis" — describes methods of collecting, preserving, and transporting samples, of tracking and manipulating (diluting) them within the laboratory, and of recording and reporting results.

Section 4 — "Enumeration of Microorganisms" — describes the membrane-filtration technique for the cultural enumeration of microorganisms and the spread-plate technique for cultural enumeration of anaerobic microorganisms. It discusses nutrient media for total coliforms, fecal coliforms, heterotrophs, fungi, non-saprophytes, Gram-negative bacteria, Gram-positive bacteria, *Legionella*, and anaerobes. It also describes the Petroft–Hauser chamber method and the acridine orange direct-count methods of enumerating single organisms.

Section 5 — "Media Preparation" — describes the preparation of 20 different media required for the growth of various organisms.

Section 6 — "Reagent Preparation" — describes the preparation of 11 reagents, including various stock dilution solutions, stains, and disinfectants.

Section 7 — "Storage and Maintenance of Microorganisms" — describes lyophilization of cultures, opening of lyophilized cultures, storage of cultures at low temperature (in liquid nitrogen at −196 °C), and the transfer of microorganisms.

Section 8 — "Laboratory Maintenance" — describes the procedures for maintenance of autoclaves, balances, centrifuges, glassware, and other laboratory equipment.

Section 9 — "Analytical Control" — describes bacterial-analysis, chemical-analysis, and water-suitability tests for monitoring laboratory water, tests for ultraviolet lights, and procedures for calibration of balances, thermometers, and other quantifying equipment.

Section 10 — "Safety" — describes guidelines for decontamination or sterilization of various materials and pieces of equipment, washing hands, orderly laboratory appearance to promote safe laboratory practice, dress and behavior to prevent contamination in the work area, and safety equipment.

Appendix A contains an example of a culture data sheet, of a culture quality control work sheet, and of a sample data sheet. Appendix B contains a list of 20 microbial-ecology-laboratory control organisms and illustrations of symbols used to describe the growth of colonies of microbes. Appendix C contains a figure that illustrates decimal dilution.

This work was done by Timothy L. Huff of Sverdrup Technology for **Marshall Space Flight Center**. *Further information may be found in NASA CR-184033 [N91-13856], "Microbial Ecology Laboratory Procedures Manual."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. MFS-27259

New on the Market

Edmund Scientific Co., Barrington, NJ, has designed a **stereo microscope system** for critical industrial applications where high-quality 3D perception is required to detect surface depressions and flaws to military and aerospace standards. The stereo microscope features a trinocular head with a 90° tube for video and photo applications. It has built-in incident and transmission illuminators, a large field of view, and an extra-long working distance under the objective to allow insertion of probes or tools.
For More Information Circle No. 794

Emerald Intelligence, Ann Arbor, MI, has announced version 2.1 of Diagnostic Advisor, a **software tool based on expert systems technology** and designed to help equipment manufacturers gain a competitive advantage, reduce field service costs, and increase customer satisfaction. OEMs can use it to reduce end user downtime, MTTR, MTTD, and service recalls by capturing and distributing diagnostic expertise. The easy-to-use program guides software technicians step-by-step through diagnosis and repair of machinery, equipment, and process malfunctions.
For More Information Circle No. 796

MCP Systems Inc., Fairfield, CT, has introduced the MCP-Vacuum-Casting-System for quick, low-cost, **automated production of exact plastic prototypes**. The system uses thermoplastic-type resins in silicone molds, eliminating milling and injection molding. The molds produce dimensionally-accurate castings with fine detail and thin sections, and yield a surface finish comparable to injection molding in ABS.
For More Information Circle No. 790

The 9064 multi-channel **filter/amplifier** from Frequency Devices Inc., Haverhill, MA, provides up to 64 signal-conditioning channels at approximately half the per-channel costs of current instruments, according to the manufacturer. The 9064 enables remote computer control of the IEEE-488 or RS-232 bus for versatile and convenient filtering and gain functions.
For More Information Circle No. 798

Betz MetChem, Horsham, PA, has introduced Betz Kleen® **aqueous cleaners** for solvent-free cleaning of post-fabrication metal parts. Used as an alternative to vapor degreasing, the cleaners can help metal fabricators phase out ozone-depleting substances such as CFC-113, Freon, and methyl chloroform. The Betz Kleen line comprises a balance of surfactants and alkaline builders engineered to maximize cleaning effectiveness, prevent foaming, and minimize waste treatment requirements.
For More Information Circle No. 800

The industry's first **portable infrared camera with autofocus** is available from Land Infrared, Bristol, PA. Called the Cyclops 300AF, it features easy and accurate spot temperature measurement from -45° to 980° C and the latest Minolta optical technology to bring targets automatically into focus. Applications include detecting hot spots in electrical switchgear, cable insulators, transformers, and substations; thermal insulation, cladding, and steam traps; bearing and motor temperatures; structural inspections; and quality control.
For More Information Circle No. 792

F/PORT, a high-performance, low-cost **enhanced parallel port (EEP) minicard** has been introduced by FarPoint Communications, Lancaster, CA. It provides 1.5 MB/sec data transfer. The only EEP compliant card designed for use with PCs and servers, F/PORT performs a hardware emulation of a traditional bus, transferring bytes of data with a single I/O instruction. The card allows users to take full advantage of high-speed laser printers, CAD systems, CD ROM players, removable disk drives, and tape backup systems.
For More Information Circle No. 788

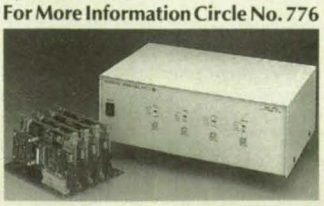
New on the Market

The COMP-CO_2LD **electronic component cooler** from Va-Tran Systems Inc., Chula Vista, CA, replaces CFCs used for board or component-level troubleshooting with recycled CO_2. The portable system chills to -78° C and saves up to 95% of operating costs when compared with CFC-based coolers. Spraying CO_2 directly on energized circuits locates weak and defective components while thermal stressing of individual board sections reveals hairline cracks and weak solder joints.
For More Information Circle No. 774

A new high-resolution 640x200 pixel **electroluminescent display** manufactured by Planar Systems Inc., Beaverton, OR, is thin, lightweight, and uses less than 7 watts for a typical screen of text and graphics. Designed as a drop-in replacement for LCDs, the model EL640.200-U3 offers wide angle viewing (>160°), brightness up to 60 fL, high contrast, crisp definition, and fast screen response.
For More Information Circle No. 778

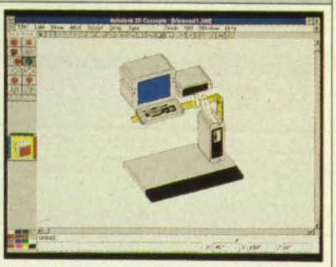
GasVue model MG-30, a **gas imaging system** introduced by Inframetrics Inc., No. Billerica, MA, permits users to safely detect and image 77 invisible and hazardous gases. Employing an integrated laser and infrared imaging technology, the MG-30 locates leaks as small as 1 x 10^{-3} std cc/sec (1 kg/yr). Mounted on a shoulder or vehicle, it can be used to a distance of 30 meters.
For More Information Circle No. 784

National Aperture Inc., Windham, NH, has introduced the MC-3SA, a **multi-axis servo amplifier** that can supply servo power for up to four axes simultaneously. Its unique modular design and compact size enable easy integration into existing motion systems that use miniature DC motors with or without encoders. The MC-3SA incorporates multiple velocity-servo power modules designed to drive miniature DC, brush-type motors from 10-15 mm, up to +/-12 Vdc.
For More Information Circle No. 776



Ferran Scientific, San Diego, CA, has unveiled the Micropole Sensor System, a miniaturized **quadrupole analyzer** featuring a top operating pressure of 15 millitorr, small volume occupied in chamber (<5 cc), range options up to 200 amu, and dual filaments with automatic changeover. Designed for use in industries employing vacuum processing machines, the system communicates over an RS-232 line to any host or IBM-compatible computer.
For More Information Circle No. 780

The first commercial open, distributed **Integrated Project Support Environment (IPSE)** based on international standards such as PCTE and UNIX has been announced by Alsys Inc., Burlington, MA. Called FreedomWorks, the system integrates and controls specification, design, coding, testing, configuration, and project management within the software life cycle and Ada and C language development. All project information is stored in a unique, object-oriented repository enabling graphical, Windows-based access to objects that may be geographically dispersed or located on multiple servers.
For More Information Circle No. 786



Autodesk Retail Products, Bothell, WA, has introduced Autodesk 3D Concepts for Windows, **3D conceptual design software** combining the precision of 3D CAD technology with the ease of a graphical user interface. Priced at $249, the program features on-screen visual tools such as the rotation cube, the visible ground plane, and tracking. Files can be loaded directly and imported/exported via .DXF for use with other CAD, CAE, and CAM programs.
For More Information Circle No. 782

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POSITIONS WANTED

Recently graduated Ph.D in mechanical engineering, specialized in numerical modeling of combustion, fluid mechanics, and heat transfer processes (especially radiative transfer). Had four years work experience in academics and industry. Previously developed HVAC software for design use. Looking for position in consulting, HVAC, energy, and combustion systems industries.
Box number 88

BS/MS (thesis: urethanes) in plastics engineering, U-Mass, Lowell. Book, patents, publications. 20 years diverse experience in extrusion, cost effectiveness, material application, manufacturing, research & development, defense, composites, and limited mold design. In-depth project effort from conception through market introduction. Desire growth position with aggressive mid-size/large company. Will relocate. Reply: Box 86, Tyngsboro, MA 01879-0086.
Box number 89

Quality assurance engineer with experience in statistical process control, quality system development, and maintenance; receiving, in process and final inspection, subassembly, and system test and process control. Product types include electronic components, printed circuit boards, sheet metal parts, machined parts, and electromechanical and electromagnetic assemblies.
Box number 90

Electronics and computer engineer; MEEE, BSEE. Available for full-time temporary positions within 1.5 hours of northeast NJ. Broad background with digital/analog, circuits/systems, computer hardware/software/firmware; design, development, analysis, integration, modifications and interfacing. Experience includes imaging, graphics, microcomputers, C, real time, video, DACs, sampling, communications, CAD, and parallel processing. Tel: 201-497-3272.
Box number 91

Creative engineer with extensive experience in quality, technology modernization, and manufacturing improvement. Excels in identification and resolution of key operational issues limiting manufacturing and financial performance. Seeks position in operation management with a growth-oriented company.
Box number 92

Operations/engineering manager (BSEE, MSEE, MBA) with over 20 years experience in high tech design/manufacturing. Possess strong combination of business/technical experience with unique ability to move between engineering and manufacturing to move products from concept to market. Strong organizational, analytical, and problem solving skills with track record of successful execution.
Box number 93

Data base designer/administrator, experienced in C3/1, logistics, manufacturing, simulation, models, embedded real time, project leader, 20 years VAX, CDC, IBM; Ingres, Sybase, other RDBMs, custom-contractor liaison, EBI (11/90).
Box number 94

Creative, energetic engineering executive with hands-on and supervisory expertise in all phases of development of control, communications, and safety products. Seeks contract employment. Willing to travel anywhere but not relocate from New England. Work on long-term solutions or on your immediate problems, full- or part-time.
Box number 95

Five of seven years technical experience in space systems and scientific payload engineering. Bachelors in aerospace engineering with graduate coursework. Have supervised as many as five people. Integrated an international life sciences and academic community with space station. Macintosh Word and graphics applications plus BASIC and FORTRAN. Enabled User Mission database to serve 200% more clients.
Box number 96

Ph.D in mechanical engineering with four years of teaching/research experience. Interested in research, design, and development in materials processing, microelectronics, thermal sciences, and CFD. Excellent communications (written/oral) skills. Good at experimental and numerical work; in developing software (PCs and mainframe). Will relocate and travel. Permanent resident of USA.
Box number 97

EIT, BSME working towards MSME interested in co-op or summer position in mechanical or aerospace fields. Strong interest in both solid and fluid mechanics. Graduate courses completed in mechanical vibrations and finite element analysis. Two years experience researching chaotic behavior in axially loaded beams using a shaking table. Would like to perform research applying towards Master's thesis.
Box number 98

MSEE graduate seeking entry-level position. Experience with PC-instrumentation, analog/digital, electro-mechanical control systems, semiconductor material measurement with RF. Successful projects history. All phases of R&D (software/hardware). Languages: C, Pascal, QuickBasic, MS-DOS. Hard working, self-motivated, will work/relocate for 35k/yr. Mr. M.L., 8 Oak St., Lehighton, PA, 18235; Tel: 215-377-0931.
Box number 99

Graduate professional engineer with registration (PE) from six states and member of ASHRAE. Have 30+ years of experience in all phases of engineering: management, construction, teaching, design, specification writing, marketing, sales, and maintenance. Worked extensively with defense-related industry, heavy chemical plants, paper and pulp, cement, public health engineering, water treatment, project management, HVAC, plumbing, and fire protection. Successful national and international assignments with Fortune 500 companies.
Box number 1A

Recent BSME graduate with considerable industry experience. Have experience in both mechanical design and manufacturing. Strong skills in stress analysis, statistical methods, and computer applications, including AutoCAD, Lotus, and finite element analysis programs. Also familiar with manufacturing techniques such as machining, die stamping, TIG welding, JIT and SPC. Honor student. Will relocate. Tel: 904-441-9344.
Box number 2A

FCC and NARTE certified radio and telecom engineer. Qualified GSI5. Familiar with ANSI/IEEE and Mil/DOD standards. Secret clearance and US Passport. Specialist in test systems and transmission systems. Will consider short- and long-term assignments. Experienced program/project manager. US Navy veteran. Certified electronics instructor.
Box number 3A

BSCS with engineering, five years McDonnell Douglas engineer/scientist, real-time applications. Any computer or technical work appreciated, not greedy, just need to work. Good writing skills, non-smoker, non-drinker, have health insurance. PO Box 7114, Daytona Beach, FL 32116-7114; Tel: 904-760-9362.
Box number 4A

Multimedia systems developer, strategic analyst/planner to solve high tech problems--full-time or consultant. Member of ANSI and ISO Experts Groups on electronic still pictures imaging, and compression of audio, digital image and motion-video. Led MPEG-Video/Audio system design. Systems experience: APOLLO, Manned Orbiting Laboratory, FAA Fault Tolerant Computer System, and supercomputers. Alfred Riccomi, Tel: 214-644-8875.
Box number 5A

Seeking an applied physicist position. 10+ years of research experience with statistical, reactor, plasma, and radiation physics, electric/nuclear propulsion, fusion technology, transport theory, reliability/risk analysis, and x-ray imaging. Worked on DOE/DOD/NASA contracts. Ph.D in nuclear engineering. Expertise in computational methods.
Box number 6A

Application specific integrated circuit, ASIC, partitioning, selection, design, and test implementation specialist. 12 years system and logic design; 15 years digital semi-custom, custom, and ASIC VLSI designs. Will get you into a cost-effective product. Seeking a contract or captive position. Allen Whedon, Tel: 916-983-1353; Fax: 916-983-3424.
Box number 7A

Ph.D in ChE seeking position in materials, process, systems, or product R&D. Experienced in emulsion polymerization and polymers processing, extrusion, fluid flow, and rheology modeling (CFD), paper processing and chemistry, ceramics processing, adhesion science, plastic films orienting and coating, printing, and lamination. Involved in systems theory, simulation, artificial intelligence and total quality, new business and commercial development.
Box number 8A

Mechanical engineer. BSME/EIT. Experience in equipment engineer and process controls. Worked in wind study research for the analysis of resources. Graduate studies in mechanical engineering. FORTRAN, LOTUS, Freelance and computer proficient. Fully bilingual (English/Spanish). Willing to work in areas other than ones of experience. Willing to relocate.
Box number 9A

To submit an ad for inclusion in this column, send a copy of your resume and a 50-word summary to: *NASA Tech Briefs*, 41 East 42nd St., New York, NY 10017, ATTN: Jim Westbrook.

To Request Resumes:

To obtain resumes corresponding to the above **Positions Wanted Ads**, fill out this form and mail to: *NASA Tech Briefs*, 41 East 42nd St., New York, NY 10017. ATTN: Jim Westbrook, or call 1-800-944-NASA and ask for Jim Westbrook.

Send resumes for the following box numbers (limit 5):

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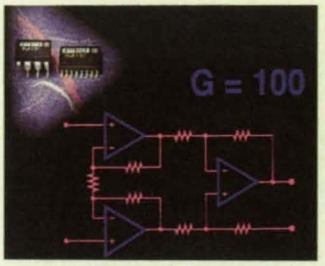
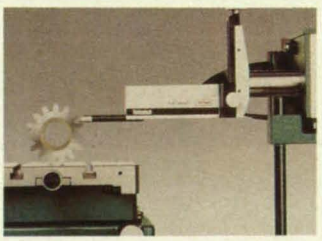
New on the Market



A general-purpose **instrumentation amplifier** with an internally fixed gain of 100 is available from Burr-Brown Corp., Tucson, AZ. Its precision and low cost ($3.25 in 1000s) make the INA131 suited for such applications as bridge, thermocouple, and RTD sensor signal conditioning. On-chip laser-trimmed resistors provide high gain accuracy (.024% max) and drift (10 ppm/°C max), while low offset (50 μV) and drift (0.25 μV/°C max) eliminate external trimming. Input bias current is 2nA and common mode rejection is 115 dB min.
For More Information Circle No. 764

Yamashita Engineering Manufacture Inc., Mission, KS, has unveiled the EDEC-2000, a **digital decoder and line doubler** designed to enhance and improve NTSC video output. It reduces noise, minimizes smearing, and eliminates distracting artifacts such as visual scan lines, cross-color, and dot and chroma crawl. Features include a 3D digital comb filter for Y/C separation, motion adaptive line scanning interpolation, image enhancement, and noise reduction with 10-bit digital processing technology to convert poor composite or S-VHS video to sharp RGB RS170 output.
For More Information Circle No. 762



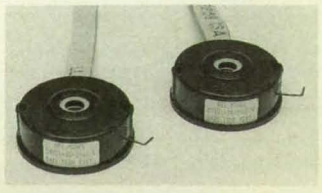
The Focodyn **optical probe** from Mahr Feinpruef Corp., Cincinnati, OH, allows nondestructive surface texture measurement of soft, liquid, sticky, or highly polished materials including foils, paper, paint, magnetic disk media, rubber, and copier drums. The probe's 1-micron-diameter laser beam provides discrimination of detail where conventional diamond styli are unable to detect fine surface flaws. Its slender measuring arm permits noncontact roughness measurement inside bores and other confined areas.
For More Information Circle No. 766

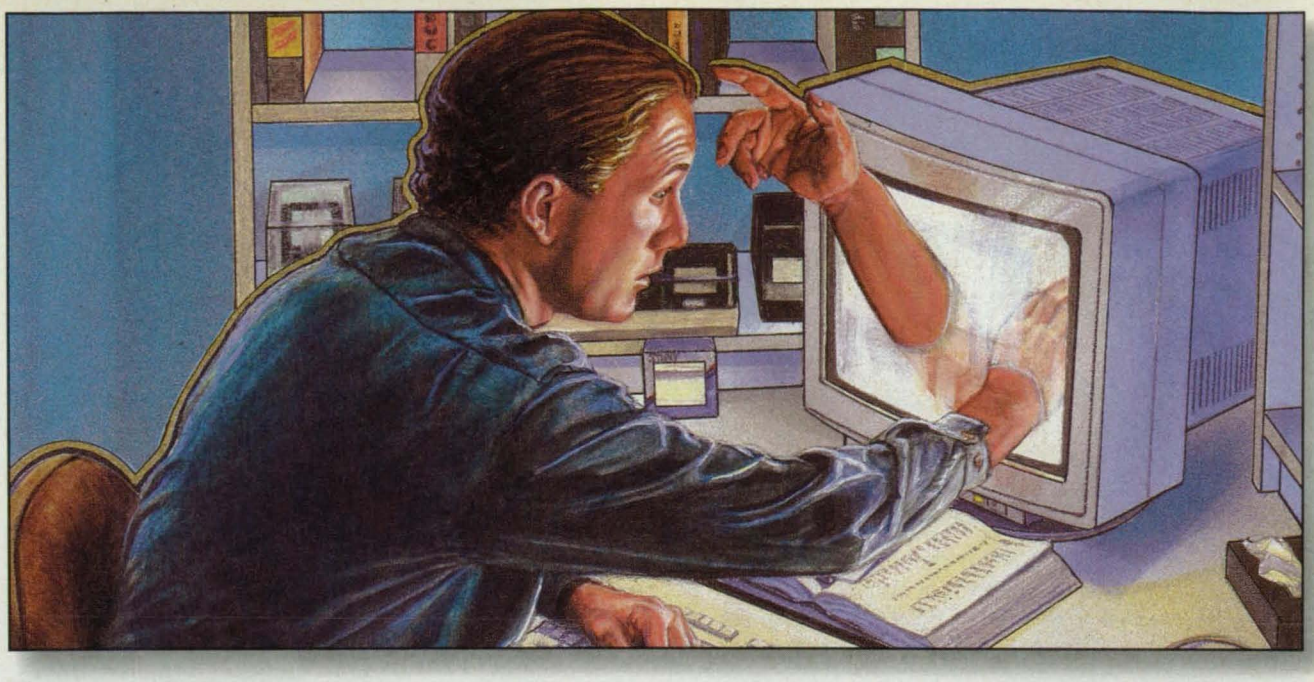
Textron Specialty Materials, Lowell, MA, has applied its chemical vapor deposition expertise to develop **silicon carbide reinforcing fibers** for use in ceramic matrix composites. SCS™ fibers maintain their strength at temperatures over 1370° C, have improved creep strength, and will bend around a much smaller radius for weaving and bending into complex shapes.
For More Information Circle No. 772

A low-cost, high-performance $LiTaO_3$ **pyroelectric infrared detector** (PID) has been announced by ACI Components, Laguna Hills, CA. Use of lithium tantalate permits equal or better response times and nearly duplicates the sensitivity of higher-cost PXT PIDs. The ACI sensor's unique construction nearly eliminates "popcorn noise." The temperature range for the YIR series of sensors is -20 to 80° C, with operating voltages of 3-10 Vdc.
For More Information Circle No. 760

ROHM Corp., Antioch, TN, has introduced the first **laser diode** able to read and write magneto-optical disks. The multi-mode laser diode provides high optical output and longitudinal multi-mode oscillation below 7 mW. It can be applied in PCs, CD ROM-type data storage devices, and audio components where short access time and high sound quality are desirable, as well as optical measurement devices, sensors, and optical cards.
For More Information Circle No. 768

BEI Motion Systems Co., San Marcos, CA, has integrated an **optical encoder and brushless motor commutator** in one compact package. Dubbed the CMX21, it eliminates the need for Hall-effect sensors, commutation magnets, couplings, and extended housings. Precision digital commutation output enables increased motor performance, higher torque, and reduced current draw, motor ripple, and heat dissipation.
For More Information Circle No. 770





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The reality check can be frightening because it forces you to ask tough questions. Could your design be lighter? Or faster? Or run more quietly? Can manufacturing produce it? Do your current vendors have the components you need? And so on.

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Company Name

Division

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2. Your Industry: (please check only one)
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B. ❑ Agriculture
C. ❑ Appliance/Consumer Products
D. ❑ Automotive/Ground Transportation
E. ❑ Communications
F. ❑ Computers/Office Equipment/Systems
G. ❑ Consulting
H. ❑ Energy/Utilities
J. ❑ Fabricated Metal Products
K. ❑ Government/Defense
L. ❑ Industrial/Commercial Machinery
M. ❑ Medical/Pharmaceutical
N. ❑ Mining
P. ❑ Plastics/Elastomers/Materials
Q. ❑ Printing/Publishing/Graphic Arts
R. ❑ Process Manufacturing
S. ❑ Sporting Goods/Leisure
T. ❑ Other (please specify): _____

3. Number of employees in your company:
A. ❑ 1-20
B. ❑ 21-100
C. ❑ 101-500
D. ❑ 501-1000
E. ❑ 1001-5000
F. ❑ 5000+

4. Product Interest (check as many as apply):
A. ❑ CAD/CAM/CAE/CIM
B. ❑ Computer Hardware
C. ❑ Coatings/Lubricants
D. ❑ Electrical Components
E. ❑ Electronic Components
F. ❑ Electro-Optics
G. ❑ Engineering Document Management/Imaging
H. ❑ Hydraulics & Pneumatics
J. ❑ Joining Systems/Adhesives/Fasteners
K. ❑ Mechanical Components
L. ❑ Metals/Alloys
M. ❑ Nonmetals/Plastics/Elastomers
N. ❑ Motion Control/Power Transmission/Fluid Power
P. ❑ QA/QC/Testing
Q. ❑ Sensors & Controls
R. ❑ Shapes & Forms
S. ❑ Other (please specify): _____

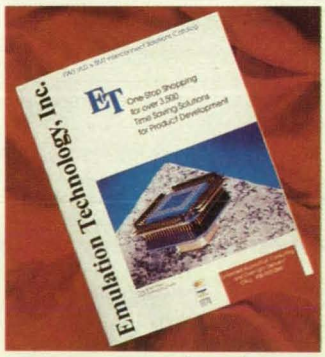
Reed Exhibition Companies
Committed to Excellence

For More Information Circle No. 397

New Literature

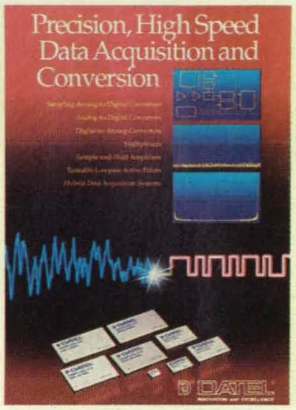
Akuloy RM **modified nylon alloys** featuring low moisture absorption, increased impact strength, and improved heat resistance are described in a brochure from DSM Engineering Plastics, Evansville, IN. The alloys offer performance characteristics superior to polypropylene and can be more cost-effective than nylons, according to the manufacturer. Applications include power tool housings, plugs, cable ties, gears, pump housings and impellers, fans, and electrical/electronic parts.
For More Information Circle No. 714

The 115-page Metalog Guide™ from Struers Inc., Westlake, OH, offers a systematic, ten-step procedure for **sample preparation**. The user selects a material according to the color-coded Metalogram™, a matrix of hardness vs ductility, then follows preparation guidelines optimized for each material. The guide addresses all preparation parameters, including pressures and times for cutting, grinding, and polishing.
For More Information Circle No. 710



A 160-page **VLSI and SMT interconnect solutions** catalog from Emulation Technology Inc., Santa Clara, CA, highlights adapters and accessories used with development systems such as emulators, logic analyzers, and memory and logic programmers. The publication features more than 500 new adapters including test clip, emulator, logic analyzer, programming, and prototyping adapters for 63 PQFP packages.
For More Information Circle No. 704

Fenwal Electronics Inc., Milford, MA, has published a catalog describing its negative and positive temperature coefficient (NTC/PTC) **thermistors**. Featured NTC thermistor lines include ISO-CHIPS™, glass encapsulated chip, and UNI-CURVE® interchangeable R-t curve matched chip. Silicon- and ceramic-based PTC thermistors also are included.
For More Information Circle No. 708



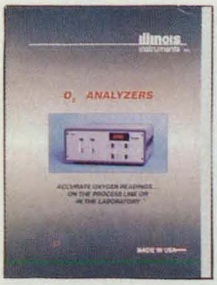
A short-form catalog released by DATEL Inc., Mansfield, MA, describes precision, high-speed **data acquisition and conversion products**. New products include sampling and nonsampling analog-to-digital converters, digital-to-analog converters, multiplexers, sample-hold amplifiers, and tuneable active filters. The catalog provides a two-page tear-out reference section covering FFT basics and data converter formulas such as frequency domain specifications, S/H specifications, anti-alias filters, and logarithms.
For More Information Circle No. 702

A bulletin published by Penn Engineering & Manufacturing Corp., Danboro, PA, highlights CONNECT'R WARE™ self-clinching **fasteners** designed to reduce the amount of hardware needed, thereby speeding assembly while providing secure attachments. Fastener types profiled include type DSOS™ for mounting D-Sub connectors to panels; type IPIS™ for panel mounting 50 Series IPI connectors; and type C2CS™ self-clinching standoffs for cable-to-cable applications.
For More Information Circle No. 712

A 114-page **motors** catalog from Maxon Precision Motors Inc., Burlingame, CA, describes a wide range of DC moving coil and brushless motors, spur and planetary speed reducers and gearheads, analog tachometers, optical encoders, and electronic drives. The publication includes an applications sizing and technical assistance section.
For More Information Circle No. 706

NASA Tech Briefs LITERATURE SPOTLIGHT

Free catalogs and literature for NASA Tech Briefs' readers. To order, circle the corresponding number on the Reader Action Request Form (page 99).



REVIEW OXYGEN ANALYZERS

A four-color brochure introduces a line of oxygen analyzers for the laboratory or process line. Suited for monitoring the oxygen levels in all types of gas streams. Trade oxygen levels for ppb to 100% are accurately determined by these ruggedly constructed instruments. No periodic maintenance or special operator skills required. Intrinsically safe and battery-operated versions are also available.

For More Information Circle No. 301

PC-TEKTRONIX EMULATION SOFTWARE

EM4105-Plus is quality PC software emulating Tektronix 4105/07 color terminals. Offers high resolution hardcopy drivers: Color PostScript, HP LaserJet, DeskJet 500C, plotters. VT320 and Tektronix 4010/14 emulation, Kermit, Xmodem file transfer, modern dialer included. Extensive network support is available.

Diversified Computer Systems, Inc.

For More Information Circle No. 302

VERSATILE BORON NITRIDE

Combat® boron nitride is available in machinable solids, powders, coatings, and aerosol. Solids used as electrical insulators, high-temperature, non-wetting crucibles and fixtures, breakrings, and nozzles for molten-metal applications. Powders used as additives in plastics and cosmetics. Coatings used in metal, glass, and plastic industries for mold release and antioxidant.

The Carborundum Co.

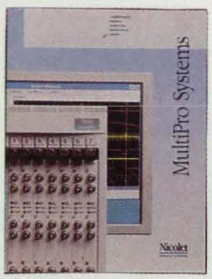
For More Information Circle No. 303

COATING ADHESION TESTER

PATTI measures adhesion tensile strength using compressed air to apply a continuous load to a 1/2" OD pull-stub bonded to the test coating. The maximum pressure is measured and converted to psi. Substrates may be flexible or rigid, flat or curved. Six piston ranges to choose from, up to 10,000 psi. Satisfies ASTM D4541 requirements.

SEMicro Corporation

For More Information Circle No. 306

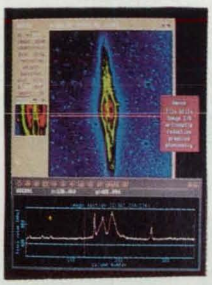


MULTI-CHANNEL TRANSIENT ANALYZERS

The Nicolet MultiPro Transient Analyzer gives you all the inputs you need to handle two or 200 channel applications. These complete turnkey systems, which are up and running in minutes, are powerful and flexible, and use an easy-to-follow Microsoft® Windows™ environment.

Nicolet Measurement Instruments

For More Information Circle No. 305



MS-DOS® IMAGE ANALYSIS SOFTWARE

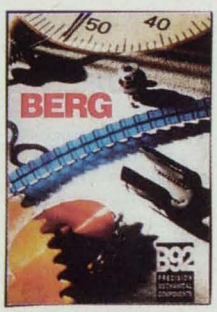
New! Axiom Research, Inc. MIRA (Microcomputer Image Reduction & Analysis) software: fast, full-featured, low-cost image display, reduction, and analysis for MS-DOS 5.0 Input 3-/16-bit integer, 32-bit real 1D/2D data, including CCD images to 2K X 2K with user-defined formats. Over 100 operations coded in assembly language for workstation graphical/numerical performance. Multi-window graphical interface.

For More Information Circle No. 304

HIGH RESOLUTION VIDEO CCD CAMERA

Brochure from Tietz Video & Image Processing Systems GmbH describes compact CCD-1000 1250-line camera with RS-232 programmable gain/exposure control. 25 fps interlaced. Analog/digital ports transmit 60dB dynamic range images to monitor or BSS-1000 frame grabber. Complete image processing solutions for medical, industrial, and surveillance applications. Fax USA (602)622-5667.

For More Information Circle No. 307

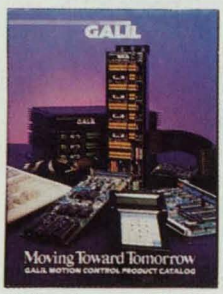


B92 CATALOG RELEASE

The latest catalog from W.M. Berg, Inc., coincides with Berg's silver anniversary. Founded in 1967, Berg has grown to become a recognized industrial leader of miniature precision mechanical components. A significant amount of new items are added as well as expanding previous product lines. Featuring 60,000 standard components, 80% of which we are able to ship from stock within 24 hours. Available in metric version too: M92.

W. M. Berg, Inc.

For More Information Circle No. 308



PROGRAMMABLE MOTION CONTROLLERS

16-page catalog describes full line of servo motion controllers. Includes box-level industrial controllers; multi-axis plug-in boards; and low-cost, single-axis motion cards. PC/XT/AT, STD, VME and RS-232 interfaces available. Linear and circular interpolation, gearing, programmable I/O and memory. Also power amplifiers, servo motors, and support software.

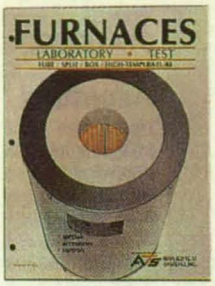
Galil Motion Control, Inc.

For More Information Circle No. 309

MOTION CONTROL PRODUCT GUIDE

Aerotech's 216-page Motion Control Product Guide describes their extensive lines of motor-driven linear and rotary positioning stages; DYNACRON microstepping translators; stepping motors and drives; servo motors, amplifiers and drives; and brushless drives. Also described is Aerotech's UNIDEX™ motion controller line. A special four-page insert describing the capabilities of Aerotech's Systems Engineering Division is included.

For More Information Circle No. 310



LAB/TEST FURNACES

A 36-page catalog (Bulletin 3110) describes lab/test furnaces manufactured by Applied Test Systems. Furnaces available in tubes, splits, or boxes in configurations and sizes designed to specific customer requirements. Features include: low power consumption, fast heat-up, long element life, low shell temperature, stainless steel shell. Temperature to 3100°F.

Applied Test Systems, Inc.

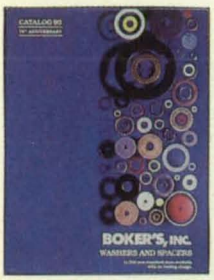
For More Information Circle No. 311

COMPUTER CONTROLLED VALVES

Brochure describes company's line of on-off, Metering and Servo Valves, Pressure Generators, Automated Pressure and flow control systems, Pressure Gage Calibration systems and capability for custom configurations. Address is Cornell University Research Park, Bldg. 4, 83 Brown Rd., Ithaca, NY 14850-1298.

Advanced Pressure Products

For More Information Circle No. 312



WASHERS AND SPACERS

New for '93! Boker's new 32-page Catalog '93 offers 11,000 non-standard sizes with no tooling charges. Outside diameters of 0.080" to 2.631", a wide variety of inside diameters and thicknesses, and 2,000 material variations create millions of possibilities. Materials include low carbon, cold rolled strip and sheet steel; five types of spring steel; low-alloy steel sheets; brass; copper; nickel silver; and such non-metallic materials as Delrin®, Teflon®, Mylar®, and nylon.

Boker's, Inc.

For More Information Circle No. 315

PROGRAMMABLE POSITION CONTROL

A complete 416-page engineer's guide with specifications, dimensions, and performance data presents brushless servos, microstepping motorsystems, indexers, linear motors and absolute encoders.

Compumotor Div., Parker Hannifin Corp.

For More Information Circle No. 314

OPTICAL REFERENCE CATALOG

Edmund Scientific's free 204-page, full-color annual reference catalog features one of the largest selections of precision optics and optical instruments, plus a complete line of components and accessories for both large volume OEM users as well as smaller research facilities and optical laboratories. It contains over 8,000 hard-to-find items including a large selection of magnifiers, magnets, microscopes, telescopes and accessories.

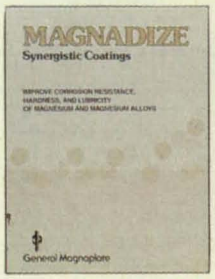
For More Information Circle No. 313

BOTTOM MOUNT SLIDES

16-page catalog details 8 models/84 variations of Chassis Trak® bottom-mount telescoping slides for heavy-duty applications. Includes diagrams, dimensions, load capacities, applications, mounting suggestions, plus custom and modification options.

General Devices Company, Inc.

For More Information Circle No. 316



COATINGS PROTECT MAGNESIUM PARTS AGAINST WEAR, CORROSION

MAGNADIZE® surface-enhancement coatings protect magnesium parts against wear, corrosive chemicals, moisture and sticking. Magnaplate-applied coatings dramatically increase surface hardness and provide permanent dry lubricity. Available in four thicknesses, they also exhibit high dielectric strength and excellent release properties.

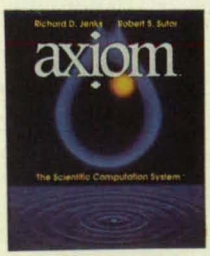
For More Information Circle No. 317

OEM PUMP CATALOG

Pump catalog provides dimensional drawings, product features, and performance curves for the standard pump modes available from Gorman-Rupp Industries. Pump designs include Bellows Metering, Centrifugal, Magnetic Drive, Oscillating, Nutating, and Peristaltic Pumps.

Gorman-Rupp Industries

For More Information Circle No. 318



COMPUTATIONAL SOFTWARE

AXIOM is the latest generation, UNIX-based computational software. Powerful symbolic and visual mathematics including hypertext documentation which can be click activated/edited for use as templates in your own work. Explore the worlds of fractal geometry, orbital mechanics, knot theory, quantum mechanics, and other computational disciplines easily—with Axiom.

Numerical Algorithms Group, Inc.

For More Information Circle No. 319

ABARIS TRAINING RESOURCES

The brochure describes nine different "hands-on" workshops in advanced composite materials technology. These workshops cover fabrication, repair, tooling, blueprint reading, adhesive bonding, engineering design for specialized repairs, and ultrasonic inspection of composites. Emphasis is placed on prepreg carbon and aramid fiber material and processes, utilizing vacuum bagging and high-temperature curing methods. Phone: 1-800-638-8441. Fax: 702-827-6599.

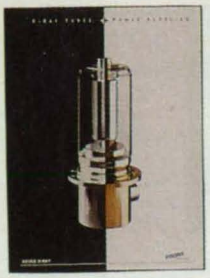
For More Information Circle No. 320

ELECTRONIC HARDWARE CATALOG

Broadest selection of hardware for electronic assemblies. 300-page free catalog includes a full range of standoffs, captive screws and nuts, chassis fasteners, handles, ferrules, spacers and washers. Special sections—new/unusual products, metric information and Mil-plating specifications. Full inventory, fast turnaround, samples. Phone: 1-800-237-0013, Fax: 201-661-3408.

Accurate Screw Machine Co.

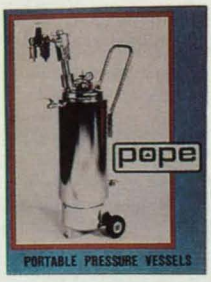
For More Information Circle No. 321



X-RAY TUBES & POWER SUPPLIES

Kevex X-Ray manufactures microfocus x-ray tubes, portable x-ray sources and high performance low power x-ray tubes. Its line of microfocus tubes includes 126KV and 160KV systems with focal spot sizes of 10 microns and smaller. The innovative line of PXS™ portable x-ray sources include several models with beam voltages from 30KV to 130KV: all PXS units can be operated from a low level DC source making them ideal for field or OEM equipment installation.

For More Information Circle No. 322



PORTABLE PRESSURE VESSELS

Pope brochure describes applications and ease of specifying vessels. High purity, sterile, or hazardous liquids stored, dispensed, mixed, or processed in ASME certified vessels. Sizes from one to 100 gallons. Standard container sizes stocked. Modifications include mixers, heaters, jackets, valves, gauges, wheels, special ports, finishes, controls, etc. Also designs for feed systems, blenders, reactors, fermenters, OEM, etc. New literature illustrates typical examples. Phone: 414-251-9300; Fax: 414-251-7387.

For More Information Circle No. 323

WORK STATIONS, LAB FURNITURE

20-page illustrated guide covers the Teclab line of technical work stations and laboratory systems furniture. Included are stations of different lengths, combined with a choice of cabinets, shelves, parts drawers, partitions, and other accessories. Catalog has dimensions, shows arrangements, describes work surfaces, and has a color selection guide. Call 800-832-5227, Fax: 616-372-6116. Address is Box 1165, Kalamazoo, MI 49005.

For More Information Circle No. 324

NEW CONCEPT IN WAVEFORM DISPLAY

Show waveforms on any VGA monitor without the complications of a computer! Use Modular Instruments' new Scroller-Scope, a compact, stand-alone, easy-to-operate unit. Capture waveforms in real time, without the fade-out common to slow sweep speeds of a conventional oscilloscope. Use it as a digital storage oscilloscope for negative-time triggering. See milliseconds to hours of data from a maximum of eight channels on a single screen.

For More Information Circle No. 325

DATA ACQUISITION & CONTROL

All new brochure of data acquisition and control hardware and software for IBM and Macintosh computers for laboratory, including new high-speed plug-in board products. Includes WorkBench Mac™ and WorkBench PC™ software for data acquisition and control using a revolutionary new icon-based graphical interface.

Strawberry Tree

For More Information Circle No. 326

DATA ACQ. HARDWARE AND SOFTWARE

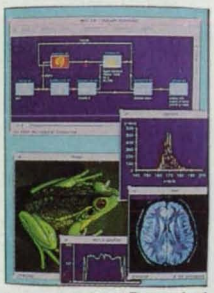
Free catalog showcases our line of turnkey PC-based data acquisition systems and new DI-200 Series plug-in cards. Our systems offer real-time display and disk streaming with playback and analysis. DI-200 products for DOS and Windows feature dual channel 16-bit DMA, with complete programmability including sample rate per channel. Prices start at $795. Call 800-553-9006.

For More Information Circle No. 327

3D MOLDED INTERCONNECT DEVISES (MID)

MIDs or plated circuits on plastic integrate mechanical and electrical functions into one component, thereby reducing the parts count, cost and complexity of electrical and electro-mechanical assemblies. Complete design through production capabilities are offered. Contact Mitsui-Pathtek Corp., 250 Metro Park, Rochester, NY 14623. Phone: 716-272-3126. Fax: 716-272-3110.

For More Information Circle No. 328



FREE WIT DEMO DISK

WIT image processing development software offers an advanced visual programming environment allowing a user to interactively design algorithms by forming arbitrarily complex graphs using icons and links. WIT provides a large set of commonly used imaging operators, supports Datacube hardware, and runs on either Sun, HP, or SGI workstations. Call 604-435-3587 or FAX a request to 604-435-8840 for your free demo disk.

Logical Vision, Ltd.

For More Information Circle No. 329

ENGINEERING FINDINGS CATALOG— *FREE*

Featuring 272 pages of components, materials and select tools in this new 1992/93 catalog. Hard-to-find items include stainless steel hypodermic tubing in heavy, standard & thin wall, shrink Teflon tubing, threaded rod, high speed drills, precision hand tools, and stainless steel, nylon & metric machine screws. Furnished in small quantities for R&D or large quantities for economical pilot production.

For More Information Circle No. 330

MOISTURE MEASUREMENT

For more than 20 years, Endress + Hauser has developed instrumentation for relative humidity and trace moisture measurement. Brochure describes measuring ranges and applications for Endress + Hauser moisture analyzers, which monitor and alarm one, two, or up to eight moisture measurement points as well as trace oxygen or pressure. Endress + Hauser, 2350 Endress Place, Greenwood, IN 46143; 1-800-428-4344.

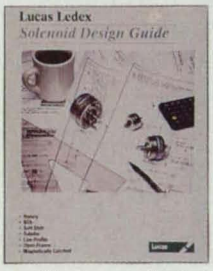
For More Information Circle No. 331

FASTCAD— POWERPACKED WORKHORSE FOR CAD

FastCAD works for you! Save time and money with FastCAD's blazing speed and dynamic user interface. If you are serious about generating fast, detailed CAD drawings, call 1-800-874-4028 for a free hands-on demo disk.

Evolution Computing

For More Information Circle No. 332



SOLENOIDS DESIGN GUIDE

Lucas Ledex' complete line of standard linear and rotary solenoids including high precision rotary, low profile, tubular, open frame, magnetic latching and brushless torque actuation models are featured in this 144-page engineering guide. Unit specifications, application data, solenoid fundamentals and interface products featured. Custom engineered prototypes available.

Lucas Ledex, Inc.

For More Information Circle No. 333

AIRBORNE DATA-TO-VIDEO ENCODER

The Merlin ME-981 series units convert digital data into video for recording on standard unmodified video cassette recorders. Application specific data interfaces are available for PCM up to 2.2 Mb/s, Mil-Std-1553, and RS-422. Ground based ME-991 Decoder restores data to its original state for analysis.

Merlin

For More Information Circle No. 335

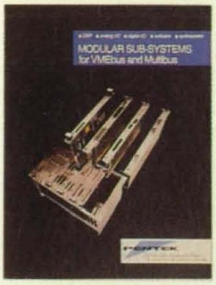
TURBO-MACHINERY ENGINEERING

Free brochure shows how companies that produce or operate compressors, pumps, or turbines can benefit from NREC's advanced engineering consulting expertise, specialized CAE/CAM software, and precision manufacturing services. Phone: 617-937-4655, Fax: 617-035-9052.

Northern Research & Engineering Corp.

For More Information Circle No. 336

DSP SYSTEMS PRODUCT CATALOG



Pentek's free 1992 catalog describes a variety of VMEbus and Multi-bus baseboards and mezzanine expansion modules. Hardware offerings include TMS320C40, 'C30, 'C25 and DSP32C processors and co-processors, A/D's and D/S's, digital I/O, SCSI interfaces, precision clock generators, TI/CEPT telecom interfaces, and VMEbus adapters for SUN and PC AT. Software offerings included. Phone: 201-767-7100. Fax: 201-767-3994.

For More Information Circle No. 337

PNEUMATIC LINEAR SLIDES

PHD's 16-page illustrated color catalog contains complete information on a new line of Pneumatic Linear Slides. Included are engineering dimensions, technical data, application information, and details on a wide range of options and accessories. These slides are available in five sizes, each with two different bearing types with standard and oversize shafts. Phone: 1-800-624-8511.

PHD, Inc.

For More Information Circle No. 338

WALL-SIZED DISPLAY FOR COMMAND & CONTROL

MediaWall ™ transforms an array of monitors or projectors into a giant computer screen for "wall-sized" displays of text, graphics, animation and scanned photographs. A direct digital interface to a computer produces images of startling clarity, making Media Wall the ideal system for command and control applications and photo analysis.

RGB Spectrum®

For More Information Circle No. 339

TOOLING COMPONENTS AND CLAMPS

This 500-page catalog contains an assortment of components including toggle clamps, modular fixturing, clamping devices, power workholding, chuckjaws, pins, knobs, drill bushings, leveling feet, and much more.

Carr Lane Mfg.

For More Information Circle No. 340

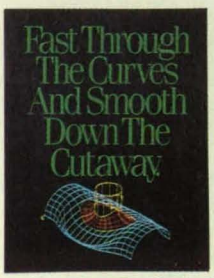
GPS TIMING FOR PC AND VMEBUS

This information folder from Bancomm describes new PCbus and VMEbus board-level Global Positioning System (GPS) Satellite Receivers. These products provide world-wide precision time (100 nanosecond) and frequency (1 part in 10E7) references inside the host computer.

Bancomm

For More Information Circle No. 341

SURFACE MACHINING SYSTEM FOR DOS

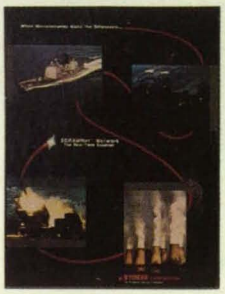


Call 800-488-3615 for literature and a working 3-disk demo of SURFCAM, an easy-to-learn, sculptured surface machining system for DOS and Windows. Complete 3D design and editing and fast 32-bit background processing at low PC-CAM prices. Phone: 818-361-5605, Fax: 818-361-1919. Address: 4221 Park Ave., San Fernando, CA 91340.

Surfware, Inc.

For More Information Circle No. 342

REAL-TIME NETWORK

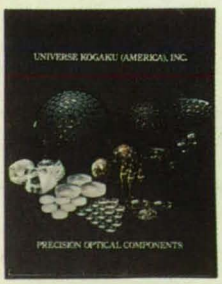


The SCRAMNet™ Network combines the real-time speed of replicated shared memory with the flexibility of a fiber optic LAN to get microsecond response from multi-vendor computers. It offers distinct advantages in critical simulations. Brochure highlights system's features.

Systran Corp.

For More Information Circle No. 343

UKA OPTICAL PRODUCTS PLUS



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Vibration Test Systems

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STANDARD REFERENCE MATERIALS CATALOG

The New Standard Reference Materials catalog from NIST lists some 1300 SRMs in 70 major categories. SRMs are well-characterized materials produced to improve measurement science and serve industry.

National Institute of Standards and Technology

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For More Information Circle No. 348

ELECTRO-MAGNETICS

Ansoft's Maxwell Field Simulators provide a dedicated tool for electromechanical, high-voltage, and magnetic applications. Links to AutoCAD, ProEngineer, SDRC, and others. Find out why more companies use Ansoft's tools for electromagnetics. Phone: 412-261-3200, Fax: 412-471-9427. Address: Four Station Square, Suite 660, Pittsburgh, PA 15219.

Ansoft Corporation

For More Information Circle No. 349

CATALOG DESCRIBES DATA ACQUISITION SYSTEMS

Both general and specialized data acquisition systems are described in this new catalog from Hi-Techniques. Modular in design, these products contain all the software for acquisition of signal data, calculation of data parameters, and output of finished documentation for both research and routine test applications. Phone: 608-221-7500.

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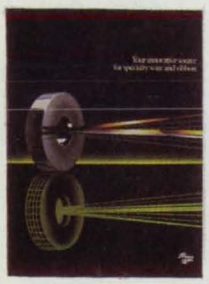

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Hunter Products, Inc.

For More Information Circle No. 354

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New color brochure describes SONEX and SONEX 1 sound-absorbing materials with patented shapes that control noise better than standard acoustical treatments. Brochure explains basic noise control techniques and presents many forms, sizes, and colors of SONEX products for industrial, office and OEM noise control. Brochure shows applications and includes information on acoustical performance.

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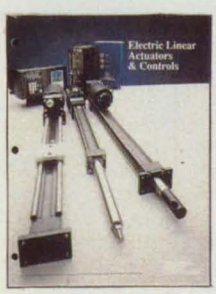


ELECTRIC LINEAR ACTUATORS

Three series of electric rodless and standard cylinders and controls are covered in this 136-page catalog. It provides performance data, comparisons, dimensions, and accessories. Additional sections provide sizings and selection design considerations and applications. Tel: 1-800-747-0064, Fax: 415-883-2094.

Industrial Devices Corp.

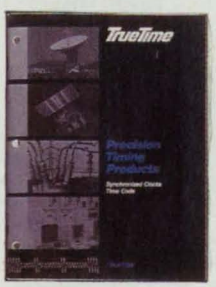
For More Information Circle No. 356

LIGHT MEASUREMENT CATALOG

All new 28-page catalog describes light measurement instrumentation for use in all environments covering the ultraviolet, visible and infrared spectral ranges. The "reader friendly" catalog provides information on radiometers, photometers, spectroradiometers, detectors, filters, input optics and various associated accessories.

International Light, Inc.

For More Information Circle No. 357



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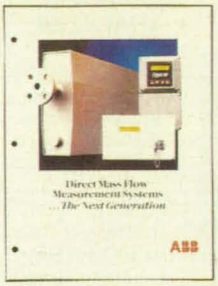

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For More Information Circle No. 361

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Cincinnati Electronics, Detector Labs

For More Information Circle No. 364

EMCOR'S EMI/RFI ENCLOSURES

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National Instruments

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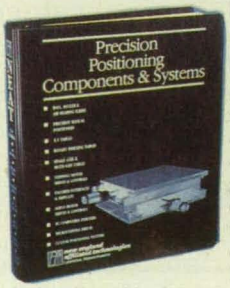

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Stanford Research Systems

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DESIGNING UNIFORM SOURCE SYSTEMS

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Labsphere

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HIGH-PERFORMANCE ALLOY

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Elgiloy® Limited Partnership

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The 1993-1994 Cole-Parmer catalog features over 1,500 full-color pages and describes more than 35,000 products covering instruments, equipment, and supplies. The catalog features 32 pages of new products, special technical data and conversion factor sections, a newly-organized fittings section, an expanded chemical resistance chart. Tel: 800-323-4340.

Cole-Parmer Instrument Co.

For More Information Circle No. 370

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COMSTRON

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NT293

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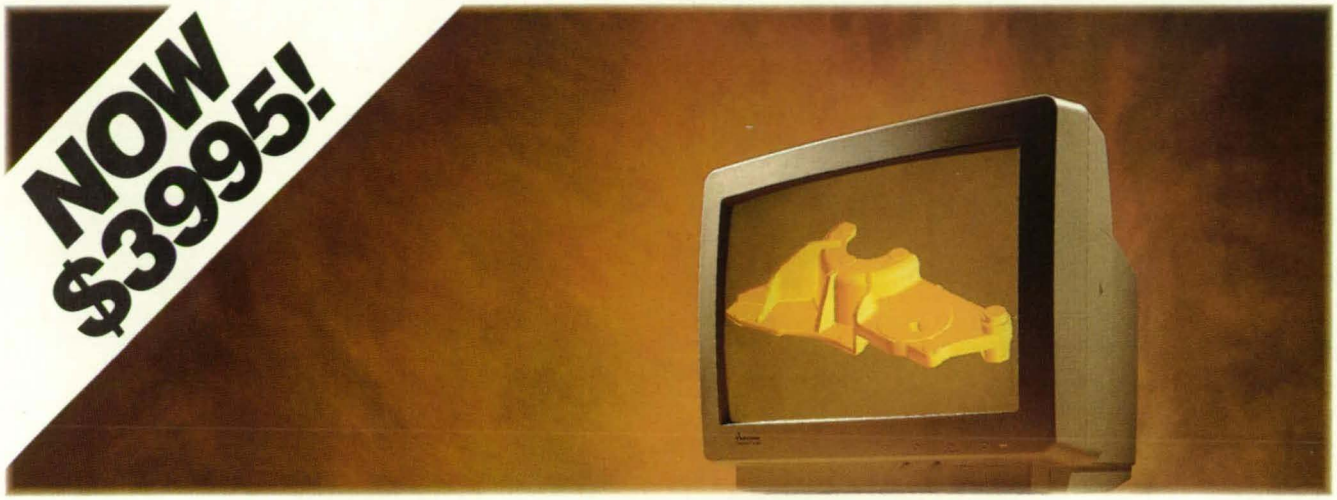

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