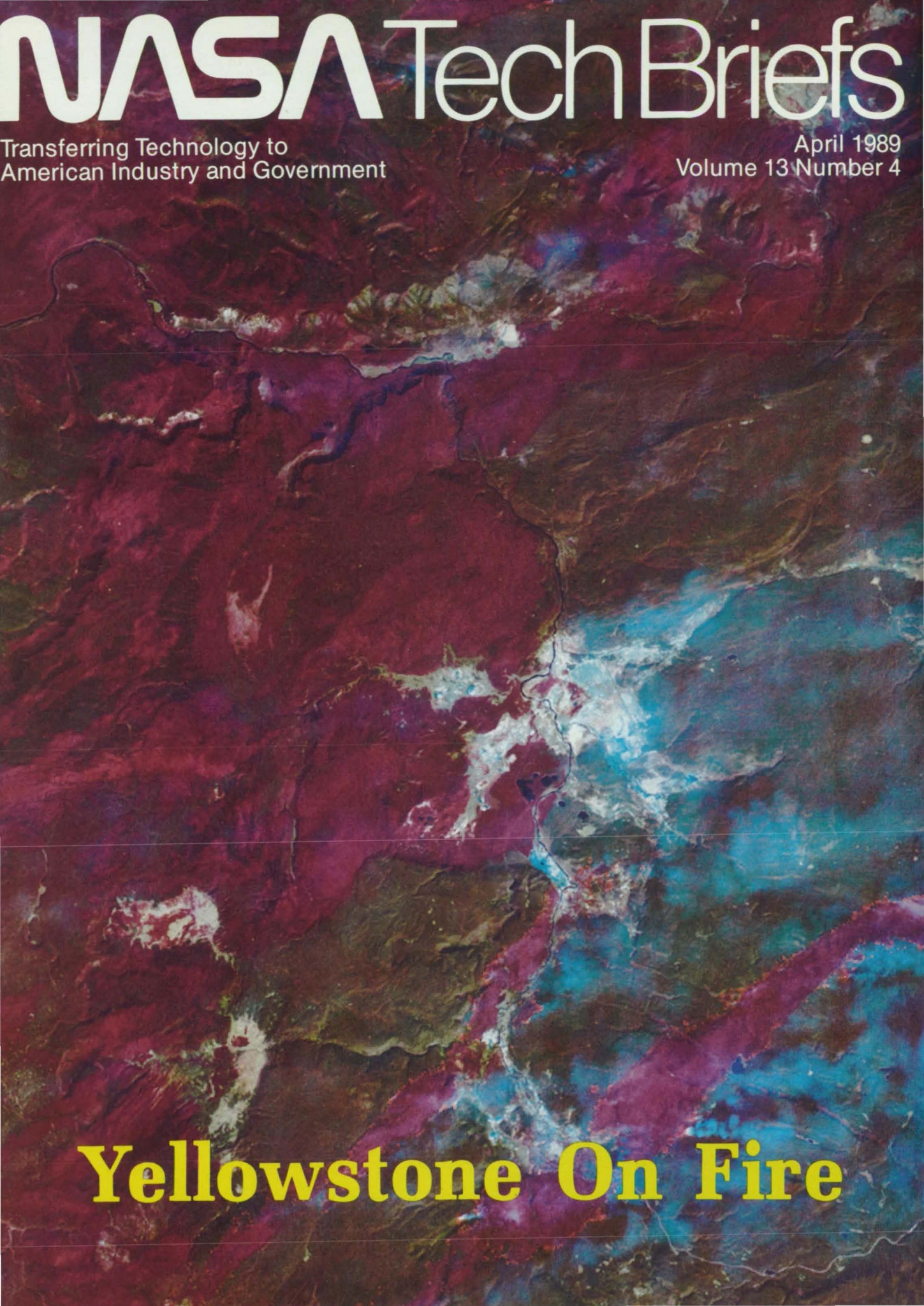
NASA Tech Briefs

Transferring Technology to
American Industry and Government

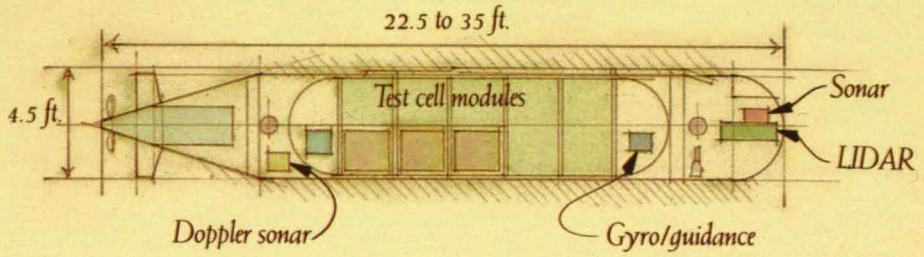
April 1989
Volume 13 Number 4

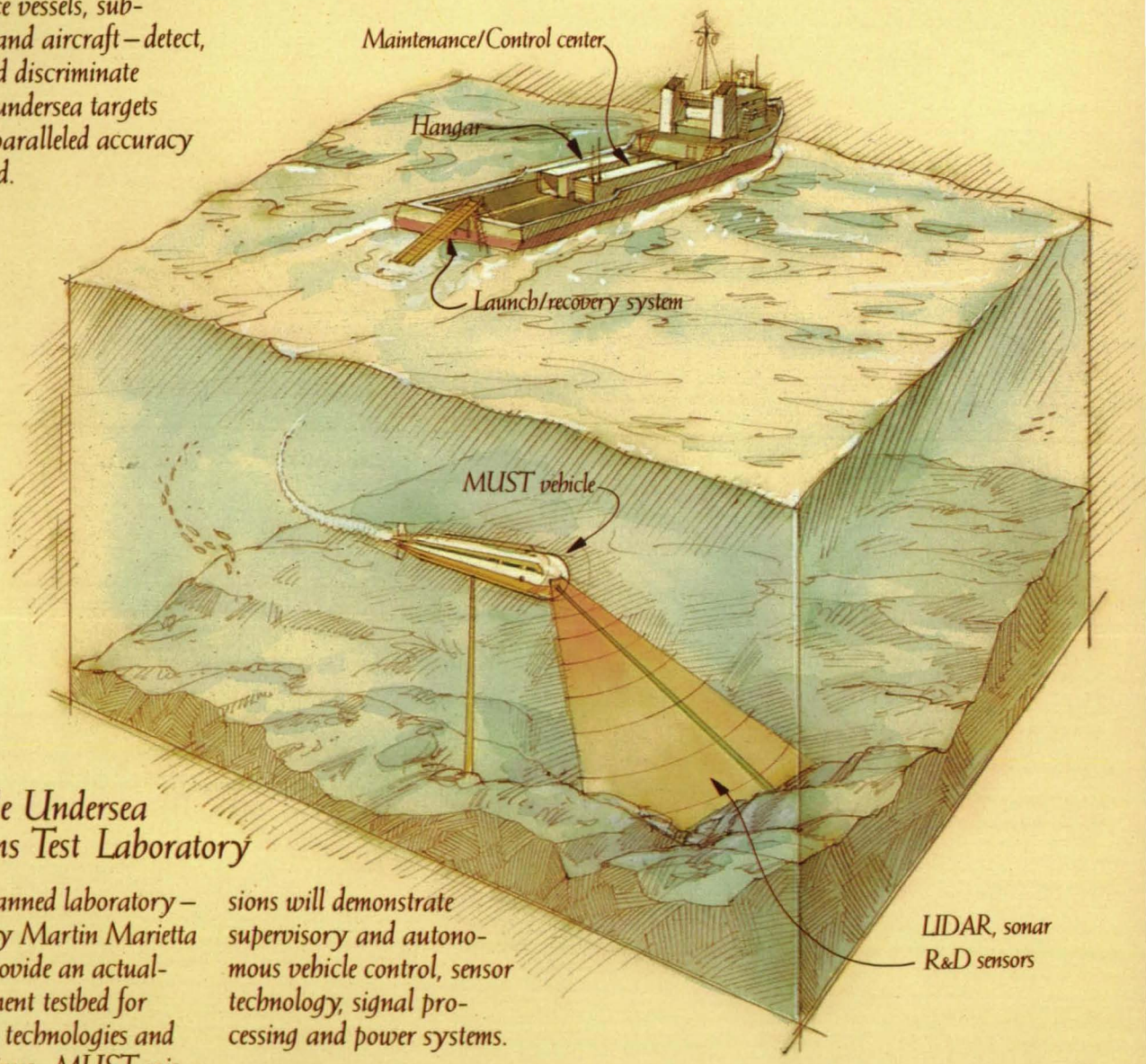


Yellowstone On Fire

Exploring new depths in sonar and signal technology.

Since Martin Marietta entered naval systems development, one focus has been underwater technology and its application to undersea warfare. This work is directed at developing, testing and demonstrating advanced sensory, control and signal processing systems and underwater laser systems to help the Navy – its surface vessels, submarines and aircraft – detect, track and discriminate between undersea targets with unparalleled accuracy and speed.



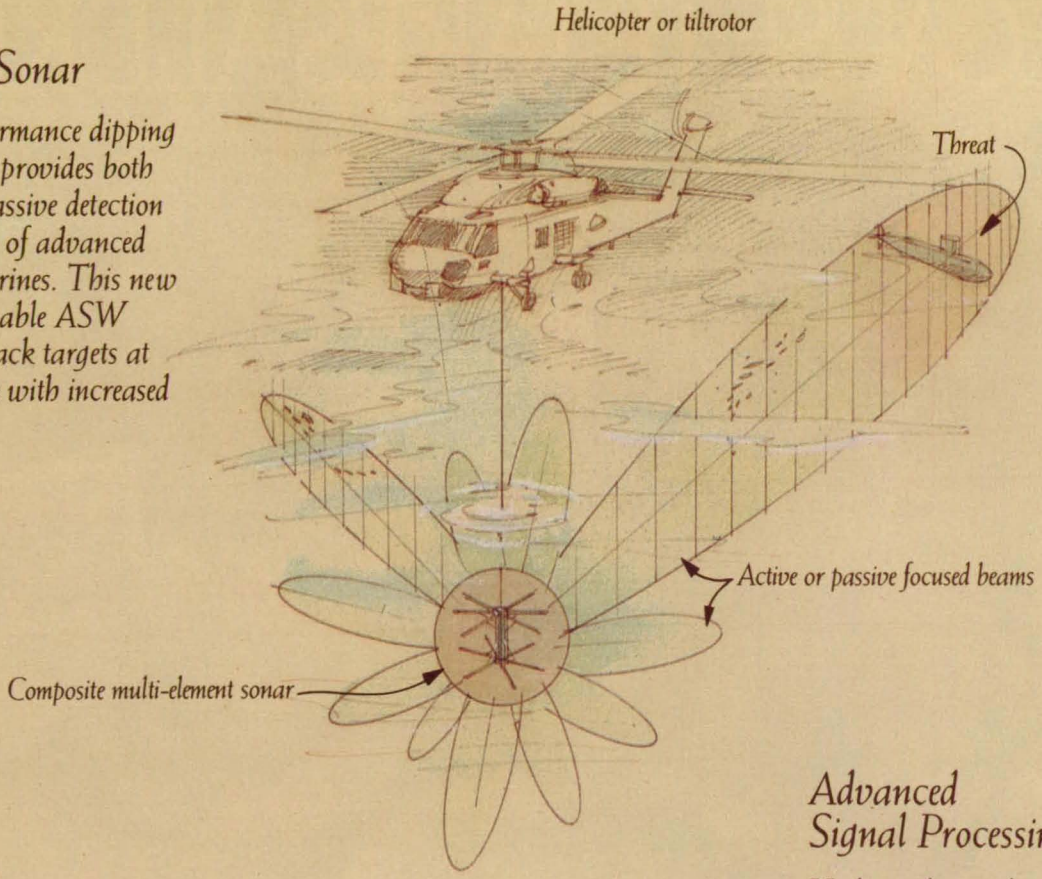


Mobile Undersea Systems Test Laboratory

An unmanned laboratory – funded by Martin Marietta – will provide an actual-environment testbed for undersea technologies and applications. MUST missions will demonstrate supervisory and autonomous vehicle control, sensor technology, signal processing and power systems.

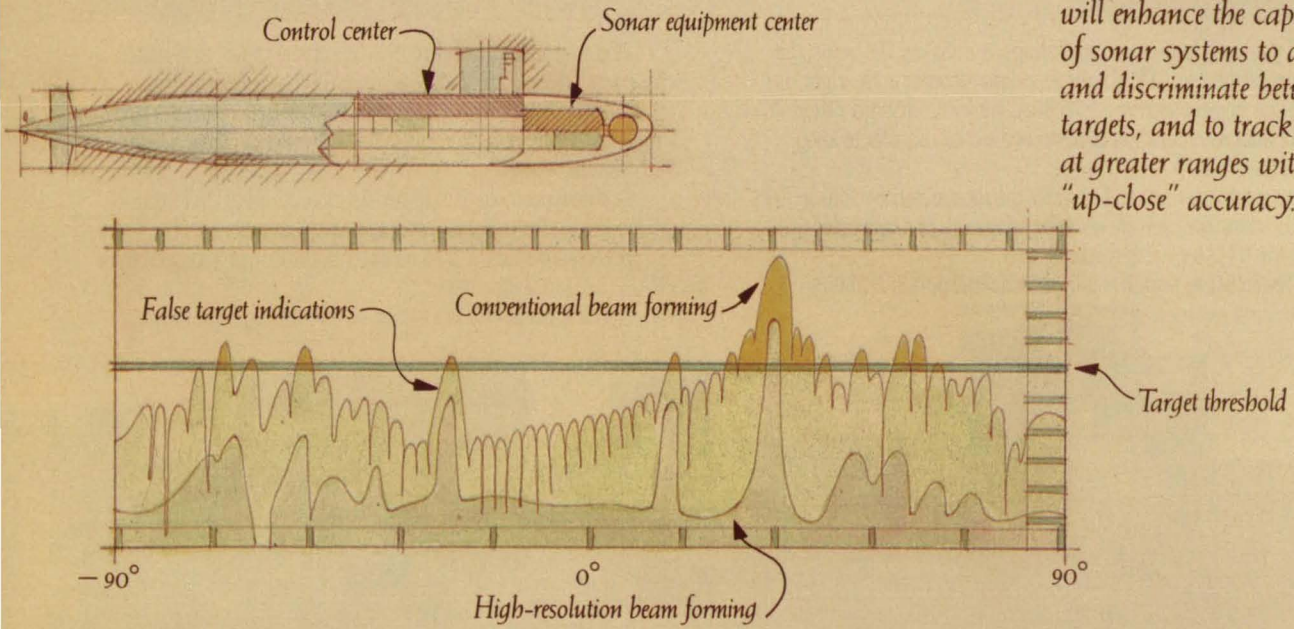
Airborne Sonar

A high-performance dipping sonar which provides both active and passive detection and tracking of advanced threat submarines. This new sonar will enable ASW aircraft to track targets at greater range with increased efficiency.



Advanced Signal Processing

High-resolution, beam forming algorithm and parallel processing systems we are developing for submarines will enhance the capability of sonar systems to detect and discriminate between targets, and to track them at greater ranges with "up-close" accuracy.



MASTERMINDING TOMORROW'S TECHNOLOGIES

MARTIN MARIETTA

6801 Rockledge Drive, Bethesda, Maryland 20817, USA

TEAC.
BECAUSE IT TAKES ALL KINDS.

If you need to measure the bumps, the shakes, the beats, the pressure, or the heat, TEAC makes a data recorder in the right size and format to meet your needs. In fact, we make so many different kinds of data recorders you almost need a data recorder to keep track of them all.

We made the first, and we offer the most extensive line of VHS data recorders. For ease of operation, economy, and convenience of media, the VHS format is the best.

We make the world's smallest 9-channel portable Philips cassette data recorder.

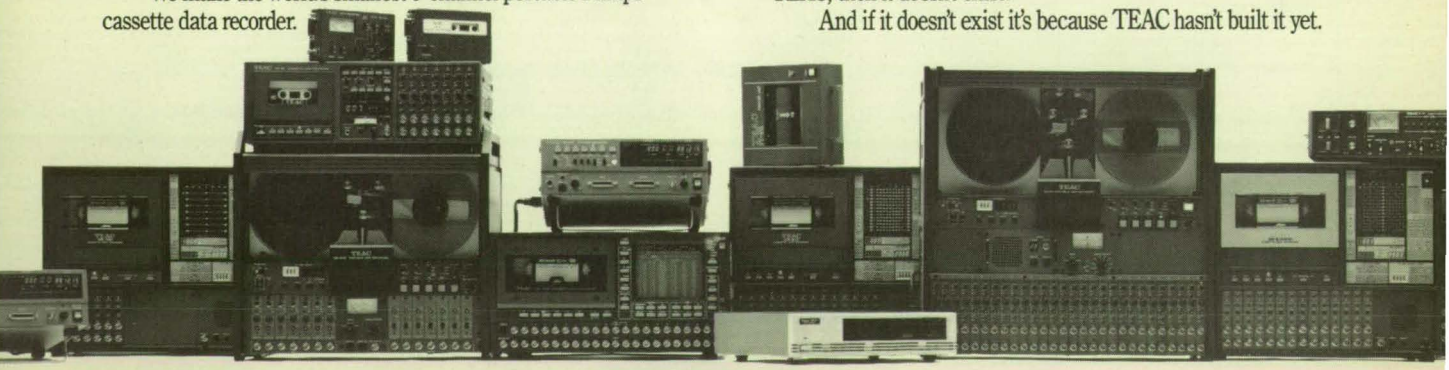
And we make a comprehensive line of reel-to-reel data recorders with extended recording times and up to 28 channels available.

We offer the widest selection of cassette data recorders from 1- to 9-channel models, from pocket-sized to sturdy laboratory and field systems.

Our new portable data recorders incorporating DAT technology are the leading edge in instrumentation recorders.

If you can't find the data recorder in the format you need from TEAC, then it doesn't exist.

And if it doesn't exist it's because TEAC hasn't built it yet.



TEAC®

Instrumentation Data Recorder Division.

Circle Reader Action No. 344

Precision Timing for the World's Most Demanding Applications

Odetics' Kode division is the technological leader for products that measure, record and generate time.

- ❑ GPS-Synchronized Time and Frequency Systems
- ❑ Time Code Generators
- ❑ Time Code Translators
- ❑ Time Code Generators/ Translators
- ❑ Synchronous Time Code Generators
- ❑ Countdown Systems
- ❑ Remote Time Displays
- ❑ Video Time Inserters
- ❑ Automatic Tape Search Systems
- ❑ Master Timing Systems

and

- ❑ Time Interval Analyzers

Odetics

Kode Division
1515 South Manchester Avenue
Anaheim, California 92802-2907
✆ 714-758-0400
FAX 714-535-8532

Circle Reader Action No. 346

Essential light tool.

You have the application. We have the DPY.
If you're still looking for the diode-pumped laser that can meet *your* needs, look at Spectra-Physics. Our array of DPY options and accessories is unparalleled in the laser industry. With our modular system design, interchangeable laser heads, choice of wavelengths and solid-state materials, you'll have the flexibility to build a laser any way you need it.

Use more power, keep a cool head.
Let your power grow without enlarging *or* overheating the laser head—the exclusive S-P Lasers fiber optic-coupled design makes it possible. Add extra power flexibility with our unique 2-diode pump module. Choose 200-mW, 500-mW, or 1-Watt pump configurations and increase your output power as your needs change.

You don't have to touch it (unless you want to).
If you're an OEM manufacturer, you can have a customized, computer-interfaced DPY in a 19-in. rack mount that fits right into your system. If your work is scientific, you'll find all the manual controls you want. In either case, you'll possess a rugged, maintenance-free laser delivering highly reliable TEM_{00} output.

From the vision of Spectra-Physics.
Put the resources of the laser industry leader behind you. We can help make *your* work the next big idea in lasers. To find out how our essential light tool can make a substantial difference in your application, contact your Spectra-Physics representative. Call 1 (800) 227-8054 in the U.S.A., or any of our sales and service centers worldwide.

High-Power Diode Pumped Lasers

Spectra-Physics

SPECTRA-PHYSICS™

All things considered in lasers.™

Circle Reader Action No. 406

SETTING THE STANDARD FOR REAL-TIME UNIX®

Everyone's talking about it now, but we've been shipping it since 1982. And we've continued to set the real-time standard every year since. RTU™, our real-time enhanced UNIX operating system, provides guaranteed response plus the flexibility and compatibility of AT&T System V and 4.2 BSD.

Scientists, engineers, systems integrators, and OEMs can choose from our family of MC68030/020-based multiprocessor computers, from 3 to 25 MIPS, with VMEbus™ and Multibus.™ They're designed for high-performance applications in data acquisition, digital signal processing, imaging, C^3I, and real-time simulation.

What's behind the trend to real-time UNIX? Want to learn how your real-time application can benefit from UNIX power and compatibility? Send in the coupon for your free copy of *Understanding Real-Time UNIX,* by Prof. John Henize.

Get in tune with the best real-time systems available.
1-800-631-2154

Send to Concurrent Computer Corp., Dept. NT9, 106 Apple Street, Tinton Falls, NJ 07724

☐ YES, please send a complimentary copy of *Understanding Real-Time UNIX.*

☐ Send me information on Concurrent real-time computer systems

NAME_____

TITLE_____

COMPANY_____

ADDRESS_____

CITY_____ STATE_____ ZIP_____

PHONE_____

MY APPLICATION IS_____

Concurrent Computer Corporation

UNIX is a trademark of AT&T. RTU, is a trademark of Concurrent Computer Corporation. VMEbus is a trademark of Motorola Corporation. Multibus is a trademark of Intel Corporation.

Circle Reader Action No. 581

NASA Tech Briefs
Transferring Technology to American Industry and Government

APRIL 1989
Volume 13 Number 4

SPECIAL FEATURES

Mission Accomplished 16

Texas High Tech Development Report 41

TECHNICAL SECTION

New Product Ideas 12

NASA TU Services 14

Electronic Components and Circuits 22

Electronic Systems 32

Physical Sciences 68

Materials 78

Computer Programs 84

Mechanics 88

Machinery 101

Fabrication Technology 107

Mathematics and Information Sciences 112

Subject Index 120

ABP BPA

Using information extracted from satellite imagery, scientists are studying how severe fires affect a forest's ecosystem. The same data could help forest managers to develop improved fire fighting techniques. See the Mission Accomplished story on page 16.

DEPARTMENTS

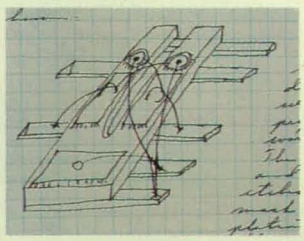
Editorial Notebook . . . 10

New Literature . . . 114

New on the Market 118

Advertisers' Index 124

On The Cover: This computer-enhanced Landsat image shows Yellowstone National Park at the height of last summer's forest fires. The bright red areas represent active fires. Smoke, pale blue, is clearly visible rising from the fire perimeter and moving to the right. Vegetation not affected by the fire appears in tones of green. The Old Faithful geyser is the light area near the center of the image. *(Photo courtesy the U.S. Geologic Survey, EROS Data Center)*



An idea that changed the world: the first integrated circuit as envisioned by inventor Jack Kilby in a notebook sketch. The circuit is one of many technological breakthroughs by Texas researchers. For more on Texas technology, turn to the special report beginning on page 41. *(Photo courtesy Texas Instruments)*

NASA Tech Briefs, ISSN 0145-319X, USPS 750-070, copyright © 1988 in U.S., is published monthly except July/August and November/December (10x per year) by Associated Business Publications Co., Ltd. 41 E. 42nd St., New York, NY 10017-5391. The copyrighted information does not include the individual Tech Briefs which are supplied by NASA. Editorial, sales, production and circulation offices at 41 E. 42nd Street, New York, NY 10017-5391. Subscriptions for non-qualified subscribers in the U.S., Panama Canal Zone, and Puerto Rico, $75.00 for 1 year; $125.00 for 2 years; $200 for 3 years. Single copies $15.00. Remit by check, draft, postal or express orders. Other remittances at sender's risk. Address all communications for subscriptions or circulation to NASA Tech Briefs, 41 E. 42nd Street, New York, NY 10017-5391. Second-class postage paid at New York, NY and additional mailing offices.

POSTMASTER: please send address changes to NASA Tech Briefs, 41 E. 42nd Street, Suite 921, New York, NY 10017-5391.

Build Your Future with Newport

You'll buy them for their value, you'll appreciate them for their convenience

New Precision Rails and Carriers

Newport's precision PRL Rails and PRC Carriers deliver smooth, straight, stable positioning plus many thoughtful features: engraved inch/mm scales, a novel dovetail design and locking mechanism for instant lockdown and easy carrier removal, and a unique optional indexing block for dependable repositioning. Available in several lengths, with English or metric mounting.

Two New Kinematic Bases

Meet the Model 110, the first Kinematic Magnetic Base. It locks down anywhere, and its kinematic mounting plate can be removed and replaced with exceptional repeatability. With its hefty holding force and generous mounting holes it offers unmatched utility, yet it costs no more than ordinary premium bases.

Also, the popular BK-1 Kinematic Base joins our popular BK-3 and BK-5, the only bases with our patented solution to mounting anywhere on the table.

New Compact Lab Jack

The Model 487, a compact lab jack with a lockable, rotating platform, is ideal for prisms, beamsplitters, cells, and small electro-optic devices like acousto-optic modulators. Features include easy-to-reach adjustments, engraved scales, and a gentle, spring-loaded optic clamp. It's the latest companion to our useful Model 485 Tilt/Rotation Stage and Model 481 Rotary Stage.

For more information on Newport's new components, call ***(714) 965-5406.***

Newport

Unshakeable Quality

Newport Corporation
18235 Mt. Baldy Circle
Fountain Valley, CA 92708
Europe: Newport GmbH
Ph. 06151-26116
U.K.: Newport Ltd.
Ph. 05827-69995

Circle Reader Action No. 509

NASA Tech Briefs
National Aeronautics and Space Administration

ABP BPA

NASA Tech Briefs:

Published by ..... **Associated Business Publications**
Editor-in-Chief/Publisher ..... **Bill Schnirring**
Associate Publisher ..... **Frank Nothaft**
Associate Publisher ..... **Robin J. DuCharme**
Managing Editor ..... **R. J. Laer**
Associate Editor ..... **Joseph T. Pramberger**
Technical Advisor ..... **Dr. Robert E. Waterman**
Production Manager ..... **Rita Nothaft**
Traffic Manager ..... **James E. Cobb**
Circulation Director ..... **Anita Weissman**
Marketing Research Manager ..... **Leo D. Kluger**
Advertising Coordination Manager ..... **Erving Dockery, Jr.**
Telecommunications Specialist ..... **Evelyn Mars**
Reader Service Manager ..... **Arlene Berrios**

Technical Staff:
Briefs prepared for National Aeronautics and Space Administration by **Logical Technical Services Corp.**, NY, NY
Technical/Managing Editor ..... **Ted Selinsky**
Art Director ..... **Ernest Gillespie**
Administrator ..... **Elizabeth Texeira**
Chief Copy Editor ..... **Lorne Bullen**
Staff Editors ..... **Dr. James Boyd, Dr. Larry Grunberger, Jordan Randjelovich, George Watson, Oden Browne, Joseph Renzler, Dr. Theron Cole, Jr.**
Technical Advisers ..... **Dr. Arthur Gilman, Dr. Jay Kirschenbaum**
Graphics ..... **Luis Martinez, Vernald Gillman, Charles Sammartano**
Editorial & Production ..... **Bill Little, Frank Ponce, Ivonne Valdes, Paul Marcus**

NASA:
NASA Tech Briefs are provided by the National Aeronautics and Space Administration, Technology Utilization Division, Washington, DC:
Administrator ..... **Dr. James C. Fletcher**
Assistant Administrator for Commercial Programs .... **James T. Rose**
Deputy Assistant Administrator (Programs) ..... **Henry J. Clarks**
Deputy Director TU Division (Publications Manager) .. **Leonard A. Ault**
Manager, Technology Utilization Office, NASA Scientific and Technology Information Facility ..... **Walter M. Heiland**

Associated Business Publications
41 East 42nd Street, Suite 921, New York, NY 10017-5391
(212) 490-3999 FAX (212) 986-7864
President ..... **Bill Schnirring**
Executive Vice President ..... **Frank Nothaft**
Vice President ..... **Domenic A. Mucchetti**
Vice President Marketing ..... **Mark J. Seitman**
Controller ..... **Felecia D'Amato**

Advertising:
New York Office: (212) 490-3999 FAX (212) 986-7864
Sales Manager ..... **Robin DuCharme**
Regional Sales Manager (Mid-Atlantic) ..... **Michelle Larsen**
Account Executive ..... **Debby Crane** at (201) 967-9838
Account Executives (Midwest) ..... **Jack Cartwright** or **Paul Lesher** at (312) 501-4140
Account Executives (Eastern MA, NH, ME, RI) **Lee Arpin** or **Paul Gillespie** at (617) 899-5613; **Bill Doucette** at (617) 278-7792
Account Executive (Western MA, CT, VT) **George Watts** or **David Haggett** at (413) 253-9881
Account Executive (WA, OR) ..... **Kelly Horton** at (503) 629-5597
Account Executives (So. Calif., AZ, NV, NM) for Area Codes 818/213/805 **Thomas Stillman** or **Melanie Binkley**
and for Area Codes 619/714—**Leslie Alley** at (213) 372-2744

NTBM-Research Center
Account Supervisor ..... **Lourdes Del Valle**

YOU NAME IT. AIRESEARCH IS INVOLVED WITH LIFE SUPPORT.

Throughout the thirty-year history of the NASA manned space program, AiResearch has supported the lives of a generation of space explorers.

We drew our first breaths aboard the Mercury flights. We were there when the whole world held its breath during America's first EVA, a spacewalk from a Gemini capsule. We watched over Apollo's one great step for mankind. And for six months, we orbited with Skylab, providing an atmosphere conducive to scientific research.

Today, working with several of America's most prestigious aerospace contractors, we're expanding our broad technological base. With several systems aboard the space station.

Supporting this growth in technology is the Allied-Signal Engineered Materials Research Center. Here we explore materials and techniques not available elsewhere. Technology that will eventually take life support beyond earth orbit.

Make our world-class facilities and other space experience part of your next project. After all, no one should work in a vacuum.

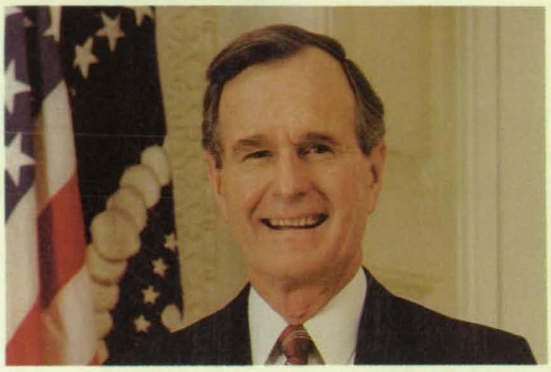
AiResearch Los Angeles Division, 2525 West 190th Street, Torrance, CA 90509. (213) 512-5488.

Allied-Signal Aerospace Company

Allied Signal

Circle Reader Action No. 656

Editorial Notebook



THE WHITE HOUSE
WASHINGTON

March 13, 1989

Dear NASA Tech Briefs Reader:

It gives me great pleasure to extend to you my warmest greetings and to offer my heartfelt congratulations to the staff of NASA Tech Briefs for the success of this outstanding publication.

In late 1984, NASA entered into a joint venture with Associated Business Publications, making NASA Tech Briefs the first government publication in history to accept paid advertisements. That arrangement relieved the government of publication costs, increased circulation, and resulted in a tremendous savings to the American taxpayer. It was truly good news for all of us.

As a Texan, I am particularly proud to note that this month's issue will feature a special section spotlighting high-tech opportunities in the Lone Star State. Over the years, Texans have made substantial contributions to the success of NASA and the high-tech industry. Many are eager to showcase their companies and expertise to the vast scientific audience reached by NASA Tech Briefs.

I have always been a strong supporter of an ambitious space program, and as I said on February 9th before a Joint Session of the Congress: "We must have a manned space station; a vigorous, safe space shuttle program; and more commercial development in space." More commercial development will bring greater opportunities for NASA Tech Briefs to inform potential users of NASA spin-offs. And that promises great benefits for all Americans.

Best wishes for the continued success of NASA Tech Briefs.

George Bush

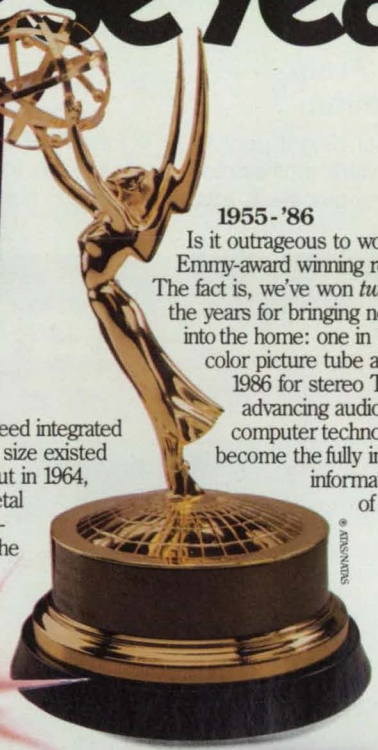
We, the publishers of NASA Tech Briefs, are proud to have had the unwavering support of George Bush over the past five years. His enthusiasm has inspired all of us involved in this technology transfer effort, and has made our uphill journey a much easier climb. We applaud the President's continued support of a strong U.S. civil space program, which will benefit generations to come.

Brice Gelmaring

Still Crazy After All These Years.

1946
When the David Sarnoff Research Center was working on color TV in the early 1940's, people may have thought, "That's crazy!" Yet, in '46 we publicly demonstrated a practical, all-electronic compatible color TV system. It was accepted as the industry standard in 1953, and is still used today.

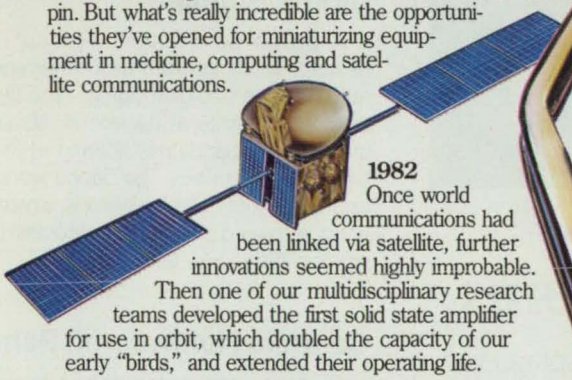
1964
In the 1950's, the concept of low-power, high-speed integrated circuits a few thousandths of a square inch in size existed only in science fiction, and the laboratory. But in 1964, we introduced the first complementary metal oxide semiconducting chip. Then demonstrated its marketplace value by building the first CMOS 8-bit microprocessor.



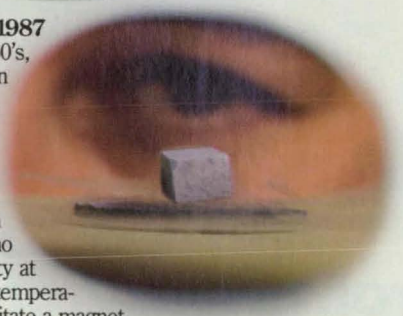
1955 - '86
Is it outrageous to work with an Emmy-award winning research center? The fact is, we've won *two* Emmys over the years for bringing new technology into the home: one in 1955 for the tri-color picture tube and another in 1986 for stereo TV. Today, we're advancing audio, video and computer technologies that may become the fully integrated home information center of the future.

® ATAS/NATAS

1986
Was it preposterous of us to try to reproduce the power of a room-sized laser in a smaller unit? No, we actually made our latest surface-emitting diode lasers smaller than the head of a pin. But what's really incredible are the opportunities they've opened for miniaturizing equipment in medicine, computing and satellite communications.



1982
Once world communications had been linked via satellite, further innovations seemed highly improbable. Then one of our multidisciplinary research teams developed the first solid state amplifier for use in orbit, which doubled the capacity of our early "birds," and extended their operating life.



1987
During the early 60's, we were a pioneer in superconductivity research, and the leader in developing commercial applications for superconducting wire which operated at extremely low temperatures. Modern superconductors have no resistance to electricity at twice the previous temperature and can levitate a magnet like the one shown here, but we're working on superconductive circuits that will operate at room temperature.

For over 40 years, the David Sarnoff Research Center has been turning man's wildest flights of fancy into marketplace realities.

Now, after all those years as a proprietary R&D facility for RCA and General Electric, Sarnoff is an independent contract research center.

And business is growing like crazy.

Our continuing success in contracts and joint ventures ranges from computerized automobile controls and radar measurements for steel blast furnaces to plasma physics.

Work in progress spans everything from high-definition television systems to transmitting data by laser to erasable optic disks. For our current capabilities report, contact Joseph C. Volpe, Vice President, Marketing, at the David Sarnoff Research Center, CN 5300, Princeton, NJ 08543-5300, or call (609) 734-2178.

Then bring us *your* troublesome projects, allegedly impossible technological hurdles and seemingly unreachable goals.

We're crazy enough to turn them into serious successes.

DAVID **Sarnoff** RESEARCH CENTER
A subsidiary of SRI International

Heads in the clouds, feet on the ground.

Emmy statuette is trademark of ATAS/NATAS.

Circle Reader Action No. 604

The Sarnoff Center will be located in booths 2302-2304 at the CLEO-QLES Conference, the Baltimore Convention Center, April 25-27. Come see us!

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 14). NASA's patent-licensing program to encourage commercial development is described on page 14.

Better PFAE's From Direct Fluorination

New low-molecular-weight perfluoroalkylethers (PFAE's) were synthesized by direct fluorination. The process is attractive because it often involves a single-step reaction and uses cheap starting materials. PFAE's have attractive characteristics as high temperature lubricants and hydraulic fluids. (See **page 80**).

Directional Hearing Aid

A hearing-aid device indicates visually whether a sound is coming from the left, right, back, or front. Visual displays, microphones, and signal-processing circuits can be built into eyeglasses, visors, caps, or other common headgear to indicate these directions. (See **page 34**).

Dynamic, High-Temperature, Flexible Seal

A new seal consists of multiple plies of braided ceramic sleeves filled with small ceramic balls. This dynamic, flexible seal can confine hot gases at temperatures up to 1,100 °C without coolant or at higher temperatures when cooled by transpiration. Promising applications are in hypersonic aircraft engines and other advanced propulsion systems. (See **page 101**).

Detector for FM Voice or Digital Signals

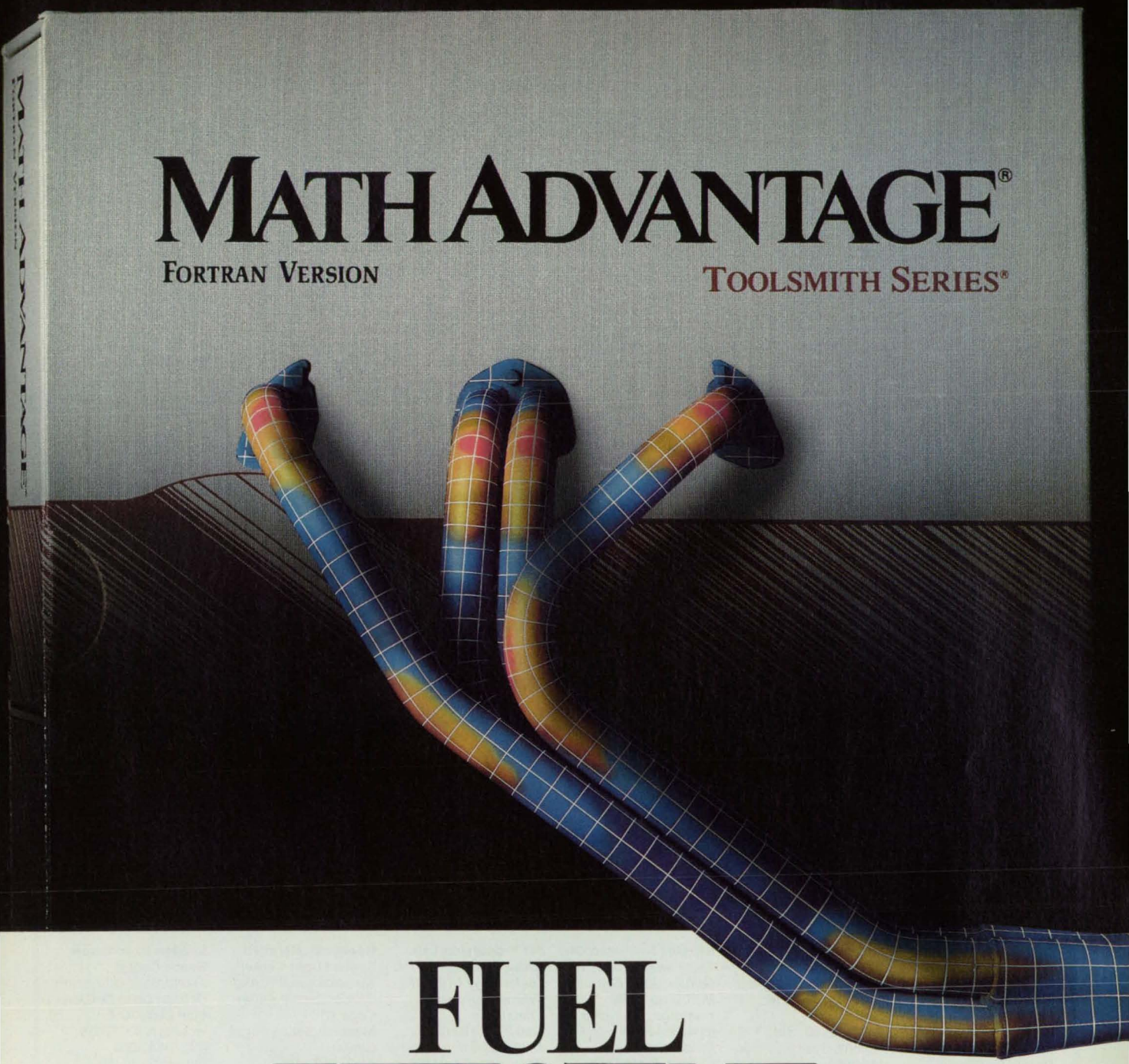
A proposed frequency-modulation detector would operate with either analog audio signals or digital signals. The detector could operate at baseband, obviating the need for band-pass filtering at the intermediate frequency. The device would be useful in mobile communications, where the trend is toward integrated voice and data service. (See **page 66**).

Ceramic Honeycomb Panels

Ceramic honeycomb panels serve as lightweight, heat-resistant structural members. Depending on the choice of ceramic materials, the panels are expected to withstand temperatures as high as 1,800 °C. (See **page 108**).

Metal Oxide/Zeolite Combination Absorbs H_2S

Mixed copper and molybdenum oxides supported in the pores of zeolite have been found to remove H_2S from a mixture of gases rich in hydrogen and steam, at temperatures from 256 to 538 °C. Such an absorber of H_2S can clean up gas streams from fuel processors that incorporate high-temperature steam reformers or hydrodesulfurizing units. (See **page 81**).



FUEL EFFICIENT.

Get maximum compute-engine performance for every application, with Math Advantage® from QTC.

Math Advantage is the de facto standard for math libraries in high-speed computing environments. It's developed and optimized by QTC's team of mathematicians, applications engineers, and supercomputer experts. It features over 260 frequently used but hard-to-program subroutines. And it runs on over 40 systems ranging from Cray X-MP to IBM PC, Cyber to VAX, Sun to Mac.

Best of all, Math Advantage gives you FORTRAN, C, and Ada versions of algorithms like FFTs, eigensolvers, matrix operations, and BLAS, all completely *ready-to-run*. So it helps you optimize the most valuable resource of all—your time.

Because it's from QTC, the experts in high-performance development tools, Math Advantage also comes with unmatched documentation, support, and technical excellence.

See for yourself—over 10,000 Math Advantage users already have. Contact QTC at 1-800-234-0168, or Telex 910 240 2827 for more information.

QTC
Quantitative Technology Corporation

Circle Reader Action No. 570

HOW YOU CAN BENEFIT FROM NASA'S TECHNOLOGY UTILIZATION SERVICES

If you're a regular reader of TECH BRIEFS, then you're already making use of one of the low- and no-cost services provided by NASA's Technology Utilization (TU) Network. But a TECH BRIEFS subscription represents only a fraction of the technical information and applications/engineering services offered by the TU Network as a whole. In fact, when all of the components of NASA's Technology Utilization Network are considered, TECH BRIEFS represents the proverbial tip of the iceberg.

We've outlined below NASA's TU Network—named the participants, described their services, and listed the individuals you can contact for more information relating to your specific needs. We encourage you to make use of the information, access, and applications services offered by NASA's Technology Utilization Network.

How You Can Utilize **NASA's Industrial Applications Centers**—A nationwide network offering a broad range of technical services, including computerized access to over 100 million documents worldwide.

You can contact NASA's network of Industrial Applications Centers (IACs) for assistance in solving a specific technical problem or meeting your information needs. The "user friendly" IACs are staffed by technology transfer experts who provide computerized information retrieval from one of the world's largest banks of technical data. Nearly 500 computerized data bases, ranging from NASA's own data base to Chemical Abstracts and INSPEC, are accessible through the ten IACs located throughout the nation. The IACs also offer technical consultation services and/or linkage with other experts in the field. You can obtain more information about these services by calling or writing the nearest IAC. User fees are charged for IAC information services.

Aerospace Research Applications Center (ARAC)
Indianapolis Center for Advanced Research
611 N. Capitol Avenue
Indianapolis, IN 46204
Dr. F. Timothy Janis, Director
(317) 262-5036

Rural Enterprises, Inc. Central Industrial Applications Center/NASA (CIAC)
P.O. Box 1335
Durant, OK 74702
Steve R. Hardy, President
(405) 924-5094

North Carolina Science and Technology Research Center (NC/STRC)
Post Office Box 12235
Research Triangle Park, NC 27709
H. Lynn Reese, Director
(919) 549-0671

NASA Industrial Applications Ctr. 823 William Pitt Union
University of Pittsburgh
Pittsburgh, PA 15260
Dr. Paul A. McWilliams, Exec. Director
(412) 648-7000

NASA/Southern Technology Applications Center
Box 24
Progress Ctr., One Progress Blvd.
Alachua, FL 32615
J. Ronald Thornton, Director
(904) 462-3913
(800) 354-4832 (FL only)
(800) 225-0308 (toll-free US)

NASA/UK Technology Applications Program
University of Kentucky
109 Kinkead Hall
Lexington, KY 40506-0057
William R. Strong, Director
(606) 257-6322

NERAC, Inc.
One Technology Drive
Tolland, CT 06084
Dr. Daniel U. Wilde, President
(203) 872-7000

Technology Application Center (TAC)
University of New Mexico
Albuquerque, NM 87131
Dr. Stanley A. Morain, Director
(505) 277-3622

NASA Industrial Applications Center (WESRAC)
University of Southern California
Research Annex
3716 South Hope Street, Room 200
Los Angeles, CA 90007-4344
Radford G. King, Exec. Director
(213) 743-8988
(800) 642-2872 (CA only)
(800) 872-7477 (toll-free US)

NASA/SU Industrial Applications Center
Southern University Department of Computer Science
P.O. Box 9737
Baton Rouge, LA 70813-9737
Dr. John Hubbell, Director
(504) 771-6272

If you represent a public sector organization with a particular need, you can contact NASA's Application Team for technology matching and problem solving assistance. Staffed by professional engineers from a variety of disciplines, the Application Team works with public sector organizations to identify and solve critical problems with existing NASA technology. **Technology Application Team, Research Triangle Institute, P.O. Box 12194, Research Triangle Park, NC 27709. *Doris Rouse, Director,* (919) 541-6980**

How You Can Access Technology Transfer Services At NASA Field Centers:
Technology Utilization Officers & Patent Counsels—Each NASA Field Center has a Technology Utilization Officer (TUO) and a Patent Counsel to facilitate technology transfer between NASA and the private sector.

If you need further information about new technologies presented in *NASA Tech Briefs,* request the Technical Support Package (TSP). If a TSP is not available, you can contact the Technology Utilization Officer at the NASA Field Center that sponsored the research. He can arrange for assistance in applying the technology by putting you in touch with the people who developed it. If you want information about the patent status of a technology or are interested in licensing a NASA invention, contact the Patent Counsel at the NASA Field Center that sponsored the research. Refer to the NASA reference number at the end of the Tech Brief.

Ames Research Ctr.
Technology Utilization Officer: Laurance Milov
Mail Code 223-3
Moffett Field, CA 94035
(415) 694-4044
Patent Counsel: Darrell G. Brekke
Mail Code 200-11
Moffett Field, CA 94035
(415) 694-5104

Lewis Research Center
Technology Utilization Officer: Daniel G. Soltis
Mail Stop 7-3
21000 Brookpark Road
Cleveland, OH 44135
(216) 433-5567
Patent Counsel: Gene E. Shook
Mail Code 301-6
21000 Brookpark Road
Cleveland, OH 44135
(216) 433-5753

John C. Stennis Space Center
Technology Utilization Officer: Robert M. Barlow
Code HA-00, Bldg.1103
Stennis Space Center, MS 39529
(601) 688-1929

John F. Kennedy Space Center
Technology Utilization Officer: Thomas M. Hammond
Mail Stop PT-PMO-A
Kennedy Space Center, FL 32899
(407) 867-3017
Patent Counsel: James O. Harrell
Mail Code PT-PAT
Kennedy Space Center, FL 32899
(407) 867-2544

Langley Research Ctr.
Technology Utilization Officer: John Samos
Mail Stop 139A
Hampton, VA 23665
(804) 864-2484
Patent Counsel: George F. Helfrich
Mail Code 279
Hampton, VA 23665
(804) 864-3523

Goddard Space Flight Center
Technology Utilization Officer: Donald S. Friedman
Mail Code 702.1
Greenbelt, MD 20771
(301) 286-6242
Patent Counsel: R. Dennis Marchant
Mail Code 204
Greenbelt, MD 20771
(301) 286-7351

Jet Propulsion Lab.
NASA Resident Office
Technology Utilization Officer: Gordon S. Chapman
Mail Stop 180-801
4800 Oak Grove Drive
Pasadena, CA 91109
(818) 354-4849
Patent Counsel: Paul F. McCaul
Mail Code 180-801
4800 Oak Grove Drive
Pasadena, CA 91109
(818) 354-2734
Technology Utilization Mgr. for JPL: Dr. Norman L. Chalfin
Mail Stop 156-211
4800 Oak Grove Drive
Pasadena, CA 91109
(818) 354-2240

George C. Marshall Space Flight Center
Technology Utilization Officer: Ismail Akbay
Code AT01
Marshall Space Flight Center,
AL 35812
(205) 544-2223
Patent Counsel: Bill Sheehan
Mail Code CC01
Marshall Space Flight Center,
AL 35812
(205) 544-0021

Lyndon B. Johnson Space Center
Technology Utilization Officer: Dean C. Glenn
Mail Code IC-4
Houston, TX 77058
(713) 483-3809
Patent Counsel: Edward K. Fein
Mail Code AL3
Houston, TX 77058
(713) 483-4871

NASA Headquarters
Technology Utilization Officer: Leonard A. Ault
Code CU
Washington, DC 20546
(202) 453-2636
Assistant General Counsel for Patent Matters: Robert F. Kempf, Code GP
Washington, DC 20546
(202) 453-2424

A Shortcut To Software: **COSMIC®**—For software developed with NASA funding, contact COSMIC, NASA's Computer Software Management and Information Center. New and updated programs are announced in the Computer Programs section. COSMIC publishes an annual software catalog. For more information call or write: **COSMIC®**, 382 East Broad Street, Athens, GA 30602 *John A. Gibson, Dir.,* (404) 542-3265

If You Have a Question . . . **NASA Scientific & Technical Information Facility** can answer questions about NASA's Technology Utilization Network and its services and documents. The STI staff supplies documents and provides referrals. Call, write or use the feedback card in this issue to contact: **NASA Scientific and Technical Information Facility,** Technology Utilization Office, P.O. Box 8757, Baltimore, MD 21240-0757. *Walter M. Heiland, Manager,* (301) 859-5300, Ext. 242, 243

Without Compromise . . .
The Modgraph GX-2000

High Resolution Graphics Terminal

A Quality High-Resolution Image . . .

The GX-2000 is the latest in Modgraph's series of high-resolution graphics terminals. In a contemporary low profile enclosure, the GX-2000 offers our field proven TEK 4010/4014 and DEC VT220/100 emulation in a reliable low cost graphics terminal backed by a full one year warranty.

Additional standard features provided in the GX-2000 include windowing capabilities and DEC SIXEL graphics. Standard hardcopy interfaces are dot matrix, inkjet, and laser.

An extra large 15″ flat screen produces a crisp 1024 × 780 resolution image with TRUE ZOOM capability standard. Optional features include: memory for three additional fully independent graphics screens, TEK 4631 hardcopy interface, composite video output, mouse, data tablet, or trackball.

Modgraph

149 Middlesex Turnpike, Burlington, MA 01803
(617) 229-4800, outside MA (800) 327-9962

Image courtesy of Computervision Corp.

Circle Reader Action No. 337

Mapping A Fire's Aftermath

This TM image collected by Landsat 5 on October 2, 1988 has been color-coded to delineate the major burned areas within Yellowstone.
(Photo courtesy the EROS Data Center)

Last summer, wildfires ravaged more than a million acres of forest in Yellowstone National Park. To gauge the fire's impact on Yellowstone's ecosystem, the National Park Service is studying high-resolution images of the park captured by Landsat spacecraft orbiting 438 miles above the Earth.

Researchers are concentrating on an especially clear post-fire image generated on October 2, 1988 by Landsat 5's thematic mapper (TM), an advanced scanning instrument developed by the Hughes Aircraft Company under NASA's sponsorship. The TM detects radiation reflected and emitted by Earth objects —such as trees—in wavelengths of the electromagnetic spectrum invisible to the human eye. Since each object has its own unique spectral "signature," it is possible to distinguish among a broad range of surface features and conditions, and to create computer-processed pictures or maps that highlight important features in a variety of colors.

In coordination with the National Park Service, scientists at the EROS Data Center in Sioux Falls, South Dakota are analyzing the October image using the Land Analysis System (LAS), a powerful image processing software system jointly developed by the EROS Data Center and NASA's Goddard Space Flight Center. LAS enables the scientists to calculate the total burn area and to plot burn intensity levels, which are indicated by subtle variations in color on the composite image.

"We want to identify the severely burned areas that are going to need the most attention in coming years," explained Donald Ohlen, an applications scientist with the EROS Data Center. The burn intensity research could help reveal soil erosion problems caused by the fire, Mr. Ohlen said. "There's potential for erosion problems anywhere you have a steep slope that's been badly burned," he explained. "By combining Landsat burn intensity data with elevation data taken from topographic maps, we could pinpoint those critical areas."

The Yellowstone wildfires of 1988: Twelve separate blazes began in late July, and by the time the fires were brought under control in October over 1.4 million acres were affected.
(Photo courtesy the Boise Interagency Fire Center)

The researchers plan to superimpose a pre-fire vegetation cover map over the October 2nd satellite image in order to determine how much of each vegetation class burned away. This information should help modify current fire behavior models, which are used in developing fire-fighting strategies. "We could learn a lot about which types and age classes of timber will fuel a fire, and which are the best barriers to the fire's spread," explained Steven Botti, Fire Management Specialist for the National Park Service. "In the future, that information would help us determine where we would need to concentrate our fire-suppression activities, and would also point out the areas where we might allow the fire to die out on its own."

The enhanced Landsat data may also be used by ecologists to study how the intense fire will affect Yellowstone's wildlife population. "Changes in vegetation cover brought on by the fire will be more beneficial to some species than others," Botti stated. "Ecologists will want to know whether certain burned areas favor, say, an elk habitat over a buffalo habitat."

Phase Two

Landsat TM acquisitions slated for this summer and fall will aid in monitoring Yellowstone's rehabilitation. The new data will enable foresters to document changes in vegetation density and distribution and to assess the overall rate of regeneration. Moreover, the updated images will be used to map the green islands of vegetation that will serve as seed sources for the burned regions.

By comparing images of Yellowstone from one year to the next, park managers will be able to discern if trees partially burned last summer have subsequently died. "Fire burned the bark on a number of trees that showed up green in the October 2nd image," explained Donald Despain, a research biologist with the National Park Service. "Those trees would be dead by late summer and therefore would have a different type of reflectance and appear as a different color on the new images. We could map the dy-

If you're in the market for a UNIX® workstation, we're the company you should be talking to.

$5490

DN3000 with 15" 1024 x 800 monochrome display

$6490

DN3000 with 19" 1280 x 1024 monochrome display

$9400

DN3000 with 15" 1024 x 800 color display

$8490

DN3500 MC68030-based workstation with 15" 1024 x 800 monochrome display

$9490

DN3500 MC68030-based workstation with 19" 1280 x 1024 monochrome display

$9990

DN3000 with 15" 1024 x 800 monochrome display and a 155MB ESDI disk

We can talk price.

We'd like to begin this conversation by making six points. Price points, that is.

Because within our family of UNIX® workstations are six machines whose prices are as low as their technology is high.

Take for example, our family of personal workstations. Machines that offer superior networking ability and even MC68030 performance for less than $10,000.

Prices that become even more impressive when you realize they include 4MB of memory, a floating point coprocessor, an IBM PC AT®-compatible bus, and a choice of Ethernet,® Apollo® token ring, or IBM token ring networks.

So when you're ready to talk price, ask us about our Series 3000™ and Series 3500.™ Or better yet, just let the numbers speak for themselves.

apollo

We can talk performance.

Price isn't the only attribute of our workstations that speaks for itself.

Recent tests pitting the Apollo Series 10000™ against workstations, minis, superminis and mainframes declared the 10000 an undeniable victor. Expertly running complex applications up to seven times faster than its challengers.

Such an outcome could hardly be achieved by conventional means. Instead, the Series 10000 required an entirely new architecture, making it the only office-sized UNIX® server and workstation to yield true supercomputer performance.

With up to four CPUs, the 10000's *PRISM*™ architecture delivers performance 100 times that of a VAX® 11/780. Yet costs as little as $6500/MFLOP, one-tenth that of the competition.

All of which suggests that if extraordinary performance is what you're after, the Series 10000 from Apollo will leave you speechless.

apollo

And we can talk to any computer you'd ever want to talk to.

The only story bigger than our performance capabilities is our open computing environment. As a founding member of the Open Software Foundation, Apollo is committed to providing a broad range of computing alternatives.

Today every Apollo workstation can communicate over OSI, DECnet,® Ethernet or IBM token ring networks and accept VME-, SCSI- or PC AT-compatible equipment. Our support for UNIX® (Berkeley 4.3 and System V.3 SVID compliant), MS-DOS™ and X Window System™ assures that your application software is truly portable. And our adherence to standards such as PHIGS and GKS streamlines graphics-intensive applications.

What's more, Apollo's de facto industry standard for distributed computing, the Network Computing System,™ allows users to share data and computing power in a single integrated environment. Resulting in a new way of computing that's both more elegant and more efficient than any other.

Give us a call soon. You'll find that our actions speak even louder than words.

apollo

For more information, call 1-800-323-1846 (Massachusetts, 1-800-847-1011) or write Apollo Computer, 330 Billerica Road, Chelmsford, MA 01824.

Circle Reader Action No. 591

ing areas throughout the forest and get an accurate assessment of how many trees were actually killed by the fires."

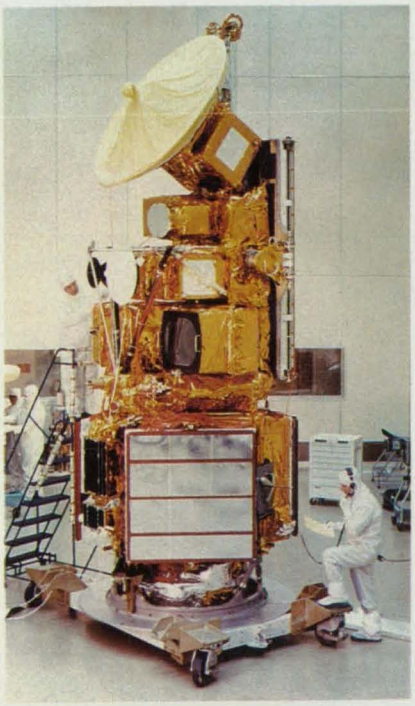
Presently, satellites are of little practical use in tracking active fires because it takes too long (about two weeks) to receive and process a digitized image. "By that time the fire has either been put out or has moved on to a new location," commented Mr. Botti. "For (satellite) remote sensing to be useful during a fire, you would have to be able to transmit and process the pictures in a matter of hours. That kind of capability is still far in the future."

A NASA Innovation

The Landsat system, first developed by NASA during the 1970s, is now operated under a Government contract by the Earth Observation Satellite Company (EOSAT) of Lanham, Maryland. Landsats 4 and 5 presently relay 38,800 new images to Earth each month. Fourteen countries receive pictures from the space satellites, while Pakistan and Ecuador are building ground stations to pick up the data as well.

Although the remote sensing program has been beset by budget difficulties, the Government continues to fund construction of Landsat 6, which is scheduled for launching in 1991.

Over the years, Landsat data has been used not only by foresters and ecologists, but also by agriculturists, geologists, oceanographers, and others concerned with land management. □



The Landsat 5 spacecraft
(Photo courtesy the General Electric Company)

Electronic Components and Circuits

Hardware Techniques, and Processes

22 Stable 1.25-W CW Methanol Laser
24 Spectrum-Modulating Fiber-Optic Sensors
24 Metal Film Increases CCD Quantum Efficiency
26 Output-Isolation and Protection Circuit

Books and Reports

30 Increasing and Combining Outputs of Semiconductor Lasers
31 Optically-Controlled Microwave Devices and Circuits
31 Igniter Simulator

Stable 1.25-W CW Methanol Laser

Thermally stable design keeps the rate of drift of frequency within ±100 kHz per hour.

NASA's Jet Propulsion Laboratory, Pasadena, California

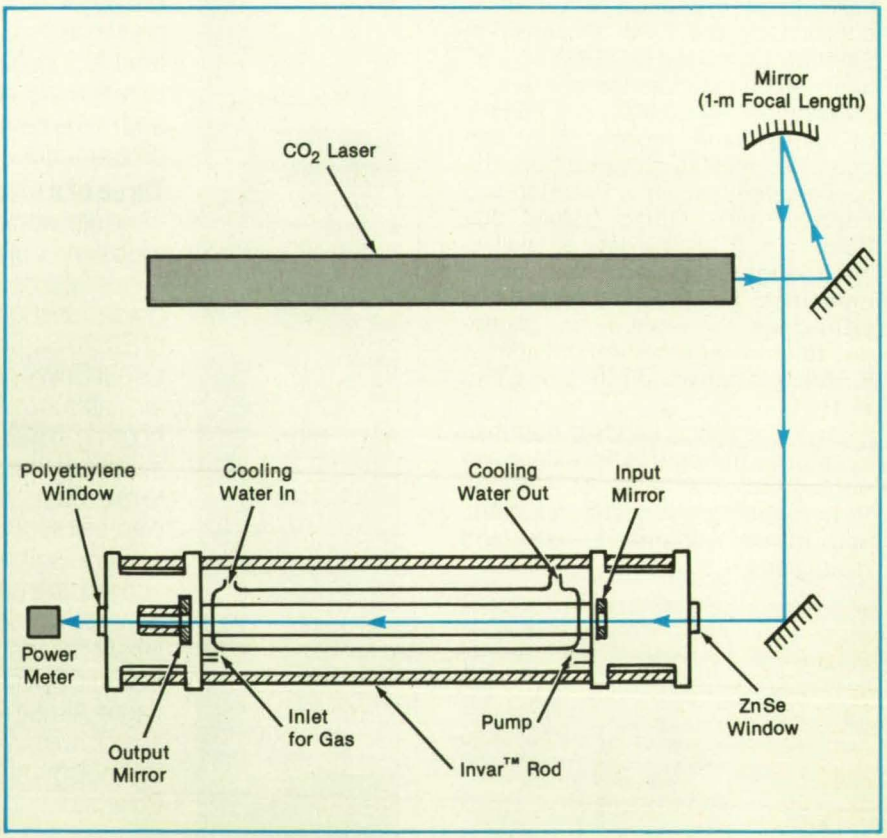
A far-infrared (FIR) laser operating at the 119-μm-wavelength transition of methanol achieves very low drift in frequency. The continuous-wave (CW) FIR output is 1.25 W when the laser is pumped by a 125-W commercial CO_2 laser. The rate of drift of the output frequency is found to be less than ±100 kHz per hour because the laser is designed to have low thermal-expansion coefficients and because the temperatures of the input and output couplers are held within 0.1 °C of the fixed values.

The laser (see figure) incorporates coaxial input and output coupling via windows and 5- and 10-mm-diameter holes, respectively, in water-cooled, gold-coated, flat copper end mirrors. A Z-cut quartz window behind the output coupler has a dielectric coating to reflect the radiation from the CO_2 pump laser. The folded pump optics have a focal length of 1 m. Because the ZnSe window in the input path is the only piece of transmissive optics in the pump line, the long-term performance of the laser should be improved. The output window is made of white, high-density polyethylene.

The FIR waveguide is housed in a Pyrex™ tube 240 cm long and 3.4 cm in inside diameter, with a coaxial water jacket. Translational and rotational mounts provide coarse and fine adjustments of the input and output mirrors. The mirrors and mounts are all placed in the lasing medium to avoid the need for bellows.

Heretofore, increased output power has been the main goal in the development of FIR lasers, but the development of tunable-sideband laser systems for applications in spectroscopy makes stability of frequency an important requirement as well. The improved performance of the new laser is achieved by the following design features:

- Reflecting optics are used wherever possible to minimize degradation of the electromagnetic modes in the CO_2 laser caused by damaged antireflection coatings on transmitting optics.
- The input and output assemblies are placed within the lasing medium to minimize external effects on the length of the laser resonator cavity and to avoid the mechanical instabilities that would be introduced by the use of bellows.
- The input and output couplers are cooled to reduce further the thermal source of changes in frequency.
- The wall of the resonator is cooled to 5 °C, and helium is added as a buffer gas to overcome the power-limiting effect of a quantum-mechanical vibrational transition. The peak output power is obtained when the partial pressures of methanol and helium in the lasing medium are 300 and 250 μm Hg (40 and 33 Pa), respectively.

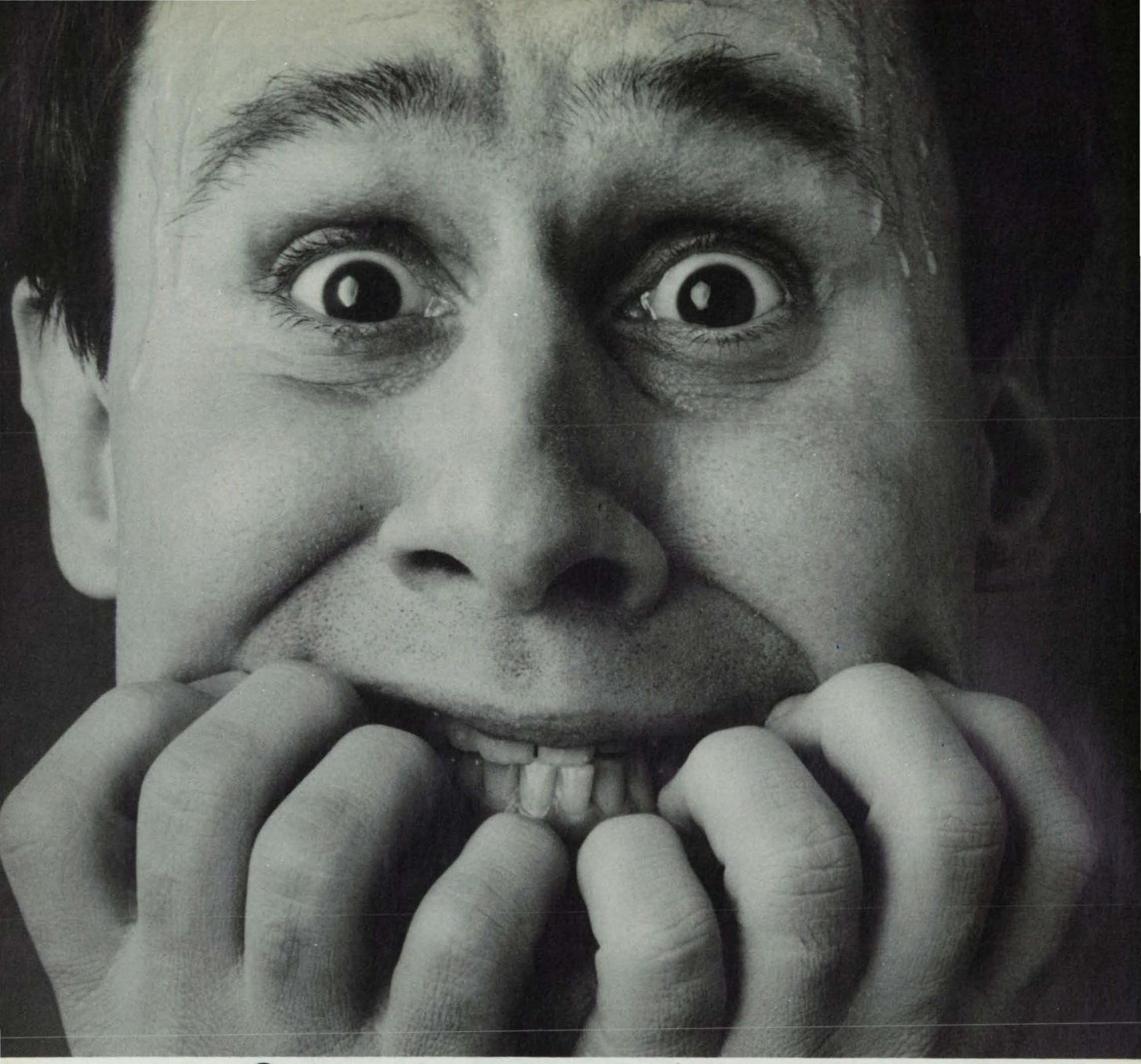


This **1.25-W Far-Infrared Laser** operating at the 119-μm (2,522.8-GHz) transition of methanol has a frequency-drift rate of less than 100 kHz per hour.

The stability of the frequency was measured by a heterodyne technique. The 80.5-GHz signal from a klystron was mixed with the 2,522.8-GHz laser signal, generating sidebands at 2,442.3 GHz and 2,603.3 GHz. The change in frequency of the klystron required to tune the lower sideband to the 2,442.3-GHz absorption line of SO_2 was taken to be the change in the frequency of the laser signal.

This work was done by Jam Farhoomand and Herbert M. Pickett of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 61 on the TSP Request Card.*

NPO-17346



Sometimes overnight is absolutely, positively too late.

We're not knocking the other guys, but sometimes you need to get it there right away. The very same day. Today, not tomorrow.

With TWA's Next Flight Out® delivery service, you're in business.

Even as you read this, TWA planes are about to take off. We can make sure your small package is on the next flight out to any one of over 100 U.S. cities. And we'll deliver it door-to-door or airport-to-airport. Same day. Seven days a week.

We'll give you our money-back guarantee and Frequent Flight Bonus miles, too (exciting details when you call).

We also deliver next day to Europe and second day to the Middle East.

So for anything up to 70 pounds domestic and 50 pounds international, just call the 800 number. It's that easy. It's *not* that expensive. And most of all, it's fast —very, very fast.

1-800-638-7380

For information or immediate pick-up, ask for Agent 164.

Circle Reader Action No. 438

Spectrum-Modulating Fiber-Optic Sensors

Susceptibility to variations in transmissivity is reduced.

Lewis Research Center, Cleveland, Ohio

A family of spectrum-modulating fiber-optic sensors is undergoing development for use in aircraft-engine control systems. Fiber-optic sensors offer the advantages of small size, high bandwidth, immunity to electromagnetic interference, and light weight. Furthermore, they reduce the number of locations on the aircraft to which electrical power has to be supplied.

The development of spectrum-modulating fiber-optic sensors is prompted by the high sensitivity of simple intensity-modulating sensors to changes in the transmissivity of the fiber-optic link. Transmissivity changes of several tens of percent can be caused by simply remating the connectors of the fiber-link. Replacement or repair of the components of the fiber-link as well as various types of environmental effects can also produce large transmissivity changes.

In a spectrum-modulating sensor, different wavelengths of light are modulated by different amounts as a function of the measured variable so that the valve of the measured variable can be inferred from ratios of intensities at these wavelengths. Because the transmissivity of a fiber-optic link is largely insensitive to wavelength (for wavelengths that are sufficiently close together), the ratios are nearly link-independent.

In one particularly-effective spectrum-modulation method, a binary representation of the measured variable is encoded onto the output spectrum of the sensor via the presence or absence of light in a number of adjacent wavelength channels (see Figure 1). The resolution of this digital transducer is 2^N, where N is the number of channels or bits.

In a spectrum-modulating position encoder, shown in Figure 2, broadband light from an LED is dispersed by a grating and graded-index lens across the channels of a reflective code plate. For an N-bit encoder, the normally absorptive code plate contains a number of reflective regions that are arranged in N parallel channels in a manner that provides a digital representation of the position of the code plate. The presence (or absence) of a reflective region at the illuminated portion of a particular channel indicates that the bit corresponding to that channel is a one (or a zero). Only those wavelengths of light that are directed to a channel in the "one" state are reflected back through the lens and grating into the output fiber. The output light of the sensor is analyzed using a second grating and lens in combination with a photodiode array. A reference channel, that is always "one" enables the receiver to compensate for changes in the transmissivity of the fiber link, thus providing an extremely high degree of link-independence.

This work was done by Glenn Beheim of **Lewis Research Center** *and Klaus Fritsch of John Carroll University. Further information may be found in NASA TM-88968 [N87-17700], "Spectrum-Modulating Fiber-Optic Sensors for Aircraft Control Systems."*

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-14662

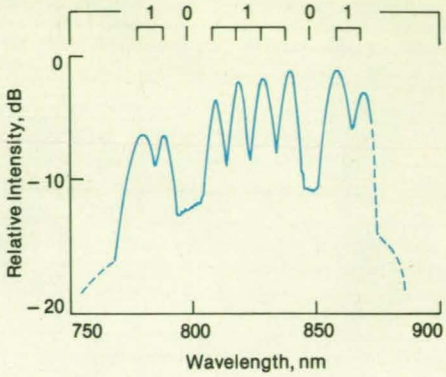


Figure 1. For a spectrum-modulating sensor having a digital output, the **Value of Each Bit** is determined by the intensity of light at a corresponding wavelength channel.

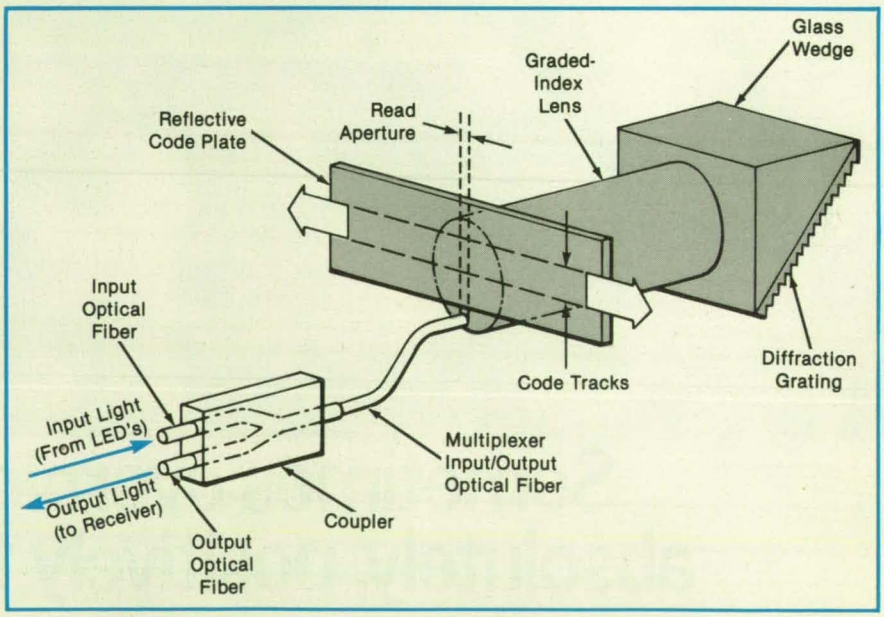


Figure 2. A **Spectrum-Modulating Position Encoder** uses a grating and lens to direct a different wavelength onto each channel of a reflective code plate.

Metal Film Increases CCD Quantum Efficiency

A CCD structure provides the means of obtaining 100-percent internal quantum efficiency over a large spectral range.

NASA's Jet Propulsion Laboratory, Pasadena, California

A thin layer of platinum or of other high-work-function metal applied to the back side of a rear-illuminated charge-coupled device (CCD) achieves the quantum efficiency (QE)-pinned state, an ideal condition allowing the sensor to achieve 100-percent internal charge-collection efficiency within its photosensitive volume. The metal layer, called the flash gate, is easily applied by tungsten vacuum deposition during the last step of the sensor fabrication.

To achieve the QE-pinned state in a back-side-illuminated CCD, the back side must be properly accumulated after thinning; that is, treated to create a strong elec-

TEAM WORK

ARIANE PUTS SATELLITES INTO SPACE THAT SPEAK 27 LANGUAGES. AS INDUSTRIAL ARCHITECT AEROSPATIALE COOPERATES WITH 11 EUROPEAN COUNTRIES PROVIDING SPACE-AGE TECHNOLOGY AND MANAGEMENT SKILLS. WITH THE NUMBER OF SATELLITES LAUNCHED FOR AMERICAN COMPANIES, WE PROVE OUR CAPABILITY OF WORKING TOGETHER. AND AEROSPATIALE HAS BUILT MORE THAN 40 TECHNICALLY DIVERSIFIED SATELLITES, MANY OF THEM WITH AMERICAN PARTNERS. WORKING AND CREATING TOGETHER KEEPS US UP THERE. MEET THE TEAM.

aerospatiale

AEROSPATIALE INC. 1101 15TH STREET NW WASHINGTON DC 20005
PHONE: 202 293 0650

tric field to sweep signal-photogenerated electrons away from the back side to the front-side collecting potential wells. In the absence of an accumulation layer, positively-charged interface states located at the Si/SiO_2 interface deplete the silicon and in turn generate an electric field in the opposite direction toward the back side, causing signal carriers to be lost to recombination. This undesired field condition results in very poor as well as unstable detector quantum-efficiency performance, particularly in the blue and ultraviolet regions of the spectrum, where the absorption length of the photons through silicon are extremely short. The accumulation is established by the flash gate through the work-function difference between the gate and the silicon, causing the electrons to collect on the metal layer and generate a net negative surface potential of a few tenths of a volt. This small voltage creates an accumulation layer of holes in the silicon, generating a strong electric field (>1,000 V/m) at the immediate back-side surface in the direction of the front side.

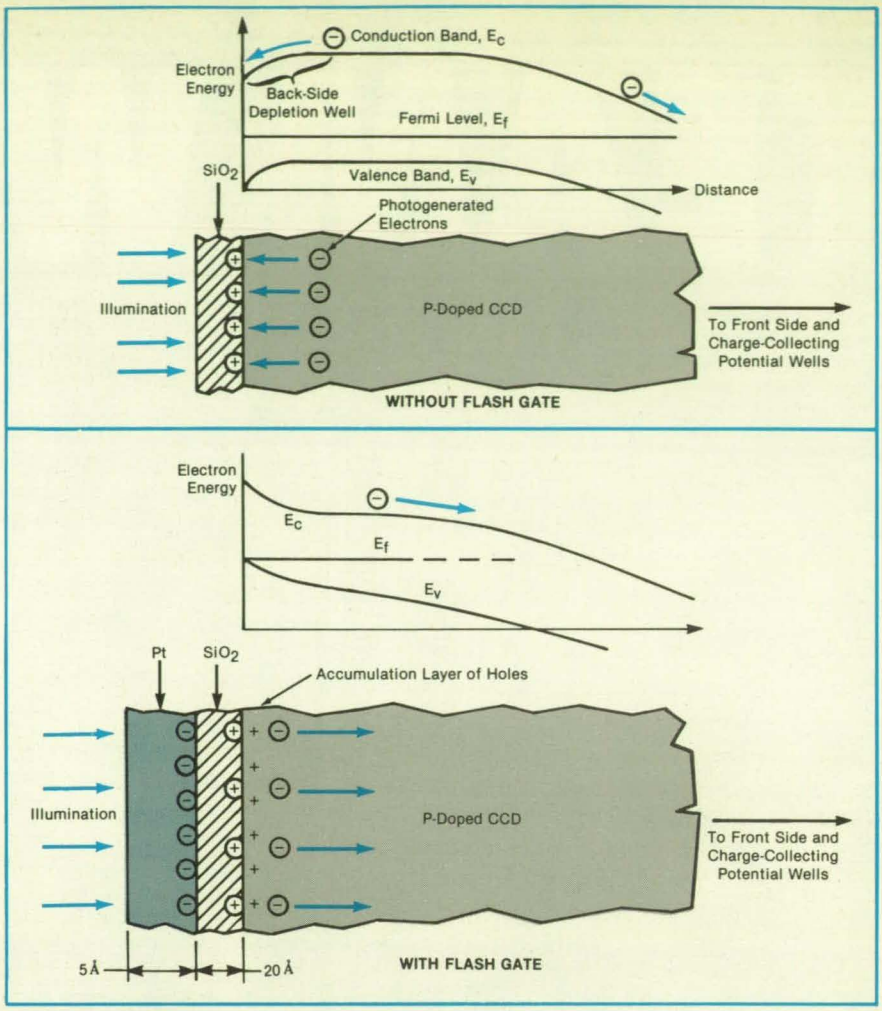
Because the flash gate is so thin (typically less than 1 monolayer), it does not attenuate the incoming radiation significantly and therefore allows the CCD to respond over a broad wavelength range of 1 Å (soft x-ray) to 11,000 Å (near infrared). Although the flash gate is being pursued by several CCD manufacturers and is applicable to many NASA CCD projects, there are still some technical problems and improvements currently being addressed in the subsequent development of this technology. One problem, for example, is that the flash system degrades when subjected to extended high-vacuum conditions at room temperature. One improvement, on the other hand, is the use of antireflection coatings deposited on top of the flash gate. Such a coating has the advantage of reducing surface reflection loss, thereby increasing the quantum efficiency of the CCD even further.

This work was done by James R. Janesick of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 84 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

Edward Ansell
Director of Patents and Licensing
Mail Stop 301-6
California Institute of Technology
1201 East California Boulevard
Pasadena, CA 91125

Refer to NPO-16815, volume and number of this NASA Tech Briefs *issue, and the page number.*



The **Energy-Band Structures** of the CCD without the "flash gate" (above) form a depletion well at the back, where photoelectrons are lost to recombination. With the flash gate (below), an electric field is generated that sweeps the signal photoelectrons away from the back side toward the front-side potential wells, where they are collected in individual pixel sites.

Output-Isolation and Protection Circuit

This circuit tolerates large common-mode voltages and normal-mode overvoltages on the output leads.

Ames Research Center, Moffett Field, California

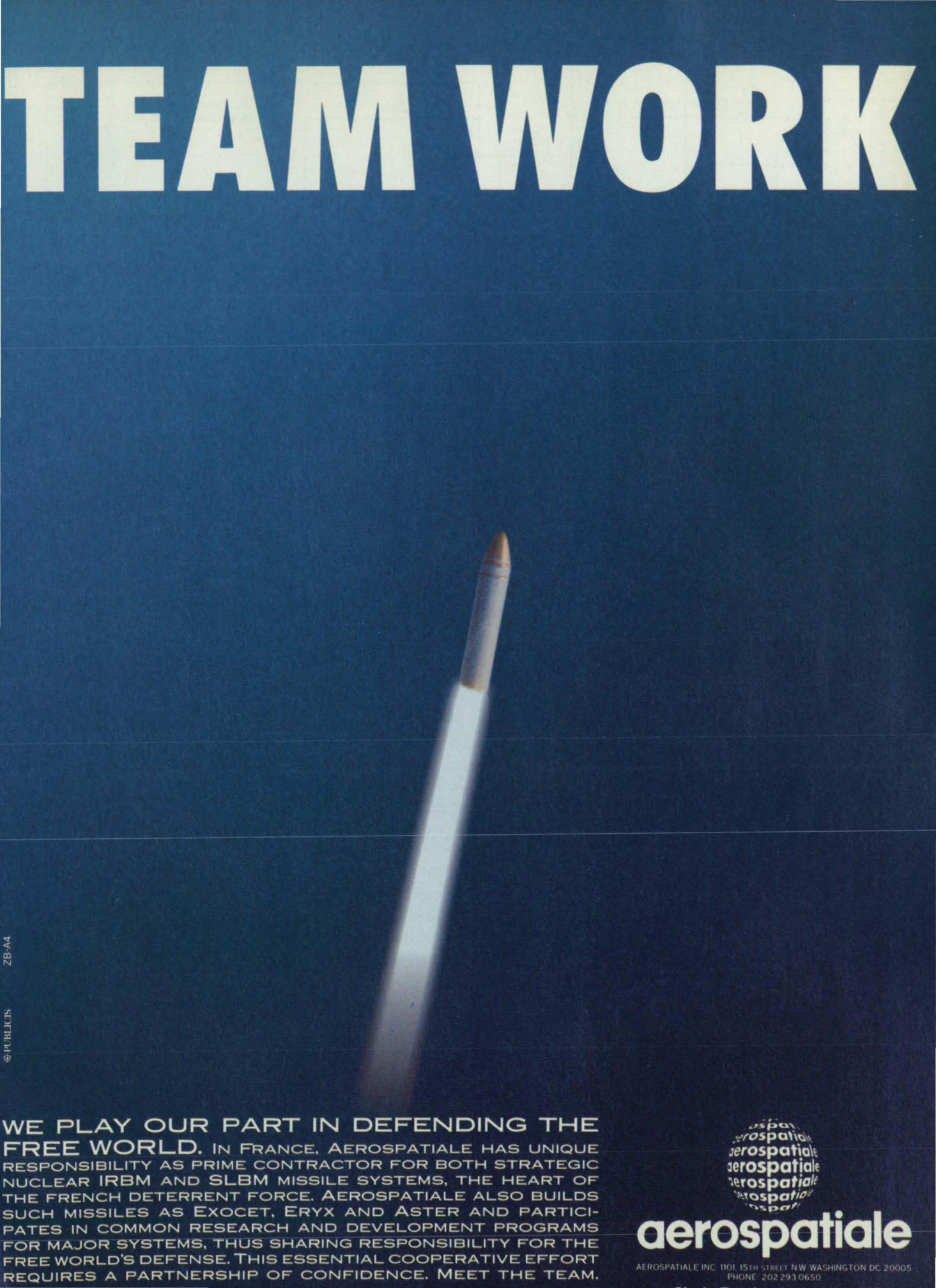
An output-isolation circuit couples precise analog signals (−10 to +10 V, 0 to 20 kHz) from a computer or from other electronic equipment to external electronic equipment that may be at a different ground potential. The circuit functions in the presence of common-mode voltages up to 2,500 Vac or 3,500 Vdc. To prevent damage from accidental connection of the output leads to powerlines or other sources of high voltage, the circuit includes features that protect the input and output signal lines against normal-mode overvoltages up to 120 V ac or dc.

In normal operation, the circuit (see figure) passes a signal from its input to its output at the same polarity and with a small gain. The principal element is U_1, an integrated circuit that includes a precise three-port isolation amplifier, which isolates its output from its input by internal transformer coupling. U_1 also provides an isolated ±15-V, 5-mA power supply. The gain of the amplifier (in this case, 1) is set by the selection of resistors R_5 and R_6. U_1 can provide an output of ±10 V.

The output of U_1 is buffered by U_2, a low-power, precise operational amplifier that is powered by U_1. This operational amplifier was chosen because it consumes very little power because and its output can swing very closely to its power-supply rails. Resistors R_1 and R_2 are chosen to set the gain of U_2 at 1.5 — a value that maximizes the output swing of U_2.

Four components provide for stability. Capacitor C_1 filters the ripple on the +15-V power supply of U_1. The internal circuitry of the negative supply has been filtered more heavily so that no external capacitor is needed. Capacitor C_2 stabilizes the ringing

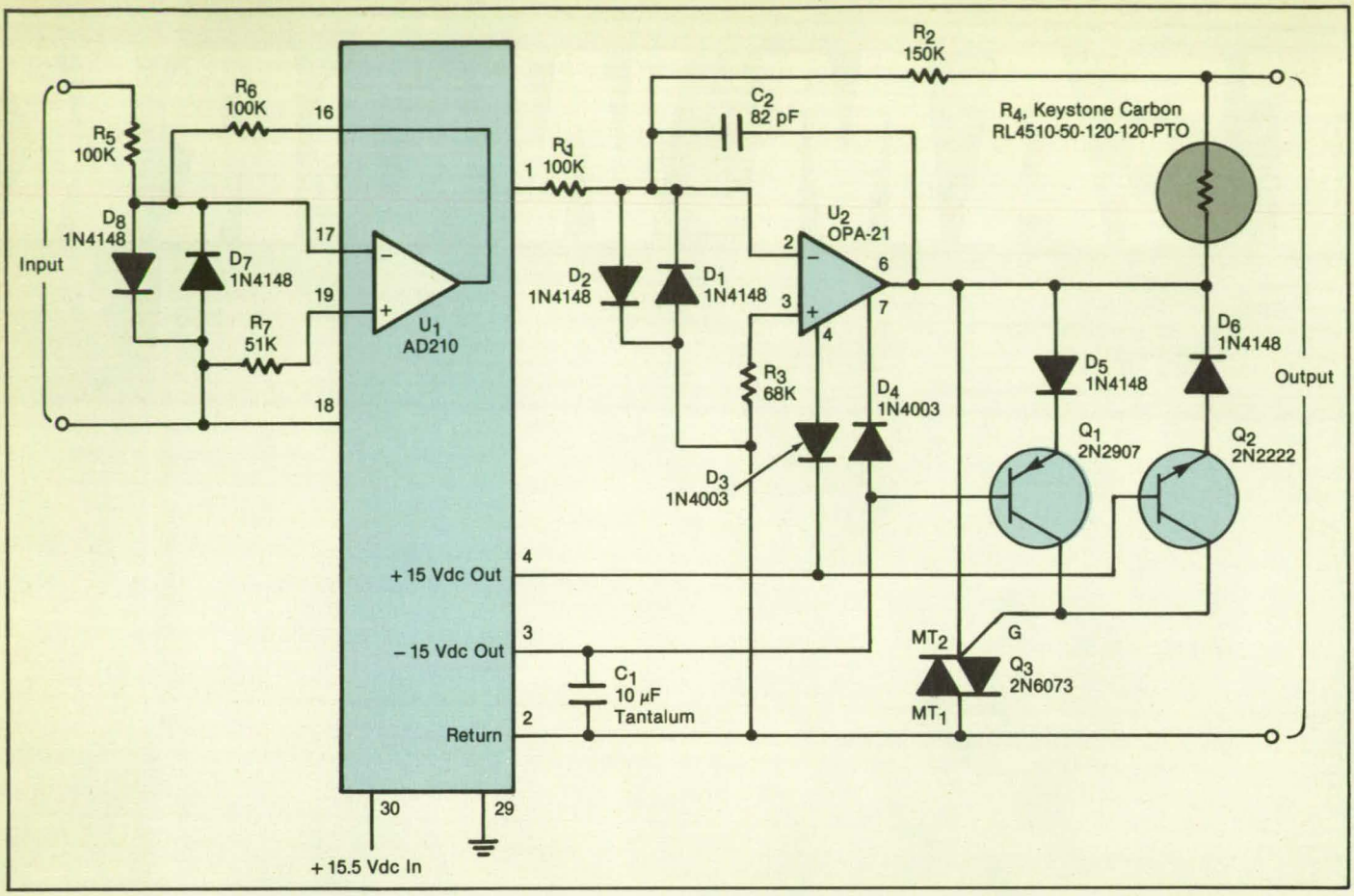
TEAM WORK



WE PLAY OUR PART IN DEFENDING THE FREE WORLD. IN FRANCE, AEROSPATIALE HAS UNIQUE RESPONSIBILITY AS PRIME CONTRACTOR FOR BOTH STRATEGIC NUCLEAR IRBM AND SLBM MISSILE SYSTEMS, THE HEART OF THE FRENCH DETERRENT FORCE. AEROSPATIALE ALSO BUILDS SUCH MISSILES AS EXOCET, ERYX AND ASTER AND PARTICIPATES IN COMMON RESEARCH AND DEVELOPMENT PROGRAMS FOR MAJOR SYSTEMS, THUS SHARING RESPONSIBILITY FOR THE FREE WORLD'S DEFENSE. THIS ESSENTIAL COOPERATIVE EFFORT REQUIRES A PARTNERSHIP OF CONFIDENCE. MEET THE TEAM.

aerospatiale

AEROSPATIALE INC 1101 15TH STREET N.W. WASHINGTON DC 20005
PHONE 202 293 0650



This **Isolation Amplifier** features high rejection of common-mode voltages and protection against input and output overloads.

NOW WORK OUR TEAM

OUR PARTNERSHIP CAN START RIGHT HERE. As a means to success, we are eager to discuss a partnership in any area of mutual interest: space, helicopters, aircraft and defense. Combining our aerospace technology with your expertise can only result in opening new frontiers. Use this space to write to us about your area of interest, and please attach your business card. We invite you to meet your Aerospatiale team.

aerospatiale

AEROSPATIALE INC. 1101 15TH STREET N.W. WASHINGTON DC 20005
PHONE: 202 293 0650

that occurs when a long cable or a complex load is connected to U_2. Resistor R_3 cancels the effects of the bias current on U_2; resistor R_7 performs the same function for the operational amplifier in U_1.

Several components protect against overloads. Diodes D_1, D_2, D_7, and D_8 are voltage clamps. D_1 and D_2 in combination with R_2 protect the input of U_2. D_7 and D_8 in combination with R_5 protect the input amplifier of U_1. D_3 protects U_1 and U_2 from reverse current in the negative supply lead of U_2, while D_4 protects U_1 and U_2 from reverse current in the positive supply lead of U_2.

When activated by sufficient current in its gate lead (G), triac Q_3 shorts MT_2 to MT_1. Any overload current on the output leads then flows safely through R_4 and the triac. R_4 is a positive-temperature-coefficient thermistor that has a cold resistance of 50 Ω. When enough current passes through the thermistor to heat it above switch temperature, its resistance increases, effectively limiting the overload current.

Transistors Q_1 and Q_2 are the overvoltage triggers for Q_3. The bases of these transistors are connected to the +15-V and −15-V power supplies, respectively. When the output voltage on the emitter of Q_1 is more positive than the +15-V output of U_1, Q_1 turns on, allowing current to flow and to turn on Q_3. In an analogous manner, Q_2 and Q_3 respond to negative overvoltages.

Diodes D_3 and D_4 enable Q_1 and Q_2 to turn on by eliminating the reverse current that would otherwise flow through U_2 when its output is driven beyond its power supply limits. D_5 and D_6 supplement the reverse breakdown potential of the base/emitter junctions of Q_1 and Q_2. Without D_5 and D_6, the base/emitter junctions would conduct in the reverse direction at voltages above 5 to 7 V, thus shorting the ±15-V power supplies to each other and to the output of U_2.

This work was done by Charles A. Wagner and Gary V. Kellogg of **Ames Research Center**. *For further information, Circle 161 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center [see page 14]. Refer to ARC-11834.

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.

Increasing and Combining Outputs of Semiconductor Lasers

Coherent and incoherent schemes are reviewed.

A paper reviews methods of increasing and combining the outputs of semiconductor lasers, with references to the literature of recent years (mostly 1986 and 1987). This is a field of great practical importance: It is necessary to increase or combine the outputs of individual lasers to obtain sufficient power for such uses as communication, ranging, remote sensing, printing, and pumping solid-state lasers.

There are several figures of merit by which one can characterize the output of a single laser or an array of lasers; which one to use depends on the application. Although the output power is one such figure, the power density (power per unit area) or the brightness (power per unit area per unit solid angle in a given direction) might be more meaningful under some circumstances. In applications in which the far-field output light is used, as in ranging and communication through free space, it is preferable to characterize the output in terms of the intensity, which is the power per unit solid angle in a given direction.

One approach to increasing power is to increase the power emitted by a single device. When operation in a single electromagnetic mode is required, the power can be increased only up to the level (usually about 100 mW) at which multimode operation sets in. When operation in a single mode is not required, power can be increased further, limited by the need to avoid excessive heating.

Outputs of laser diodes can be combined incoherently in several ways. For example, apertures can be shared to increase the power but not the brightness. Wavelengths can be multiplexed (e.g., by inverse of dispersion in a prism) to increase the brightness at the price of increased spectral width. Polarizations can be combined to increase the brightness.

Outputs can be combined coherently to increase the intensity and brightness. For example, a coherent array of N identical lasers operating in phase has N times the brightness and N times the power density in the forward direction of a similar incoherent array. The total power emitted in both cases is the same, but the angular distribution of the radiation in the coherent case is different and is typically concentrated in several narrow lobes. Coherent operation of the laser diodes in an array can be achieved by interaction, injection locking, or coherent amplification.

Output-combining schemes can be implemented by fabricating laser diodes in arrays as monolithic devices or by mounting discrete devices in arrays. Hybrid modules, each element of which by itself is a monolithic array, are also possible.

This work was done by Joseph Katz of

Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Power Combining of Semiconductor Lasers," Circle 47 on the TSP Request Card.*
NPO-17473

Optically-Controlled Microwave Devices and Circuits

Optical control increases speed and reduces the bulk of interconnections.

A NASA Technical Memorandum discusses the physical basis and the dc and microwave characteristics of optically-controlled microwave devices that have been described in the literature. The emphasis is on the responses of GaAs/GaAlAs high-electron-mobility transistors (HEMT's) and GaAs metal/semiconductor field-effect transistors (MESFET's) to light. Such devices have been used to detect radio-frequency modulation of optical signals, to control the gains of amplifiers, and to provide injection locking of oscillators.

The response of a microwave device to light is due in part to the photovoltaic effect. In addition, the absorption of light in the substrate, in the active layer, and in the Schottky and ohmic contact materials increases the density of free carriers of charge, thereby producing a photoconductive effect.

The report describes the current-versus-voltage characteristics of the reverse-biased source/gate junction (drain open) of a GaAs MESFET (0.3-μm gate length) and an AlGaAs/GaAs HEMT (0.5-μm gate length). The devices were illuminated by an AlGaAs/GaAs laser diode at a wavelength of 0.83 μm via a graded-index optical fiber of 50-μm diameter. The gains of the two devices both increase with illumination.

Recent developments in the technology of monolithic GaAs integrated circuits in both the microwave and optical domains are expected to lead to the application of optically controlled circuits in phased antenna arrays in space communications systems. At microwave frequencies, the transmission media currently available for handling control signals, such as coaxial cables and waveguides, are bulky and inflexible. Optical fiber is an attractive alternative, providing low weight, low loss, small size, broad bandwidth, and excellent isolation.

The monolithic integration of optical and microwave functions on a single GaAs substrate is expected to provide lightweight digital and analog links for control and the distribution of signals. In a typical device, light from optical fibers would be coupled through aligners to integrated photodetectors on a GaAs monolithic microwave integrated circuit: Optically-controlled microwave devices (interdigitated photodetectors) can demodulate radio-frequency signals carried by optical signals. They can also detect and amplify digital signals at rates of gigabits per second to control the functions of phase shifters and the gains of amplifiers in transmitting modules.

This work was done by Kul B. Bhasin and Rainee N. Simons of **Lewis Research Center**. *Further information may be found in NASA TM-89869 [N87-23900], "Optically Controlled Microwave Devices and Circuits: Emerging Applications in Space Communications Systems."*

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-14710

Igniter Simulator

One design simulates a variety of realistic conditions.

A report describes electronic circuitry that simulates the electrical properties of an igniter of a Space Shuttle main engine. The circuit is used to test the software of the engine controller, without having to fire a real igniter or turn on an engine. The circuit can be used in all igniter simulations and mimics the operation of an igniter more realistically than did previous versions.

The report includes a block diagram, a detailed schematic diagram, and a brief text that explain the operating modes, features, and functions of the circuit, which include the following:

- The circuit is compatible with both block I and block II Space Shuttle main engine controllers.
- The frequency and amplitude of the square-wave pulses that simulate the output of the igniter sensor can be controlled. In particular, the frequency can be varied from 25 to 125 Hz, with provision for a 75-Hz "ambient" mode that simulates the "sensor-checkout" phase of operation.
- The circuit can be controlled remotely or manually.
- The output can be opened for simulation of a fault.
- A portion of the circuit places an additional load on the igniter-command line once the igniter is commanded "on."
- The circuit obtains power from the engine controller.

This work was done by Richard A. Simon of Rockwell International Corp. for **Marshall Space Flight Center**. *To obtain a copy of the report, "Igniter Simulator," Circle 118 on the TSP Request Card.*
MFS-29402

Electronic Systems

Hardware Techniques, and Processes

32 Signal Preprocessor for Laser-Fringe Anemometers
34 Directional Hearing Aid
36 Simplified Linear Multivariable Control of Robots
37 Keyboard Emulation for Computerized Instrumentation
38 Fast Asynchronous Data Communication Via Fiber Optics
40 Interface for Fault-Tolerant Control System
65 Eight-Bit-Slice GaAs General Processor Circuit
66 Detector for FM Voice or Digital Signals

Signal Preprocessor for Laser-Fringe Anemometers

Added control and filtering functions enhance the collection of data.

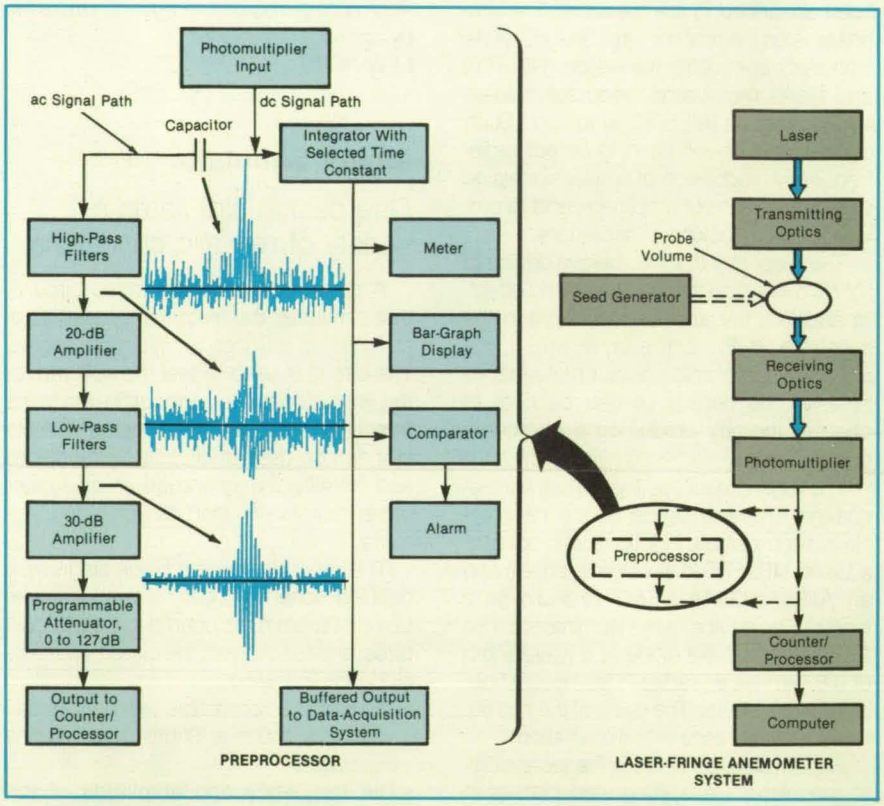
Lewis Research Center, Cleveland, Ohio

A signal-preprocessing unit that contains digital and analog circuitry is added to the existing equipment in a laser-fringe anemometer system to filter the raw anemometer signal and relieve the researcher of some tedious and difficult control functions. The preprocessor operates under the control of the same digital computer that acquires the measurement data. Both automatically and in response to control settings applied manually by the researcher, the preprocessor helps the system to establish the conditions that produce signals of the highest quality.

In a laser-fringe anemometer, the velocity of flow is measured by a photomultiplier, which detects light scattered from seed particles in the flow as they pass through the interference fringes of intersecting laser beams. Typically, the raw photomultiplier output signal is fed to a counter/processor, which measures the times of flight and times between arrivals of particles, and transmits these data to the computer. Heretofore, the researcher has had to make and record gain and filter settings manually while controlling the seed generator and other equipment; in addition to being time-consuming, the manual performance of these tasks often results in incorrect settings and, consequently, invalid data.

The new preprocessor is placed in the signal-flow path between the photomultiplier and the counter/processor (see figure). It enables the computer to control the high- and low-pass filter settings, the gain, the photomultiplier voltage, the seed generator, and the flow of data across the direct-memory-access interface between the preprocessor and the computer. Through the preprocessor, the computer can also control the "hand-shaking" signals for the interface between itself and the counter/processor.

The preprocessor first separates the dc component from the ac component of the raw photomultiplier output, filters the remaining ac component under computer control to reduce noise, then amplifies this component to a level acceptable for use by the counter/processor. Both the computer (through an analog input channel) and the researcher (through meters and alarms) can monitor the dc portion of the photomultiplier signal to ensure that it remains below the maximum allowable level.



The **Signal Preprocessor** operates under computer or manual control to filter the raw photomultiplier signal optimally.

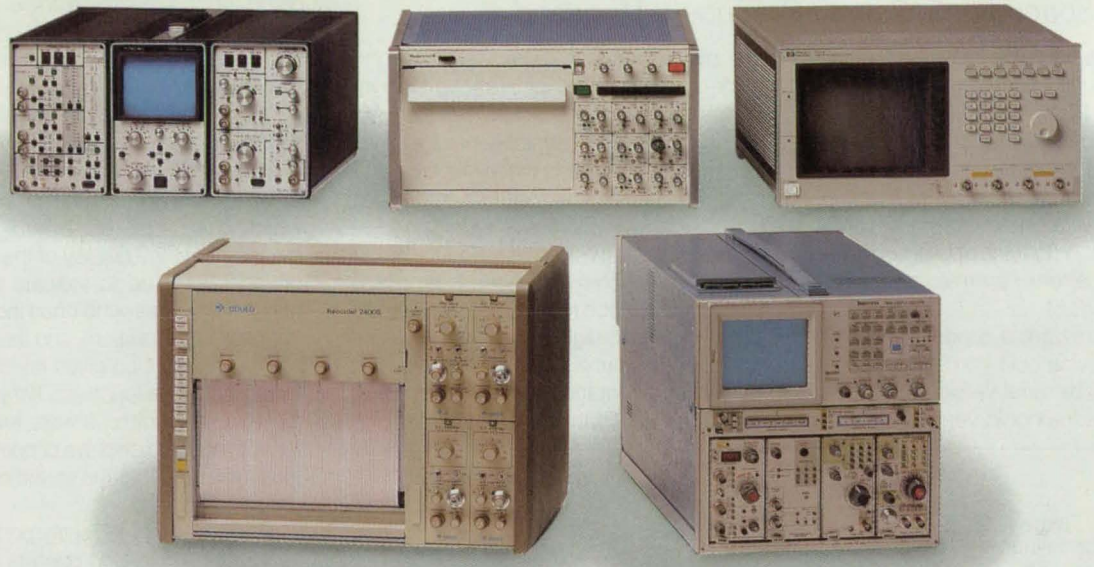
Using computer control of the various functions of the preprocessor, the researcher can monitor the effects of filters and gain on the quality of the signal. The researcher can change the settings quickly, without having to record them manually.

The design of the preprocessor allows for improvement and expansion: Algorithms could be developed to optimize the laser signal as a function of the filter settings and to determine the effects of the laser power, photomultiplier voltage, and signal gain on the resulting laser signal. The control of the laser power would require additional circuitry similar to that used to control the photomultiplier voltage.

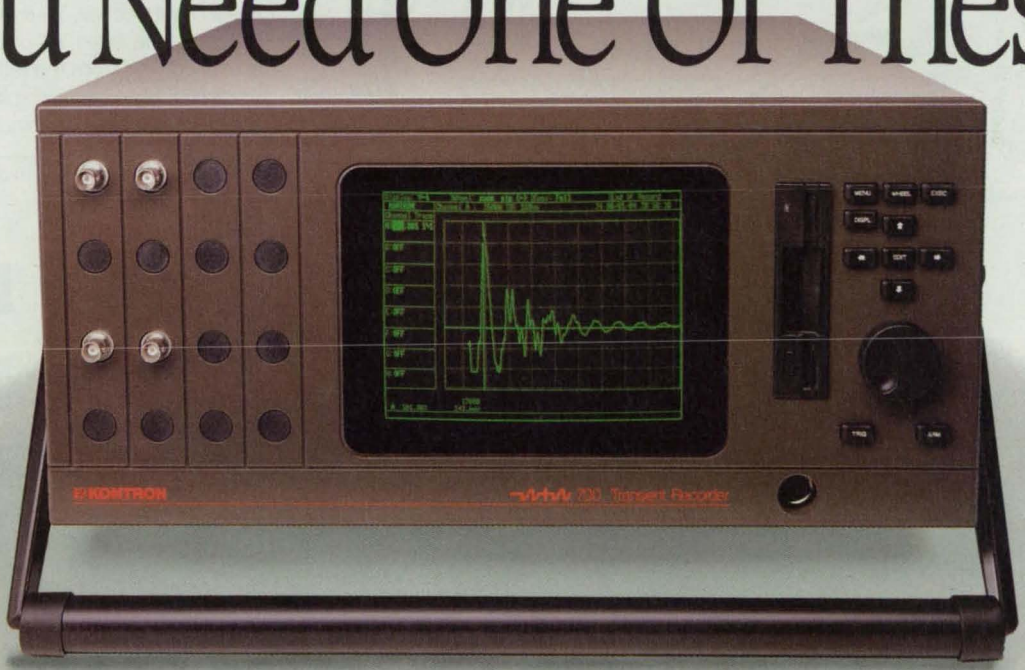
This work was done by Lawrence G. Oberle of **Lewis Research Center**. *Further information may be found in NASA TM-88982 [N87-20516], "A Computer Controlled Signal Preprocessor for Laser Fringe Anemometer Applications."*

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-14663

If You Use One Of These:



You Need One Of These:



The Kontron 700 Recorder. 1-32 Channels. 1-50 MHz. 8, 10 and 12-bit resolution. Up to 1 Mega sample memory per channel. All the muscle, depth, range and precision you need to meet the most difficult transient recording challenges.

And with an integral MS-DOS 286/386 AT® computer and 50 Mbyte hard disk, all your post-analysis (DADISP,® ASSYST,® and more) can be done right on board. Fast. And with a friendly "window" interface that makes it all seem easy.

Finally, everything you need is in one place. Even complete Ethernet and TCP/IP network support.

Independent time-bases for each channel let you record multiple events at different speeds, and see them all at once in an automatically time-correlated display.

Triggering is very flexible. And software-selectable 4-pole Bessel anti-aliasing filters let you fine-tune for the truest possible signal.

If you're using a DSO, light beam oscilloscope, storage scope, waveform or transient recorder, call today. (800) 227-8834. We need to talk about the Kontron 700. From $10,000.

KONTRON ELECTRONICS

United States KONTRON ELECTRONICS INC., 630 Clyde Avenue, Mountain View, CA 94039-7230, Telephone (415) 965-7020
Kontron Technical Centers Boston (508) 921-4700, Baltimore (301) 792-4987, San Francisco (415) 965-7020

Circle Reader Action No. 640

Directional Hearing Aid

The approximate directions of sounds are indicated visually.

Goddard Space Flight Center, Greenbelt, Maryland

A hearing-aid device indicates visually whether a sound is coming from the left, right, back, or front. The device is intended to assist individuals who are deaf in at least one ear and, therefore, unable to discern naturally the directions to sources of sound. The device can thus promote safety in street traffic, on loading docks, and in the presence of sirens, alarms, and other warning sounds.

Figure 1 illustrates a quadraphonic version of the device built into a pair of eyeglasses and a binaural version built into a visor. The quadraphonic version includes four microphones to distinguish left, right, back, and front. The binaural version includes only two microphones to distinguish left and right. Both versions include small batteries, light-emitting-diode displays, and integrated-circuit amplifiers and logic units.

In the binaural version (see Figure 2), the signal from each microphone is amplified and rectified. Each resulting dc signal is fed to an analog-to-digital converter and encoder. The output of each encoder is a 3-bit binary representation of the amplitude of sound in that channel. The encoder outputs are fed to a digital-comparator-and-logic unit to determine which channel contains the louder sound or whether the amplitudes in both channels are equal. The comparator activates a logic unit and a driver in the channel that contains the louder sound. The logic unit converts the 3-bit binary representation of amplitude to a progressive seven-interval digital representation.

The output of the logic unit controls the driver of the display unit of the channel, which is an array of seven light-emitting diodes. Thus, the display of the right or left channel lights up to indicate which contains the louder sound (thus indicating the approximate direction), and the number of diodes that light up gives an approximate indication of the loudness. If the amplitude is the same in both channels, the comparator activates the displays of both channels, thus indicating that the sound comes from ahead or behind.

The sensing and display portions of the quadraphonic version operate similarly to the corresponding parts of the binaural version. The major difference is that the quadraphonic version has four displays and includes additional comparator and logic circuitry to distinguish between the front and back channels as well as between right and left. Thus, for example, the lighting of the lower left display indicates a sound coming from the left rear, while the lighting of both lower displays indicates a sound coming from behind.

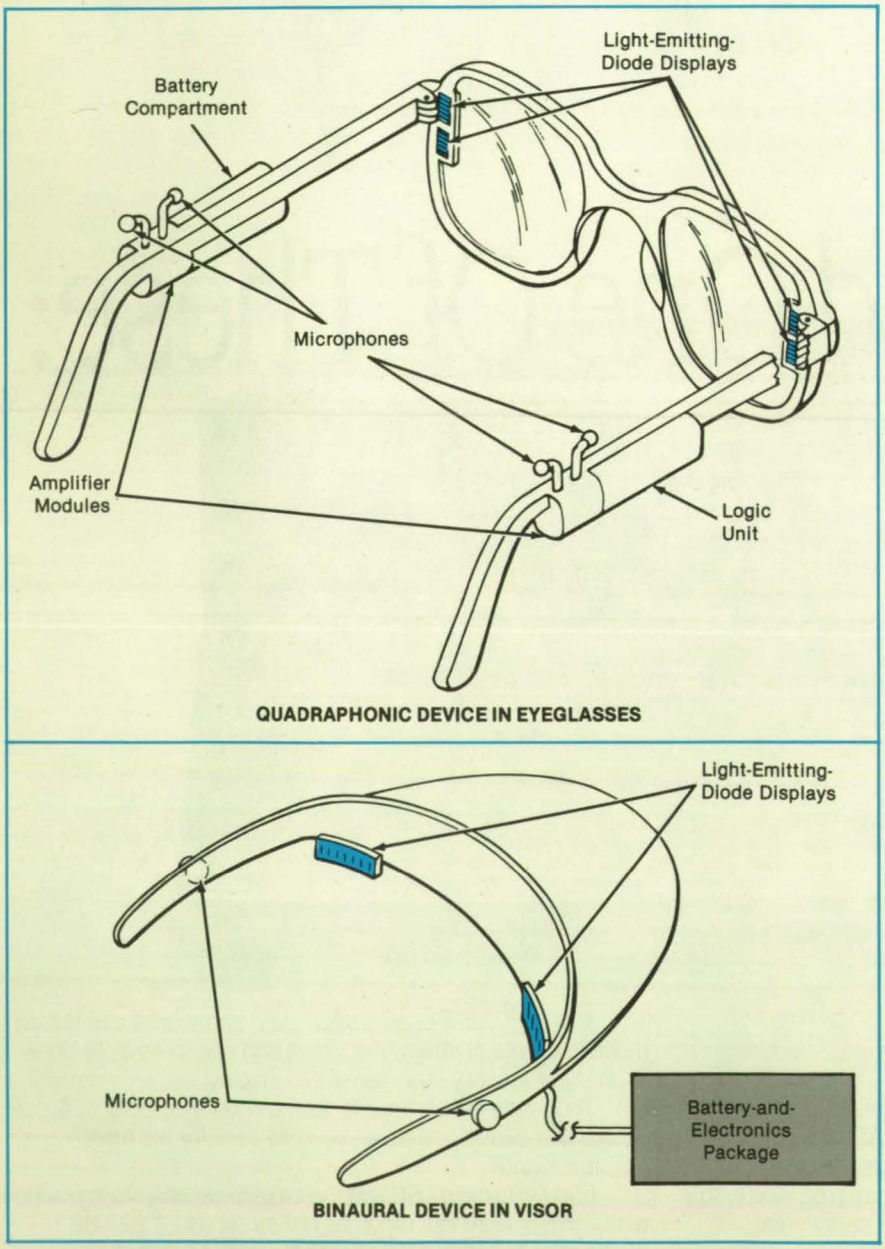


Figure 1. **Visual Displays, Microphones, and Signal-Processing Circuits** can be built into eyeglasses, visors, caps, or other common headgear to indicate the directions of sounds, thanks to the miniaturization of modern integrated-circuit technology.

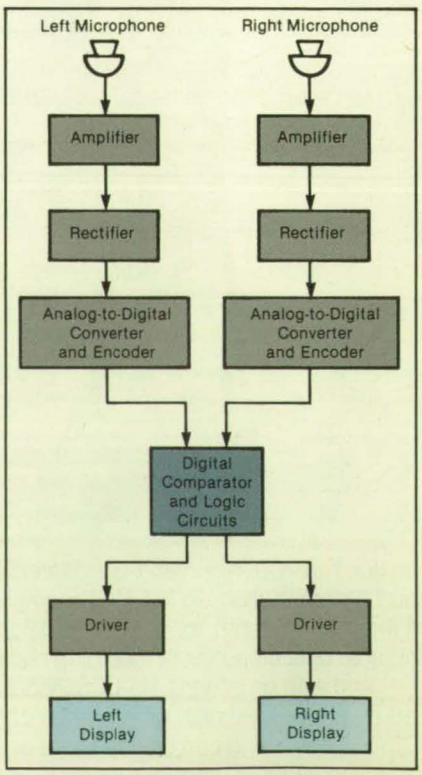
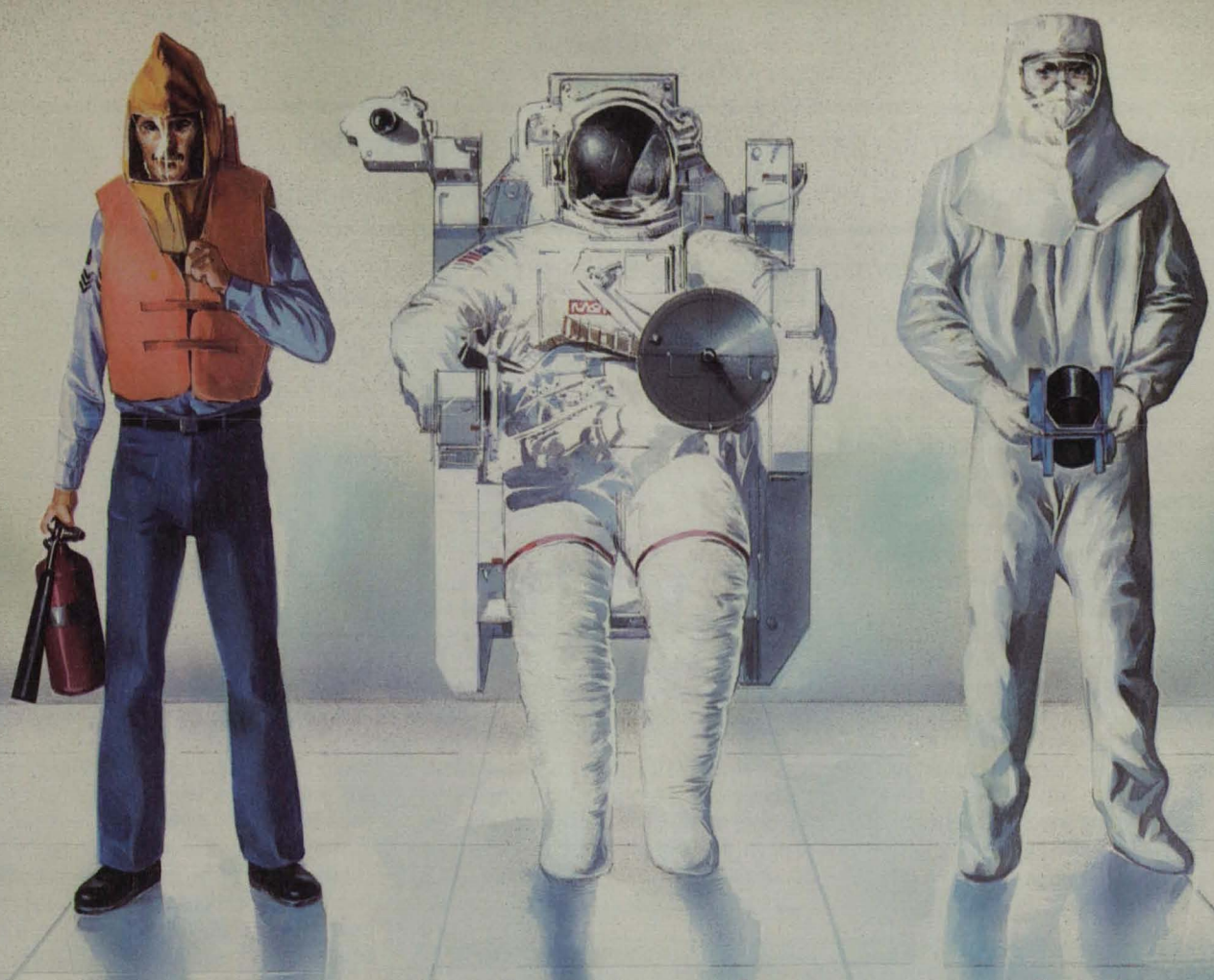


Figure 2. **Sound in Right and Left Channels** is processed, compared, and displayed to indicate the approximate direction of the source of the sound.



Their success and safety depends on your packaging and ACLAR® Fluoropolymer Film

Every packager of moisture-sensitive electronics, military, communications, and aerospace components knows ACLAR fluoropolymer film from Allied-Signal as the ultimate flexible, transparent, moisture barrier.

But beyond ACLAR's barrier properties are other characteristics vital to the safe and successful fulfillment of difficult missions.

- **Flame Retardency.** ACLAR receives excellent ratings in flame spread and vertical burn tests conducted by UL, NASA, and FAA test procedures, by not supporting combustion.
- **Low Outgassing.** ACLAR meets deep space requirements of non-contamination of critical components due to outgassing.
- **LOX Compatibility.** ACLAR meets all NASA requirements for liquid oxygen (LOX) compatibility as well as for other hypergols.
- **Chemically Inert.** ACLAR will not react with most chemicals.
- **Toughness.** ACLAR has sufficient strength and durability as an unsupported film for many packaging applications.
- **Processed Enhancements.** In addition to ACLAR's inherent properties, other performance benefits derive from advanced processing—

Static Dissipative. Treated ACLAR satisfies NASA requirements for electrostatic discharge.

Ultra-Clean. When ultra-cleanliness is required, ACLAR can be processed to meet your most stringent specifications.

Laminations. ACLAR can be laminated to other materials to meet all requirements of MIL Spec 22191 Type 1 for transparent high moisture barrier military packaging.

For more information and technical data about ACLAR fluoropolymer film, contact your Allied-Signal Performance Film Specialist today.

Allied-Signal Engineered Plastics, PO Box 2332R, Morristown, New Jersey 07960, (201) 455-5010

Engineered Plastics

Allied Signal

Circle Reader Action No. 606

This work was done by M. Jhabvala of **Goddard Space Flight Center** *and H. C. Lin of the University of Maryland. For further information, Circle 97 on the TSP Request Card.*

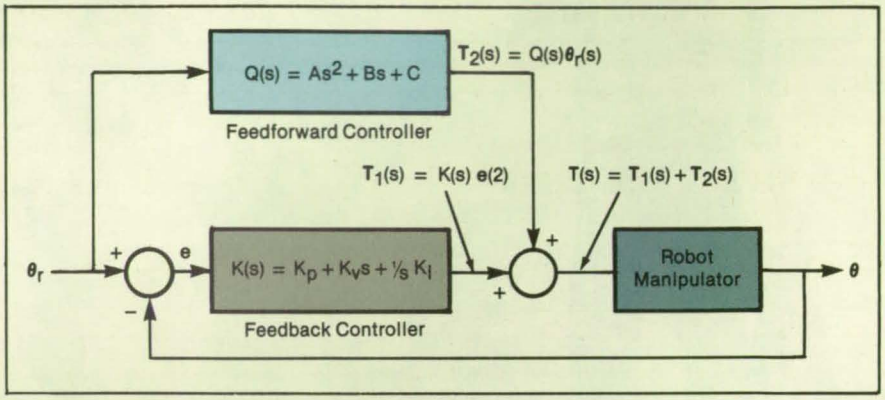
This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Goddard Space Flight Center [see page 14]. Refer to GSC-13027.

Simplified Linear Multivariable Control of Robots

Trajectories of robot joints would converge quickly to reference trajectories.

NASA's Jet Propulsion Laboratory, Pasadena, California

A simplified method has been developed to design a control system that would make the joints of a robot follow reference trajectories. The generic design includes independent multivariable feedforward and feedback controllers (see figure). The feedforward controller is based on the inverse of the linearized model of the dynamics of the robot and implements a control law that contains only proportional and first and second derivatives of the reference trajectories with respect to time. The feedback controller, which implements a control law of proportional, first-derivative, and integral terms, makes tracking errors converge toward zero as time passes.



The **Control System** implements feedforward and feedback control laws that stably drive the actual robot-joint trajectories $\boldsymbol{\theta}$ toward reference trajectories $\boldsymbol{\theta}_r$.

The control theory is based on a robot of n rotary joints, the incremental angular positions of which are described by an $n \times 1$ vector $\boldsymbol{\theta}$. The linearized behavior of the robot is expressed by

$$A\ddot{\boldsymbol{\theta}} + B\dot{\boldsymbol{\theta}} + C\boldsymbol{\theta} = \boldsymbol{T}$$

where A, B, and C are the $n \times n$ matrices of the coupled dynamics of the n degrees of freedom and $\boldsymbol{T}$ is the $n \times 1$ vector that represents the incremental control torques applied to the joints. The problem is to make the actual trajectories of the joints, $\boldsymbol{\theta}(t)$, follow or converge toward the reference trajectories $\boldsymbol{\theta}_r(t)$ (where t = time).

The $n \times n$ feedforward controller $Q(s)$ is chosen to be based on the minimal-order inverse of the robot model; that is, to process the input signals $\theta_r(s)$ according to the control law

$$Q(s) = As^2 + Bs + C$$

where s is the Laplace-transform complex frequency. This choice enables the robot to track any reference trajectory. The contribution of this controller to the overall control law is $\boldsymbol{T}_2(s) = Q(s)\boldsymbol{\theta}_r(s)$.

The $n \times n$ feedback controller $K(s)$ is intended to produce a stable closed-loop system with desired pole positions in the s plane; that is, with desired frequencies of oscillation and damping of the tracking errors $\boldsymbol{e} = \boldsymbol{\theta}_r - \boldsymbol{\theta}$. The feedback transfer function is chosen to be

$$K(s) = K_p + K_v s + K_I/s$$

where K_p, K_v, and K_I represent the $n \times n$ proportional, derivative, and integral feedback gains, respectively. This controller contributes $\boldsymbol{T}_1(s) = K(s)\boldsymbol{e}(s)$ to the overall control law.

It is possible to choose the feedback gains so that the system exhibits the desired transient response of tracking errors and so that the tracking error in each joint angle can be controlled independently. This is done by working "backward": The designer first specifies the desired damping factor ξ_k and undamped natural frequency ω_k for each angle θ_k and uses these values to determine the elements of the $n \times n$ diagonal matrices Λ_i that would yield the decoupled error dynamics ac-

cording to $\dddot{e}+\Lambda_1\ddot{e}+\Lambda_2\dot{e}+\Lambda_3 e = 0$. The required gains are then found from the following simple equations:

$$K_v = A\Lambda_1 - B$$
$$K_p = A\Lambda_2 - C$$
$$K_I = A\Lambda_3$$

This work was done by Homayoun Seraji of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 89 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

Edward Ansell
Director of Patents and Licensing
Mail Stop 301-6
California Institute of Technology
1207 East California Boulevard
Pasadena, CA 91125

Refer to NPO-16857, volume and number of this NASA Tech Briefs *issue, and the page number.*

Keyboard Emulation for Computerized Instrumentation

Experimental parameters can be retrieved or re-entered at will.

Lewis Research Center, Cleveland, Ohio

Most new scientific instruments contain microprocessor controllers. While such instruments are exceptionally versatile and simple to operate as stand-alone devices, they are often difficult to modify for incorporation into hierarchical systems with general-purpose laboratory minicomputers or microcomputers. If a communication port is included in the instrument, it often does not provide the same degree of flexibility as that of manual operation.

There are many options for making interfaces with such instruments, depending on the intelligence level at which communication takes place. A keyboard emulator has an interface at the same level as that of manual keyboard entry. Since communication and control take place at the high intelligence level in the instrument, all the instrument circuitry is fully utilized. Little knowledge of the instrument circuitry is necessary, since the only task the interface performs is key closure. All existing logic and error checking is still performed by the instrument, minimizing the workload of the laboratory microcomputer. Timing constraints for interface operation are minimal at the keyboard entry level.

A keyboard emulator interface increases the capabilities of the instrument in three ways. First, the system now has the ability to store permanently a large number of experimental parameters, which can be retrieved and re-entered at will. Second, the clock in the instrument can be synchronized with the clock in the laboratory computer, so that the entire experiment occurs during the same reference time frame. Finally, communication feedback loops can be established, and experimental parameters can be automatically adjusted in response to the measurements.

Designing a keyboard emulator interface for an instrument with discrete switches could be very difficult. However, the advent of transistor/transistor logic (TTL)-based microprocessor-controlled instrumentation has spawned keypad arrays as convenient, efficient means of entering parameters. These arrays can encode a large number of keys using only eight bits of code. It is fairly simple to build a keypad emulator to simulate a keystroke in one of

these arrays. The keyboard emulator interface allows the pulse to travel an alternate pathway that mimics the keystroke. An 8-bit parallel input/output port is sufficient for operation.

Using this approach, a microprocessor-based high-performance liquid chromatography (HPLC) solvent-delivery system was connected to a laboratory microcomputer. The computer synchronized and sequenced the entire HPLC experiment, including solvent delivery, valve control for column switching and backflushing, data acquisition, and data processing.

This work was done by P. M. Wiegand and S. R. Crouch of Michigan State University for **Lewis Research Center**. *For further information, Circle 121 on the TSP Request Card.*
LEW-14180

Fast Asynchronous Data Communication Via Fiber Optics

A transmitter and receiver convert between serial and parallel transmission and recover clock signals.

NASA's Jet Propulsion Laboratory, Pasadena, California

A transmitter and receiver (see Figure 1) have been devised for asynchronous digital communication via optical fiber at rates above 100 Mb/s. The transmitter converts parallel data to serial for high-speed transmission; the receiver recovers the clock signal and converts the data back to parallel. No phase-lock loops are used.

In a conventional asynchronous receiver of this type, the clock phase of the incoming signal is determined by oversampling that is, taking 8 to 16 samples of the first arriving bit. Because the required high sampling rate is difficult to achieve at 100 Mb/s, the new receiver design avoids oversampling altogether. Instead, a local sampling oscillator operating nominally at the clock frequency generates N clock signals of equally spaced phase, which are used to clock the incoming data into N separate shift registers.

The number N of registers or phases required is given by $N \geq 2t_b/t_s$, where t_b is the bit period, and t_s is the sampling interval. If N satisfies this criterion, then at least one of the receiver clock phases is valid, and the corresponding shift register holds the correctly synchronized data.

The serial data are framed (see Figure 2) to identify the beginnings and ends of data fields and to enable the receiver logic to clear itself after each message, generate interface-control and acknowledgement ("handshaking") signals, and mitigate the propagation of bit errors between frames.

In the transmitter, data are loaded into a shift register in parallel when a "data-ready" signal appears. When the "data-ready" signal disappears, the shift register begins to shift the data out serially in synchronism with the high-speed clock, interspersed with the framing bits. In the absence of new data, zeros are shifted out.

The timing is critical in the parallel loading of data into the transmitter shift registers: the loading pulse must be stable during the positive-going edge of the clock pulse. The required stabilization can be achieved with a pulse synchronizer. The timing is also critical in the receiver phase detector: it is necessary to center the 180° sampling interval in the 360° bit interval. This can be done by using gate delays in the path of the clock signal to the phase detector. At high speeds, where the setup and holding times of the logic constitute a large portion of the bit period, the delay can be sensitive to the serial bit rate.

A "breadboard" version was constructed of emitter-coupled-logic integrated-circuit chips, a commercial infrared fiber-optic link, and two shift registers of 22 bits (11 of which are data bits) each. With a serial bit rate of 176 Mb/s and a byte rate of 8 Mb/s, the bit error rate of each of the 11 channels was less than 2.3×10^{-11}.

This work was done by Larry A. Bergman of Caltech and Robert G. Tell of Chalmers University for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 134 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
Edward Ansell
Director of Patents and Licensing

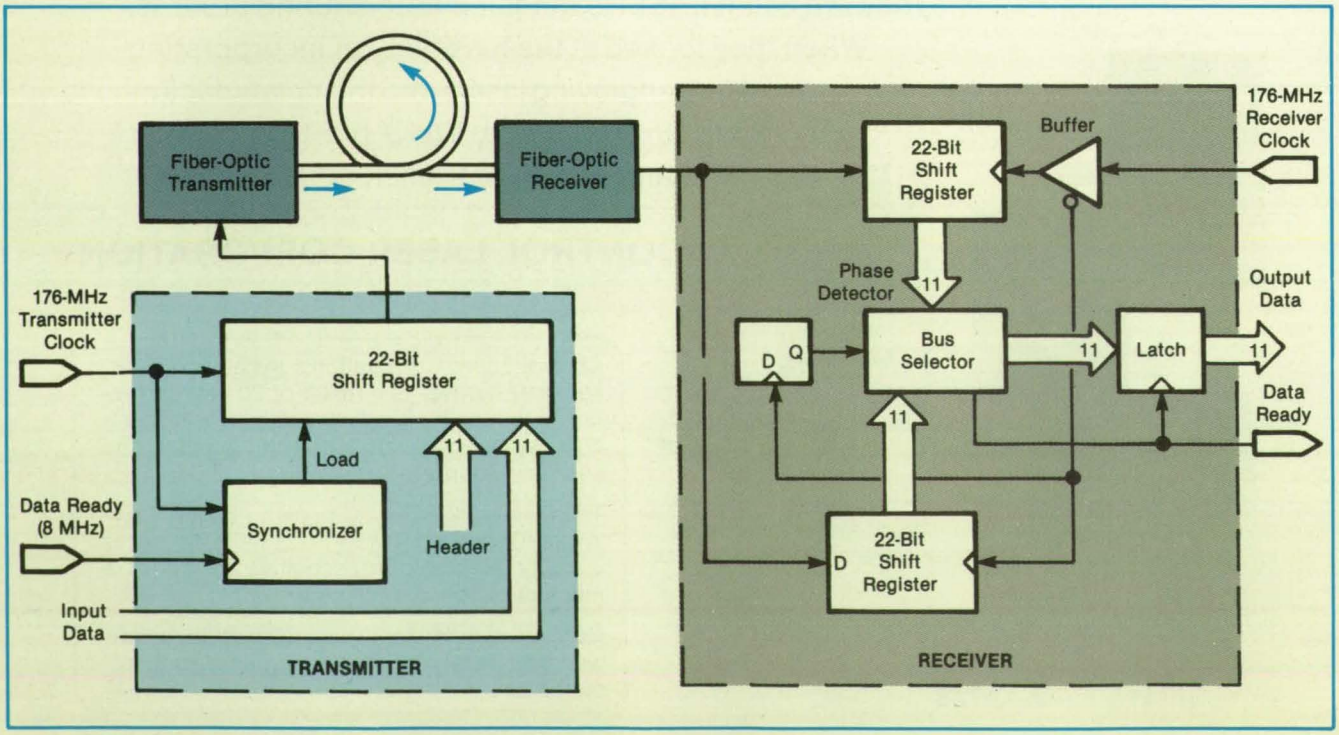
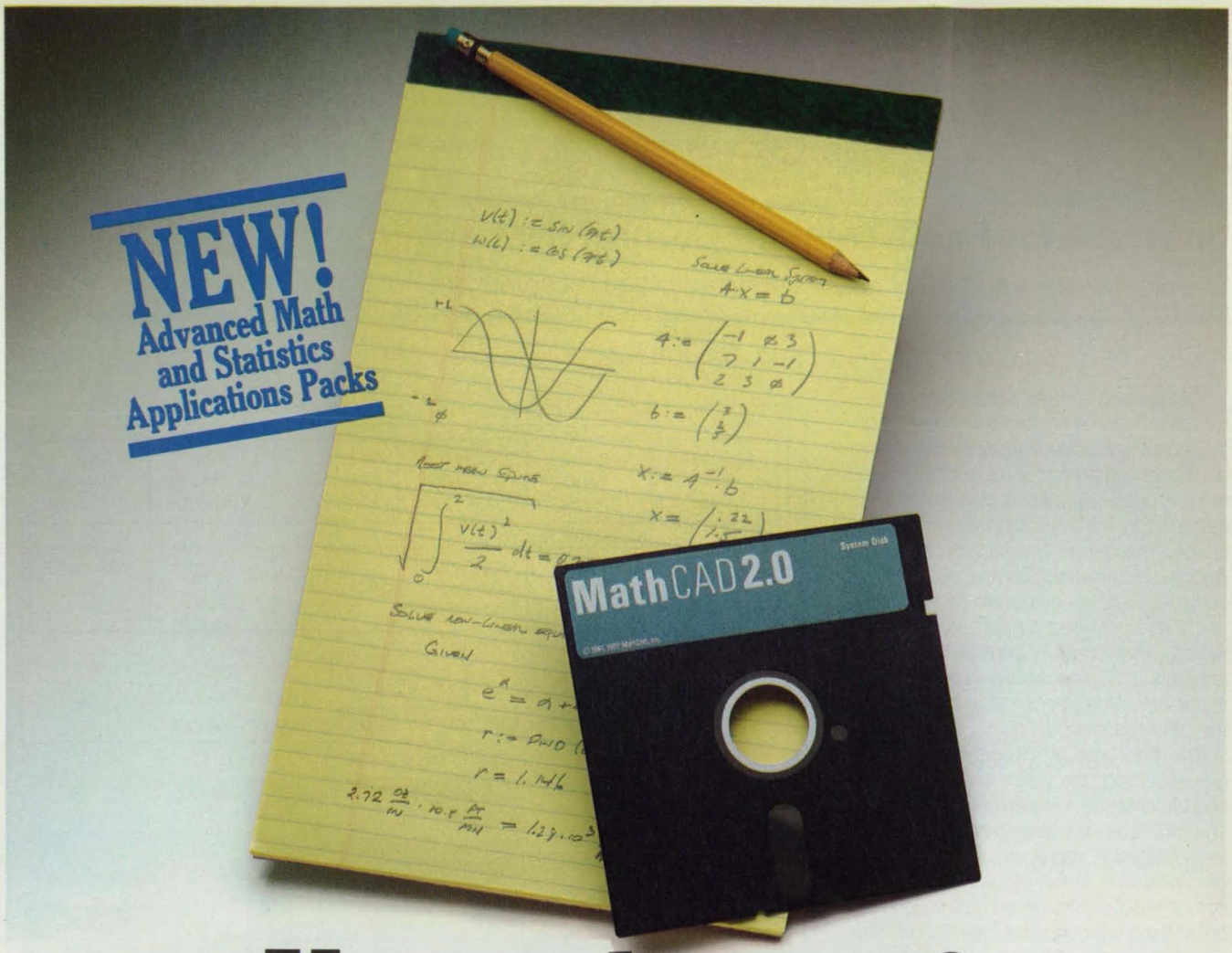


Figure 1. This **Digital Communication System** can be used to provide serial, asynchronous transmission of data over fiber optics between two computers with parallel interfaces and independent clocks.

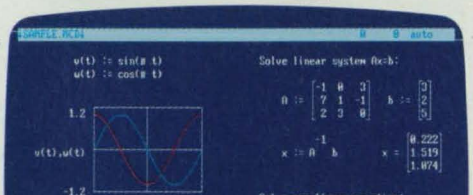


Your pad or ours?

If you perform calculations, the answer is obvious.

MathCAD 2.0.

It's everything you appreciate about working on a scratchpad – simple, free-form math – and more. More speed. More accuracy. More flexibility.



Just define your variables and enter your formulas anywhere on the screen. MathCAD formats your equations as they're typed. Instantly calculates the results. And displays them exactly as you're used to seeing them – in real math notation, as numbers, tables or graphs.

MathCAD is more than an equation solver. Like a scratchpad, it allows you to add text anywhere to support your work, and see and record every step. You can try an unlimited number of what-ifs. And print your entire calculation as an integrated document that anyone can understand.

Plus, MathCAD is loaded with powerful built-in features. In addition to the usual trigonometric and exponential functions, it includes built-in statistical functions, cubic splines, Fourier transforms, and more. It also handles complex numbers and unit conversions in a completely transparent way.

Yet, MathCAD is so easy to learn, you'll be using its full power an hour after you begin.

What more could you ask for? How about two new applications packs to increase your productivity?

The **Advanced Math Applications Pack** includes 16 applications like eigenvalues and eigenvectors of a symmetric matrix, solutions of differential equations, and polynomial least-squares fit.

The **Statistics Applications Pack** lets you perform 20 standard statistical routines such as multiple linear regression, combinations and permutations, finding the median, simulating a queue, frequency distributions, and much more.

MathCAD lets you perform calculations in a way that's faster, more natural, and less error-prone than the way you're doing them now – whether you use a calculator, a spreadsheet, or programs you write yourself. So come on over to MathCAD and join 45,000 enthusiastic users.

For more information, contact your dealer or call **1-800-MATHCAD** (In MA: 617-577-1017).

Requires IBM PC® or compatible, 512KB RAM, graphics card.

IBM PC® International Business Machines Corporation.
MathCAD® MathSoft, Inc.

MathCAD®

MathSoft, Inc., One Kendall Sq., Cambridge, MA 02139

Circle Reader Action No. 628

Mail Stop 301-6
California Institute of Technology
1201 East California Boulevard
Pasadena, CA 91125
Refer to NPO-16972, volume and number of this NASA Tech Briefs *issue, and the page number.*

Start		Data		Data		Data	End
1 1 1 1 1	0	d_1 d_2 d_3 d_4	0	d_5 d_6 d_7 d_8	0	d_9 d_{10} d_{11}	0 0 0

Figure 2. A **Frame of Data** includes a starting sequence of ones, and zeros to mark the edges of the data fields. Bit stuffing zeros at every fifth bit position in the data held makes the start bit sequence unique.

Interface for Fault-Tolerant Control System

Developmental equipment is used in research on reliable flight-control systems.

Ames Research Center, Moffett Field, California

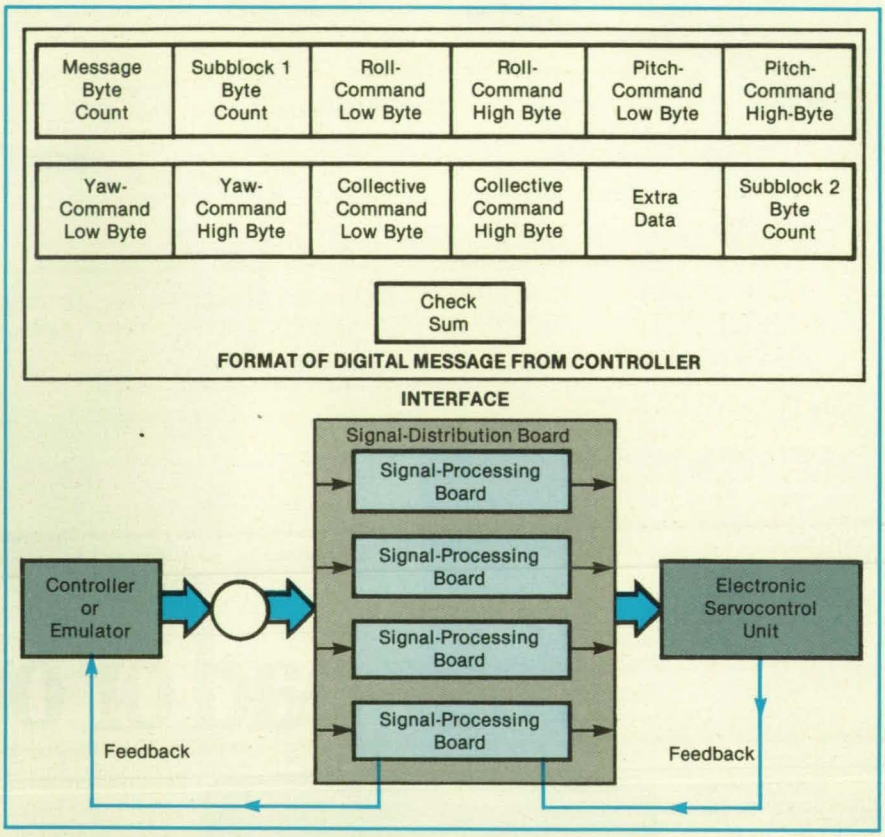
An interface unit and a controller emulator have been developed for research on electronic helicopter-flight-control systems equipped with artificial intelligence. The interface unit is an interrupt-driven system designed to link a microprocessor-based, quadruply-redundant, asynchronous, ultrareliable, fault-tolerant control system (the controller) with an electronic servocontrol unit that controls a set of hydraulic actuators. Because the controller was not available, it was necessary to build a controller emulator to provide signals to test the interface unit.

The interface unit receives a digital message from the controller or emulator and transmits data to the servocontrol unit. The interface unit also transmits a feedback message, representing the most recent positions of the actuators, from the servocontrol unit to the controller upon request from the controller (see figure). The digital messages received and transmitted by the interface unit contain a minimum of 12 bytes and a maximum of 76 bytes. The main feature of each message is the 8 bytes that describe the command for the four control axes of a helicopter.

The interface unit contains five boards. The signal-distribution board receives the digital messages from the controller and distributes them to the four signal-processing boards. The signal-distribution board includes four receivers to receive messages from the controller, one receiver to receive a request for data from the controller, one transmitter to transmit a pulse to the controller at the beginning of a feedback transmission, and one transmitter to transmit feedback messages.

The four signal-processing boards all contain the circuitry to receive data from the controller. One of these boards contains the extra circuitry needed for the feedback. The principal components used on each signal-processing board during the reception of a message from the controller are an 8751 microcontroller, a 6402A universal asynchronous receiver/transmitter, a programmable peripheral interface, and digital-to-analog converters.

The emulator is also based on the 8751 microcontroller. The emulator is used primarily to generate a digital message for the interface to receive and process. The variable update rates of the emulator make it possible to study the effect of the update rate on quantization. Attempts to smooth the quantization can be made in the interface during the time between updates because no interruptions are occurring.



The **Interface Unit** can receive digital feedforward messages from, and transmit digital feedback messages to, the controller through differential signal lines or fiber-optic cables (thus far only differential signal lines have been used). Analog signals are transmitted to and from the servocontrol unit via coaxial cables.

The 8-bit architecture of the 8751 makes the smoothing algorithms cumbersome because the data for the control axes from the controller are transmitted at 16 bits/s. Because all mathematics and shifting routines are not supported by the instruction set of the 8-bit 8751, separate routines must be written to accomplish any calculations that must be performed to smooth the output of the interface unit. The development of 16-bit microcontrollers will greatly simplify the algorithms necessary to reduce the effects of quantization.

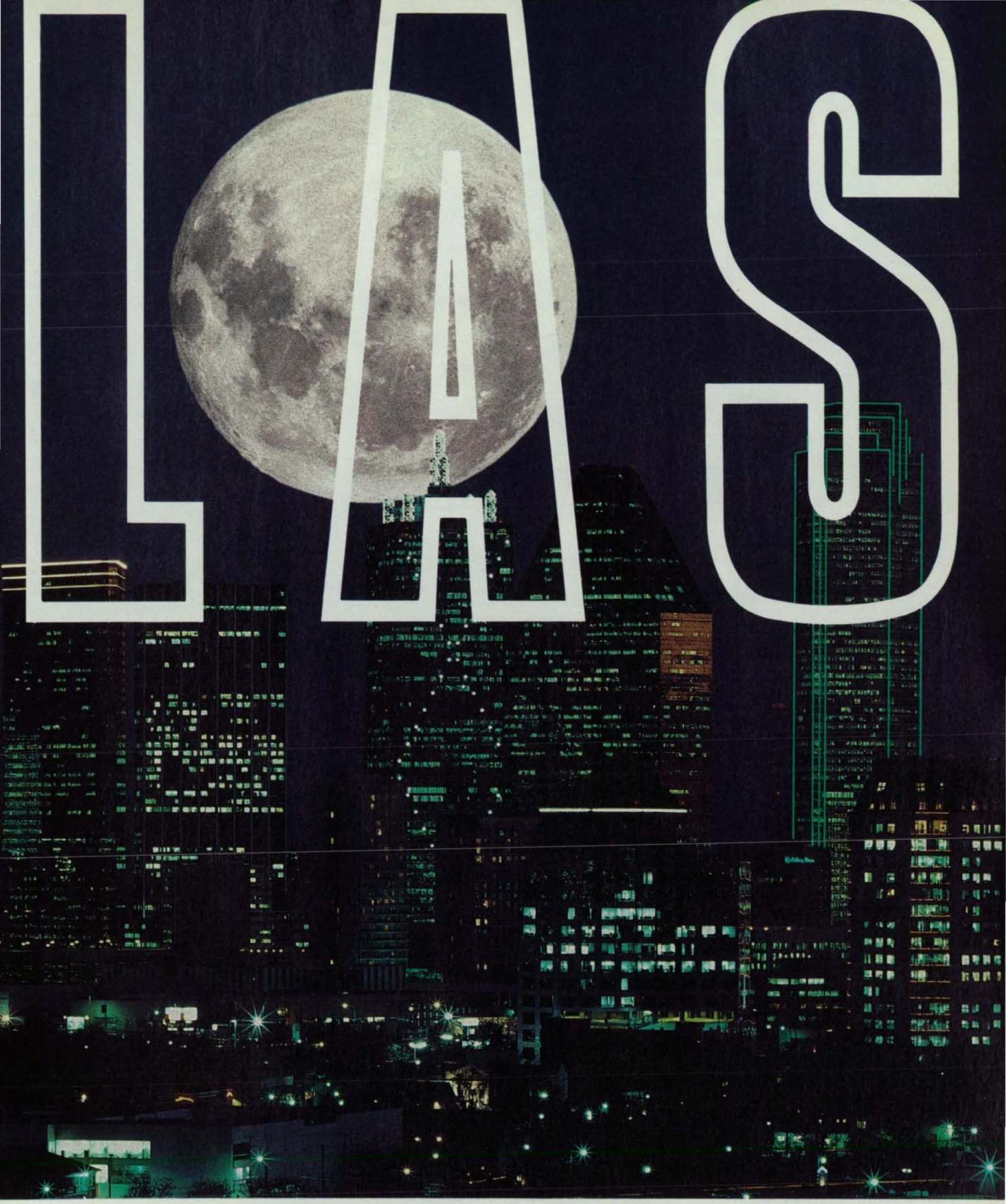
This work was done by Charles Shaver and Michael Williamson of **Ames Research Center**. *Further information may be found in NASA TM-88236 [N88-13367/NSP], "Development of an Interface for an Ultrareliable Fault-Tolerant Control System and an Electronic Servo-Control Unit."*

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.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center [see page 14]. Refer to ARC-11791.


Spanning Th
Technology
Spectrum
TEXAS:


DAL



PRAIRIE MOON

It's a place where ambition and sophistication mingle beautifully. And where dreams really do come true. No, it's not Oz. It's Dallas. And the business horizons keep getting brighter all the time. For information on business opportunities in Dallas, contact the Dallas Partnership, telephone 1-214-746-6730. For information on planning your next event here, call 1-800-232-5529. Dallas Convention & Visitors Bureau

Circle Reader Action No. 534

Texas has the third largest pool of scientists and engineers in the nation.

(Photo courtesy Texas Instruments)

Special Report:

Texas' High Tech Evolution

The Lone Star State is making major strides in such fields as aerospace, biotechnology, climatology, energy, and materials science.

Mirabeau Buonaparte Lamar, second president of the infant Republic of Texas, was something of a dreamer. He envisioned a nation that would outgrow its snug little boundaries along the Gulf coast and become an empire, challenging the United States in the westward race to the Pacific Ocean.

In his first message to the Texas Congress, in late 1838, Lamar acknowledged that empires are not built on sweat and blood alone; they are carefully forged upon the anvil of knowledge.

"The cultivated mind is the guardian genius of democracy, and while guided and controlled by virtue, the noblest attribute of man," he said. "It is the only dictator that freemen acknowledge, and the only security which freemen desire."

Lamar proposed a bold scheme to provide public education for all Texas children and higher education for those who desired it: set aside public land in each county to finance schools and pay teachers. Congress agreed, and the new republic dedicated four million acres of land—far more than any state in the U.S.— to endow a national educational system.

Lamar's empire never saw light; Texas joined the Union in 1845. But his vision of a strong intellectual foundation upon which Texans would build a prosperous future did not die.

Land set aside to finance two institutions of higher education has generated the largest public university endowment in the United States. In turn, the schools nourished by the Permanent University Fund—the University of Texas and Texas A&M University—are the roots that anchor an ever-growing statewide network of science- and technology-related businesses and research centers.

Public and private universities, government laboratories, non-profit R&D facilities, and businesses large and small have made Texas a leader in the conception, development, and dissemination of leading-edge technologies. Cooperation among the diverse sectors of the science

For nearly three decades, companies have drawn on Houston Instrument.

Now it's your turn.

Select a Houston Instrument™ plotter, and you're not only opting for the best price/performance on the market—you're choosing an industry leader with a proven track record. For nearly 30 years, companies have relied on HI for quality products, reliable service, *and* attractive prices.

Take HI's sleek new DMP–60 Series plotters—they're designed to impress even the most demanding CAD professional. Industry experts agree:

"Houston Instrument's DMP–61 delivers a remarkable combination of high speed, gorgeous plots, and very competitive price."

PC MAGAZINE *Editor's Choice Dec. 22, 1987*

HI's commitment to solid, innovative products is underlined by designed–in versatility. The SCAN–CAD™ option lets a DMP–60 Series plotter double as a scanner. The Multi–Pen accessory speeds colorful, complex drawings. And HI's one megabyte buffer board lets the DMP–60 Series plot several originals—without tying up your computer.

Proven performance, proven value—that's HI plotters. Flexible. Fast. Accurate. Software compatible. Reliable. And backed by HI's PRIORITY RESPONSE™ customer support programs which include overnight product–replacement service, leasing, and warranty coverage.

All this from an industry leader that companies have drawn on for nearly three decades—Houston Instrument.

Now it's your turn. Begin by calling 1-800-444-3425 or 512-835-0900 or writing Houston Instrument, 8500 Cameron Road, Austin, Texas 78753.

HOUSTON INSTRUMENT
A DIVISION OF AMETEK

Houston Instrument, PRIORITY RESPONSE, and SCAN–CAD are trademarks of AMETEK, Inc.

Circle Reader Action No. 550

and technology industry is creating new programs with even greater potential for the future.

In computer technology and microelectronics, for example, state universities and government agencies joined forces to help attract two key research consortia to Texas: the Microelectronics and Computer Technology Corp. (MCC) and Sematech. The consortia are returning the favor by feeding technology growth in the state through joint research with universities, scholarship programs, and by building an intellectual nucleus to attract additional technology-related ventures.

The strength of Texas' technology base and the state's desire to nurture advanced research were key reasons the Department of Energy selected a site in north-central Texas as the home for the Superconducting Super Collider (SSC), the most expensive high-energy physics project in American history.

Expected to be 20 times more powerful than the largest particle accelerator in use today, the SSC will help physicists to better understand the structure of subatomic particles and the forces that bind them together. State officials say the facility will thrust Texas into a scientific leadership role well into the 21st century—and employ 3,000 scientists and support staff members to boot.

Although Texas is best known for its contributions to aerospace and computer technology, it is making significant headway in many other areas, including biotechnology, climatology, energy, advanced manufacturing, marine science, and materials science. Together, these fields represent a valuable national resource and serve as a fitting legacy for Mirabeau Lamar and the founders of the Texas Republic.

NASA's Johnson Space Center (JSC), as photographed from a low-flying aircraft. Clear Lake is in the upper right portion of the photo. JSC's main entrance, through which 1.2 million visitors pass annually, is near the lower left corner.

Flight controllers at the Johnson Center witness the landing of the Space Shuttle Discovery last October.

Aerospace

- **NASA's Johnson Space Center and its contractors employ more than 13,000 workers in the Houston area.**
- **Texas is home to two university-operated Centers for the Commercial Development of Space.**

The aerospace industry has strong historical ties to Texas. Workers at what is now General Dynamics in Fort Worth have assembled everything from the giant B-36 Peacemaker to the F-16. Since the early 1960s, LTV in Dallas has built the reliable Scout launch vehicle. And today, Bell Helicopter Textron in Fort Worth is one of the developers of the V-22 Osprey tilt-rotor aircraft.

Perhaps the most important Texas aerospace development came in September 1963, when NASA dedicated the Manned Spacecraft Center at the edge of Clear Lake, south of Houston. Now called the Lyndon B. Johnson Space Center (JSC), the facility has served as the hub of American manned space flights since the Gemini program. Today, Johnson manages the Space Transportation System and is a primary site for Space Station design and development.

JSC also is the center of aerospace-related R&D in Texas. NASA contractors and independent commercial space enterprises line NASA Road 1 adjacent to the center, while university researchers work closely with JSC on several advanced research topics through the Centers for the Commercial Development of Space (CCDS), NASA research grants, and other cooperative programs.

One of the nearby businesses is Space Industries Inc., co-founded by long-time NASA engineer Maxime Faget, designer of the Mercury spacecraft. Space Industries has designed the Industrial Space Facility, a free-flying laboratory for experiments in materials science and other fields that require the microgravity environment of space. The 35-foot-long craft can be pressurized for visits by shuttle astronauts, but most of the time it will operate autonomously.

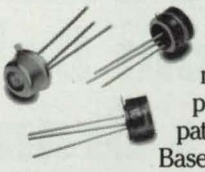
Partial fabrication of Space Station Freedom will take place at a new Grumman Aerospace facility in Houston that will employ up to 2,000 workers. Grumman is contractor for the station's crew quarters and for the orbital maneuvering vehicle, which will ferry free-flying scientific platforms to and from the station.

Advanced power systems for

General Dynamics' F-16 jet fighter (Photo courtesy General Dynamics)

The big difference between our LEDs and everyone else's.

The patented Honeywell "Caprock."



That's right. Honeywell is the only one with the special "Caprock" manufacturing process for high power LEDs that is so unique we patented it.

Based on a formation in nature, our "Caprock" LEDs emphasize high power, speed and bandwidth thus providing the best 850 nanometer "Caprock" LED in the industry. And of course, all our "Caprock" LEDs match with standard Honeywell silicon fiber optic receivers giving an excellent fiber optic link pair. Plus, our "Caprock" LEDs are available in many standard fiber optic connectors (ST® and SMA styles, Fiber-DIP and Low Profile). So remember for the best 850 nanometer components get the Honeywell "Caprock" LED and fiber optic silicon receivers. And see for yourself the big difference in your next design.

Honeywell Optoelectronics is one of the world's leading designers and manufacturers of fiber optic data communication components. *And the one choice for all your 850 nanometer fiber optic needs.* For additional information and data sheets contact Honeywell Optoelectronics, 830 E. Arapaho Road, Richardson, Texas 75081. Or call **1-800-367-6786.** In Texas call 214-470-4271.

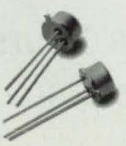
Honeywell

HELPING YOU CONTROL YOUR WORLD

SMA Low Profile Style
Transmitters
Receivers
LEDs
Photo Diodes

Fiber-DIP
Transmitters
Receivers
LEDs
Photo Diodes

Base Components
Transmitters
Receivers
LEDs
Photo Diodes



ST Low Profile Style
Transmitters
Receivers
LEDs
Photo Diodes

Fiber-DIP
Transmitters
Receivers
LEDs
Photo Diodes

ST is a registered trademark of AT&T.

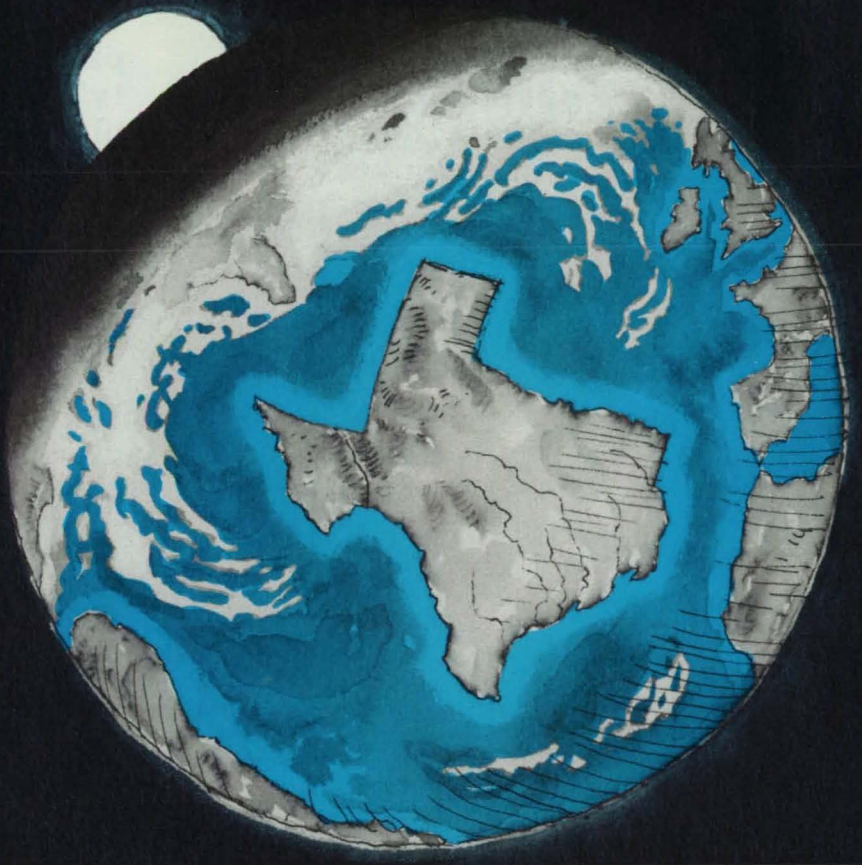
Circle Reader Action No. 486

A bird's-eye view of the Johnson Space Center's Shuttle Mockup and Integration Laboratory, which is used by astronauts in training and by planners of in-space activity

Space Station and other vehicles are being developed at Texas A&M University's Center for Space Power, a NASA CCDS formed in 1987. Center researchers work with both NASA and industry to examine materials, components, systems, and services essential to the efficient, cost-effective generation of space power. One long-range project is looking at ways to use lasers or microwaves to beam power from ground stations to orbiting spacecraft, which would drastically reduce vehicle weight requirements and launch costs while simplifying the design process.

Not all Texas space projects are related to space flight. At the University of Texas McDonald Observatory, astronomers are expanding our basic understanding of the universe. In conjunction with Pennsylvania State University, McDonald researchers have designed a unique telescope that will greatly advance the study of the stars: the Spectroscopic Survey Telescope (SST), an instrument with the light-gathering power of a 320-inch telescope at a fraction of the cost. The SST, to be built adjacent to existing McDonald telescopes in the Davis Mountains of West Texas, will consist of 85 small circular mirrors mounted atop an adjustable steel truss. The total mirror assembly will be more than 33 feet in diameter.

We're in 27 countries around the world



(Including, of course, Texas.)

d we're mighty proud to be here.
In Austin, our people are
signing and building advanced
ckplane systems—at AMP
ckaging Systems, Inc.

Also, in Round Rock, we're
oducing infrared touch input
tems for monitors, terminals,
and flat panel displays—at our
Carroll Touch Company.

And our folks at the Dallas
Sales Office are providing sales
and service support for AMP cus-
tomers throughout the region.

As the world leader in in
connect technology and produ
we're in many locations arou
the globe.

And that includes Texas.

AMP Interconnecting idea

AMP PACKAGING SYSTEMS, INC., P.O. BOX 9400, AUSTIN, TEXAS 78766-9400
CARROLL TOUCH, P.O. BOX 1309, ROUND ROCK, TEXAS 78680
AMP INCORPORATED, 1630 CORPORATE COURT, IRVING, TEXAS 75038

Biotechnology/Medicine

- **The Texas Medical Center in Houston—the world's largest medical center—consists of 39 institutions with total operating budgets of more than $2 billion per year.**
- **The San Antonio-based Texas Research & Technology Foundation is developing a 1,500-acre research park to house the city's biomedical and biotechnology research efforts.**

(Photo courtesy Tracor, Inc.)

Cell biologists can locate traces of calcium using a powerful image processing system developed by Tracor, Inc. of Austin, TX.

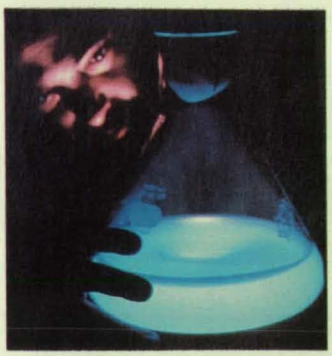
Thanks to strong technology transfer programs, Texas is a national leader in moving medical advances from the laboratory to the marketplace. This holds particularly true in the field of biotechnology, one of the fastest-growing research areas in the state. About 50 biotechnology companies operate in the Houston area, with two dozen more in San Antonio. Some examples:

— **LifeCell** markets a process to freeze-dry tissue samples for analysis or later reconstitution. Developed by a University of Texas Health Science Center professor, the process could preserve human corneas for transplants over a much longer period than previously possible.

— **Xenos Medical Systems**, established by BCM Technologies, the tech transfer arm of Baylor College of Medicine, is developing a gamma-ray camera to determine heart muscle damage and arterial blockage. The system is faster, cheaper, and exposes the patient to less radiation than other diagnostic methods.

— **Kardiothor**, another BCM venture, markets a system that recovers, cleans, and recycles blood lost by a trauma or surgery patient.

Several universities, including the University of Texas (UT) at San Antonio, UT-Austin, Texas A&M, and Rice University, have established biotechnology research centers. Texas A&M broke ground on a new $21.5 million facility at the Texas Medical Center earlier this year. Laboratory researchers are pursuing studies in such areas as recombinant DNA and mapping the human genome.



Advances in biotechnology serve both agriculture and the state's massive medical research infrastructure.

Texas A&M scientists also are examining the application of biotechnology to agriculture and veterinary medicine. One researcher is testing an experimental vaccine created to protect cattle against brucellosis. Another has developed a cotton plant resistant to a common weed killer; the plant could enable operators to clear weeds from their fields without harming the cotton.

Another strong medical research area in Texas is aerospace human factors. The Johnson Center oversees medical experiments aboard the space shuttle, and monitors the condition of returning astronauts to help design crew quarters and fitness regimes for Space Station and possible lunar bases and manned Mars missions.

The Air Force Human Systems Division in San Antonio includes the School of Aerospace Medicine, which evaluates the effects of flight (such as high-G maneuvers and thermal stresses) on flight crews, and trains physicians and nurses in the special requirements of aerospace medicine.

Climatology/Meteorology

- **Texas is a 266,807-square-mile weather laboratory, encompassing three climates—mountain, maritime, and continental—and the southern third of "Tornado Alley."**

If rain is on the way, rattlesnakes leave their dens and head for high ground. If a storm is coming, the wolves will howl loudly. And if a hard winter lies ahead, woodpeckers will peck low on trees. These observations, the result of generations of folklore, might not be considered highly scientific, but they accurately reflect the Texan's overriding interest in the weather. Since the first recorded observations by Spanish missionaries four centuries ago, Texans have tried to record, predict, and even change the weather. That tradition continues today in a number of university research projects.

Dr. Gerald North, Director of the Texas A&M Climate Research Program, is spearheading an international effort to place rainfall-measuring instrumentation in

High-Tech Answer To Acid Rain

A Texas engineer has created a device that could significantly reduce acid rain. Called the synergistic reactor, it removes sulfur dioxide from the emissions of petroleum refineries, steel mills, and coal-fired industrial plants. These facilities produce about 30 percent of the sulfur dioxide found in Earth's atmosphere; the remainder is a byproduct of the natural decomposition of organic matter.

When sulfur dioxide combines with water in the atmosphere, the resulting rain increases acidity in waterways, kills wildlife, and damages outdoor sculptures and other structures.

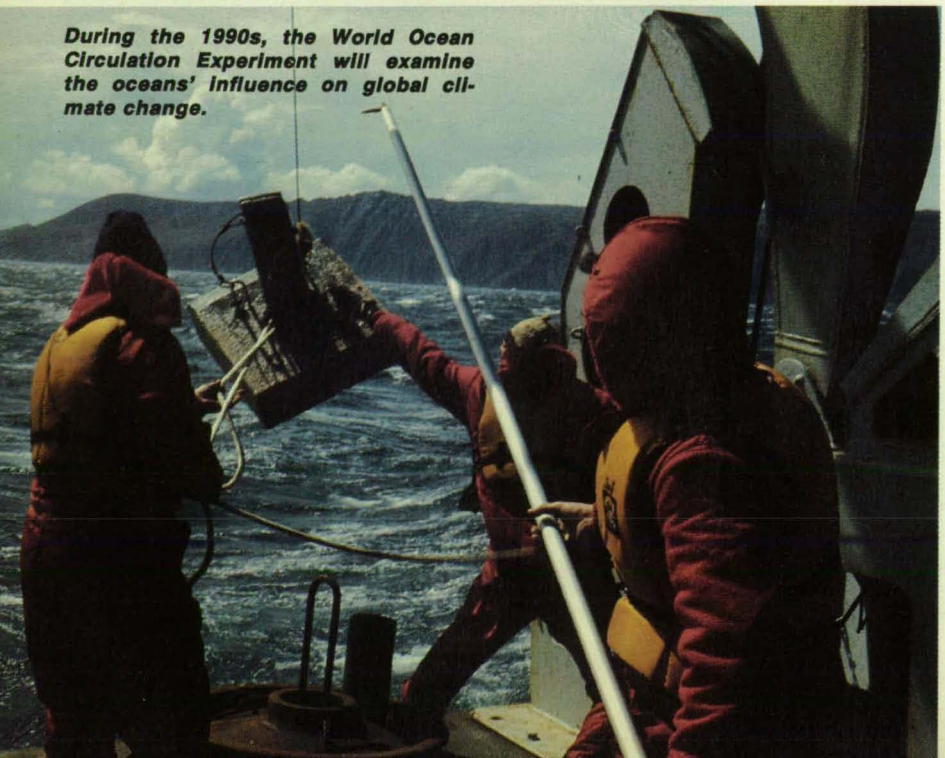
The synergistic reactor prototype, produced by University of Texas (UT) engineering students, removes nearly 100 percent of the sulfur dioxide found in industrial emissions, compared to only 60-70 percent efficiency for existing pollution control devices. The reactor also is much smaller than comparable air scrubbers, requires one-half to two-thirds less energy, uses less water, and has only one waste product—gypsum—which can be sold.

The reactor, which can be built to fit inside individual industrial smokestacks, injects a mixture of steam and ground lime into the gases formed by burning coal or other organic materials. Steam condenses around the fine gas and lime particles, creating a chemical reaction that produces dry gypsum. The gypsum particles are captured in a filter system and can be sold for use in wallboard, plaster, and other construction materials.

Aerological Research Systems (ARS), a small R&D corporation in Daingerfield, Texas, will license the reactor to other companies for commercial development. The device is based on a concept by ARS President Thomas K. Ewan, a veteran engineer. Ewan, who says the concept for the synergistic reactor "came to me in bed early one morning" in 1984, approached Dr. Leonardt Kreisle, Director of the UT-Austin Mechanical Engineering Design Projects Program, with the basic idea in 1987.

The invention has already attracted worldwide attention. Hundreds of engineers, journalists, and government officials from as far away as Japan and the Soviet Union have contacted Ewan and UT for details. Canada is especially interested because of the increasing threat there of damaging acid rains due to industrial emissions from American factories.

Ewan hopes to have a prototype system installed in a municipal power plant or industrial facility this summer for final tests, with the reactor technology available commercially by year's end. □



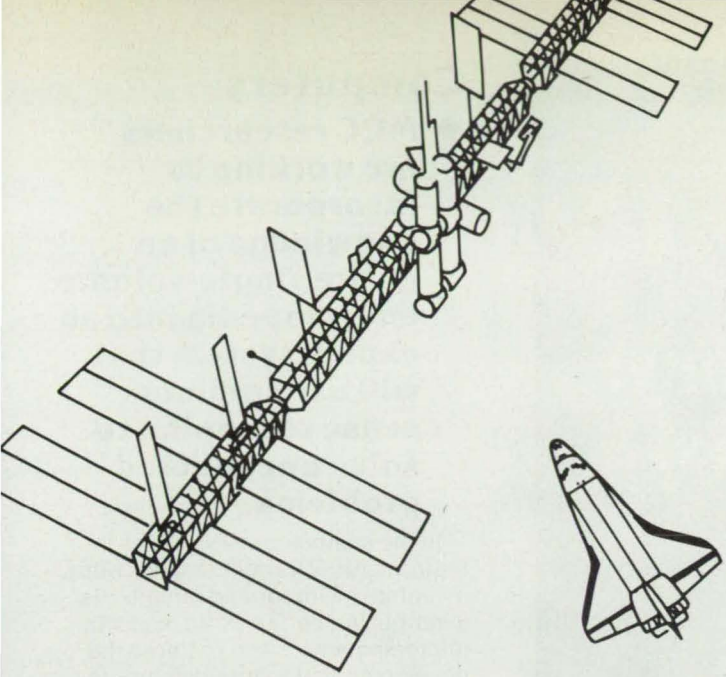
During the 1990s, the World Ocean Circulation Experiment will examine the oceans' influence on global climate change.

low-Earth orbit. The devices could measure such phenomena as El Ninos, Pacific currents that disrupt normal weather patterns for months.

North is one of three initiators of the Tropical Rainfall Measuring Mission (TRMM), a joint U.S.-Japan research program. If the project receives NASA approval, the TRMM satellite will be carried into orbit by a Japanese HII launch vehicle. From orbit, it will employ both passive and active microwave sensors to measure rainfall near the equator. TRMM data could help scientists refine their computer models of Earth's climate, resulting in improved long-range forecasting.

A second project would place similar instruments aboard Space Station; North is principal investigator for this effort, a collaboration with NASA's Jet Propulsion Laboratory.

Texas A&M also is home to the U.S. planning office of the World Ocean Circulation Experiment (WOCE). The most complex oceanographic program ever undertaken, WOCE will involve hundreds of scientists worldwide who will examine the role of the oceans in Earth's climate. Project members will use satellite data to obtain a large-scale picture of ocean circulation, and will add spot measurements from ships and land stations for more detailed information. Among the processes scientists will examine is the rate at which gasses are transferred between the atmosphere and the ocean. Determining how fast the oceans absorb carbon dioxide will help predict the rate of global warming caused by an increase in atmospheric pollutants.

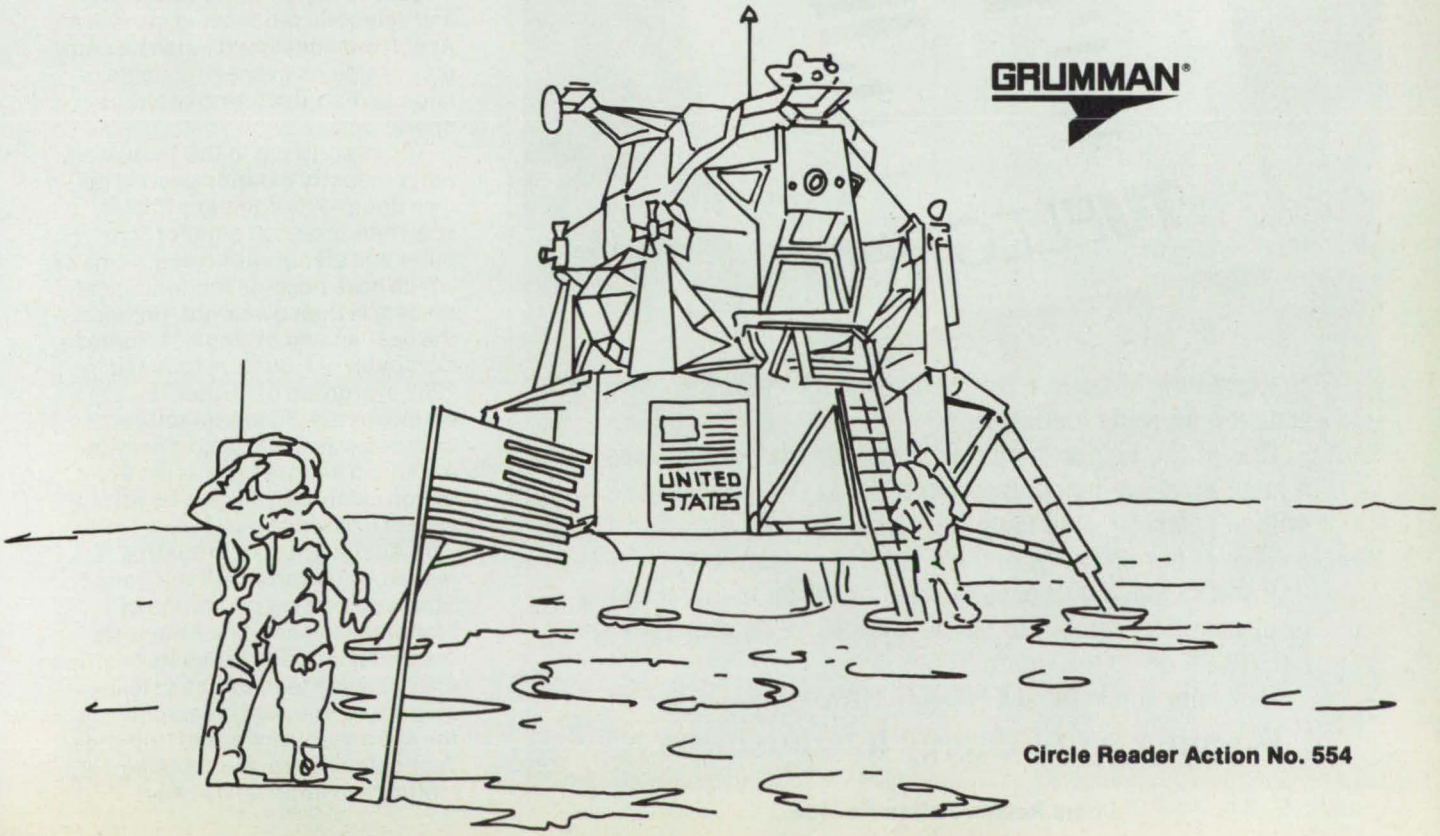


Twenty years ago, Grumman built the Lunar Module and made history. As a result, a strong partnership was formed as the futures of NASA, Grumman, and Texas became intertwined. From the Lunar Module, to the Space Shuttle, the Space Station, and beyond, that "one small step" on July 20, 1969, catapulted us toward successes that are still being realized today.

- ☐ We build the wings for the Space Shuttle, the training aircraft NASA uses to train Shuttle flight crews, and a platform astronauts use in working in space.
- ☐ We head an industry team that will oversee the development contracts on the Space Station Program, and we are participating in the design and construction of the crew quarters for the Space Station.
- ☐ We are designing a robot capable of assembling the Space Station, and are members of the team producing the Orbital Maneuvering Vehicle.
- ☐ We, with the cooperation and support of the city of Houston, are establishing a major facility at Ellington Field, adjacent to the Johnson Space Center, to house our Southwestern Development and Production Operations.

Grumman, NASA and Texas—
an historic partnership grows stronger
for a brighter tomorrow.

GRUMMAN®



Circle Reader Action No. 554

Computers

- **MCC researchers are working to incorporate the knowledge of an entire single-volume encyclopedia into an expert system that will use common-sense reasoning to solve unexpected problems.**

In the summer of 1958, Texas Instruments (TI) engineer Jack Kilby invented the integrated circuit. His invention made TI a world leader in microelectronics and fostered the development of a vibrant computer industry in Texas. Today, Texas-based companies manufacture a hefty percentage of the nation's personal computers, while research labs are creating the computing technologies of the next century.

TI remains at the forefront of computer technology through its application-specific microprocessors, artificial intelligence workstations, and extensive corporate research laboratories. The company plans to merge AI and conventional computing technologies in a series of machines based on the RISC architecture. Basic software for the machines will include object-oriented programming capabilities and symbolic processing, as well as AI software designed to tackle complex problems in specific fields, such as manufacturing or airline operations.

TI's importance to the Texas computer industry extends beyond its own doors. The company has spawned scores of smaller computer and electronics firms, some of which have become technological leaders in their own right. Perhaps the best-known example is Compaq Computer of Houston, founded in 1982 by a group of former TI employees. A PC manufacturer, Compaq was the first company in American history to pass the $1 billion sales mark in only its fifth year of existence.

In Austin, the first industrial research consortium in the United States is working on advanced techniques to help the American computer industry retain its position of worldwide technological leadership. More than 400 researchers at the Microelectronics and Computer Technology Corp. are devising methods to improve the way

American companies design, manufacture, and use computers.

Founded in 1983, MCC is a formidable research group. Some reasons:

— Almost half of its researchers, from such fields as computer science, physics, chemistry, and electrical engineering, hold doctorates.

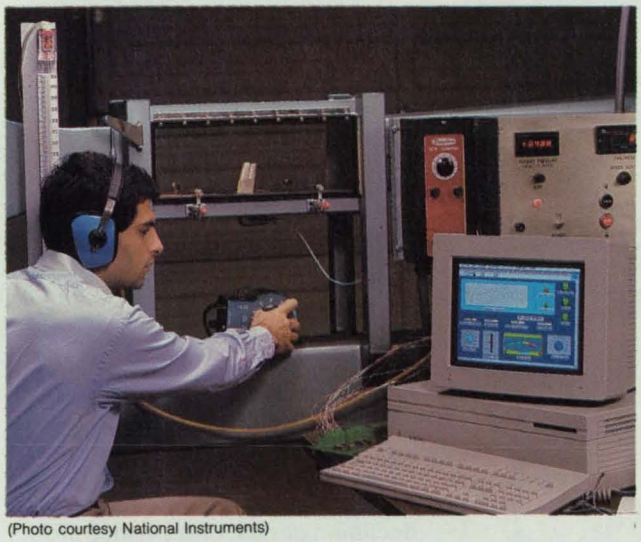
— The 200,000-square-foot headquarters building, located at the University of Texas Balcones Research Center, is equipped with several hundred computers to ensure that researchers never have to wait for an available machine.

— An international liaison program monitors Japanese and European research developments, translates reports into English, and maintains databases containing abstracts of more than 30,000 Japanese and 5,000 European technical papers.

Among MCC's research projects: an interactive worksurface that will let users write or draw on a computerized desktop. The computer will recognize the characters and store and manipulate them as if they were entered with a keyboard.

(Photo courtesy Texas Instruments)

Leading efforts in aerospace, artificial intelligence, and military systems come together in the Dallas/Ft. Worth Metroplex.



(Photo courtesy National Instruments)

A graphical programming software package created by Austin-based National Instruments controls this computer's data acquisition boards during wind tunnel testing of advanced air temperature sensors.

Energy

- **Texas produces one-third of America's domestic natural gas, and Texas refineries process a quarter of the country's petroleum.**
- **Wind power in Texas has the potential to produce up to 250,000 megawatts of electricity—four times the state's current electrical generating capacity and the equivalent of 1.3 million barrels of oil.**
- **The largest petrochemical complex in the world is located in southeast Texas.**

Texas has been awash in a sea of petroleum since the first well—Spindletop—gushed in 88 years ago. In recent years, though, the Texas oil and gas industry has suffered; dwindling reserves and declining prices have slashed production, hurting both the industry and the state's tax revenues.

Texas researchers are looking at ways to help restore the industry to health through advanced recovery techniques and improved geophysical exploration technology. In addition, Texas universities are examining alternative forms of energy to reduce the state's dependence on oil and provide clean, renewable resources well into the next century.

Leading the way in oil and gas research is the University of Texas Bureau of Economic Geology (BEG). A BEG-managed university/industry/government project is looking to develop and demonstrate new technologies that could help producers to better identify and produce natural gas resources in known fields.

Although researchers will focus on Texas fields, their results could improve natural gas production throughout the United States by improving secondary gas recovery.

Pulsing With Power

Engineers at the University of Texas' Center for Electromechanics (CEM) are applying pulsed power technology to such diverse R&D efforts as the creation of antitank weapons and the investigation of shielding materials for interplanetary spacecraft.

CEM is "on the leading edge" of pulsed power technology, according to Center Director Bill Weldon, who, along with two other engineers, invented the only completely new electric generator patented in the United States during this century: the compensated pulsed alternator, or compulsator. The generator produces several hundred powerful electrical pulses per second.

Researchers are exploring possible military, industrial, and scientific applications of both the compulsator and homopolar generators, which produce one intense pulse of electricity at a time. For example, CEM is competing with other groups to develop an antitank weapon that can fire small, nonexplosive tungsten projectiles ten times faster than rifle bullets. CEM's contract with the Department of Defense calls for production of an electromagnetic railgun capable of firing three rounds per minute for three minutes.

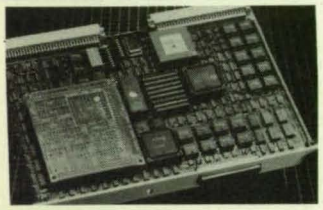
Last year, University of Texas System regents set aside more than 28,000 acres in Pecos County for a future electromagnetic railgun test range.

NASA is interested in pulsed power as a way to launch payloads into Earth orbit. Electromagnetic railguns could fling payloads into orbit for a few cents per pound, compared to a few hundred or thousand dollars per pound for current launch vehicles.

In a more exotic NASA application, CEM researchers have explored how the technology could help in designing spacecraft to withstand the descent into another planet's atmosphere. Test objects were fired through a tube filled with the same gases found in the atmospheres of Venus and Jupiter, then examined to determine how they were affected by the simulated atmospheres. The resultant data could help designers decide which materials would provide the best protection for future space probes.

Pulsed power also is useful in such everyday chores as welding and plating. Two large metal pipes can be welded together in one-tenth of a second, compared to hours with today's techniques, and the weld is stronger, cleaner, and more durable than can be achieved with conventional methods. □

A chemical plant in Texas City



Secondary gas reserves in the 48 contiguous states are estimated at 120 trillion cubic feet, one-third of that in Texas. By comparison, the United States consumed 16.7 trillion cubic feet of natural gas in 1987.

Furthermore, researchers in the Texas Tech University Department of Geosciences are developing rapid, accurate methods of identifying oil reservoirs with a high degree of variability in the size of their oil-bearing pores. This variability can make it difficult to estimate the amount of oil in a reservoir.

West Texas State University is studying ways to generate electricity with an abundant Texas resource: wind. In early 1989, the university's Alternative Energy Institute (AEI), received a grant to test new airfoil designs for wind turbines. The institute hopes to produce airfoils that will not suffer metal fatigue or structural failure.

Near the far western tip of Texas, scientists at the University of Texas at El Paso are testing a technique that can produce electricity, heat, and drinking water—all at the same time.

Researchers are conducting experiments with a solar pond—a pond with a layer of dense salt water at the bottom. The salt water traps the sun's heat, which can be used in such applications as industrial process heat, water desalination, and treatment of irrigation return flows.

The six-year-old pilot project has yielded important early results. The football field-sized pond can preheat 30,000 gallons of feedwater a day or desalinate 5,000 gallons of water a day. In 1986 it became the first solar pond in the United States capable of producing electricity.

Hazardous/ Nuclear Wastes

- **The first federally funded R&D center in Texas was established in 1987 to support the Nuclear Regulatory Commission's nuclear waste disposal programs.**

The Center for Nuclear Waste Regulatory Analyses in San Antonio is examining questions relating to the safe storage of spent nuclear fuel at a repository planned for Yucca Mountain, Nevada. The repository must safely isolate the materials for 10,000 years.

Early studies are evaluating potential seismic and chemical hazards at the storage site, as well as the stability of nuclear waste containment package materials in the presence of strong radiation and changing temperatures.

Several state universities are pursuing research in bacteriological degradation — the use of bacteria to convert toxic chemicals into harmless substances. A commercially available bacteriological process developed by a University of Houston professor renders polychlorinated biphenyl (PCB) harmless, for example, while Texas A&M researchers have devised a chemical process that converts PCBs into a mixture of bicarbonate of soda and salt. This method could cut PCB disposal costs by a factor of five or more.

NASA Tech Briefs wishes to thank Scott Stevens and Keren Ware of the Texas Department of Commerce; State Representative Asheley Smith; James Patrick of the Texas Computer Industry Council; and Scott Eubanks of the Dallas Partnership for their help in telling the Texas story.

We've Invented the Future of Instrumentation Software . . . Twice.

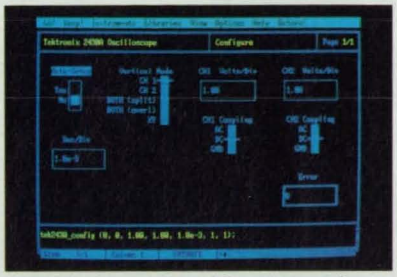
With Words With Pictures

LabWindows

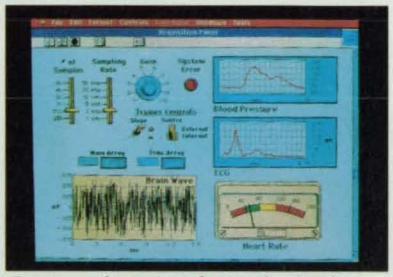
LabVIEW

Acquisition

Integrated libraries for GPIB, RS-232, A/D-D/A-DIO plug-in cards, and modular instruments.



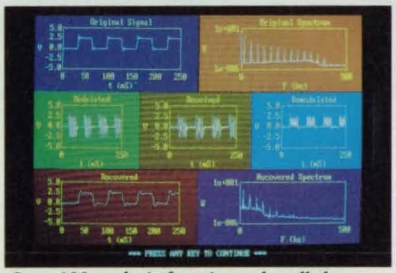
Intuitive character-based function panels that automatically generate source code.



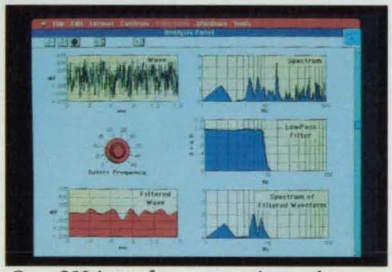
Front panel user interface with virtual instrument block diagram programming.

Analysis

Extensive libraries for data reduction, digital signal processing, and statistical analysis.



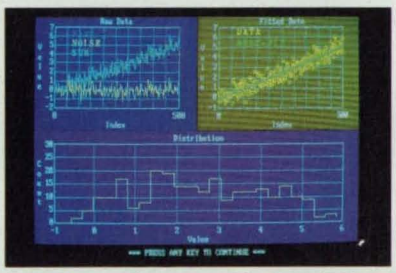
Over 100 analysis functions plus all the built-in functions of your language.



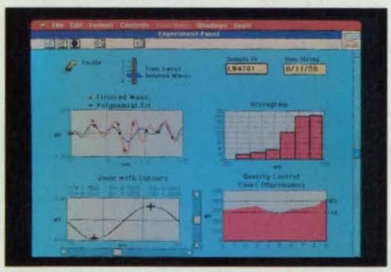
Over 250 icons for computation and analysis.

Presentation

Flexible high-performance graphics and report generation.



Extensive graphics support for CGA, EGA, MCGA, VGA, and Hercules.



Macintosh Desktop Publishing compatibility.

LabWindows®-
for the DOS-based PC and PS/2, with Microsoft QuickBASIC or C.

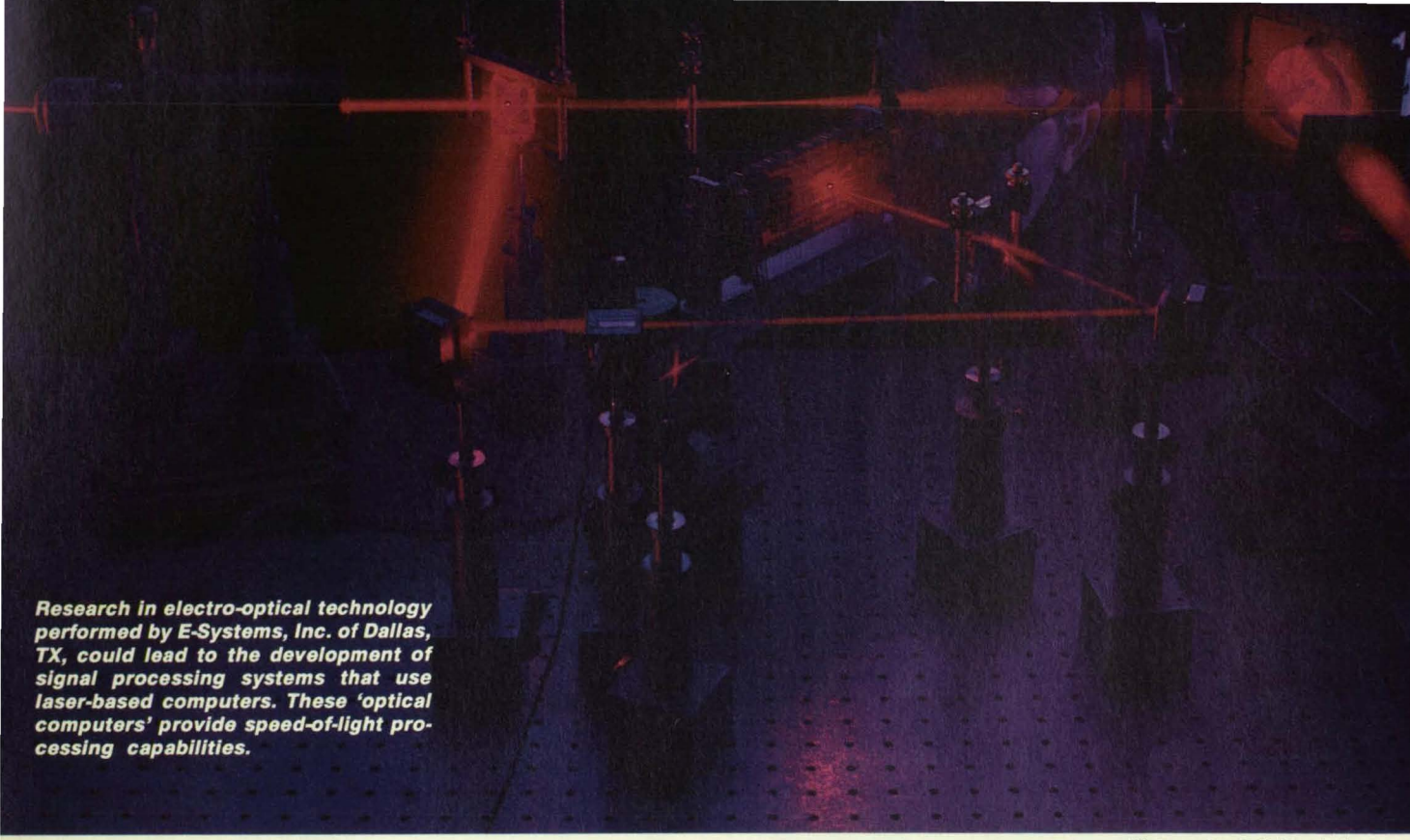
NATIONAL INSTRUMENTS®
The Software is the Instrument™

12109 Technology Boulevard
Austin, Texas 78727-6204
800/531-4742 512/250-9119

LabVIEW®-
for the Apple Macintosh.

National Instruments of Japan 81 (03) 788-1921 • **National Instruments of France** (1) 48 65 33 70 • **National Instruments United Kingdom** 44-01-549-3444 • ARGENTINA 541/46-5776 /0628 • AUSTRALIA 61 (3) 879-2322 • BELGIUM 02/735.21.35 • CANADA 416/890-2010-613/596-9300-(514) 747-7878-403/295-0822-(604) 988-2195 • CHILE 56 2253689 • DENMARK 45 02-251122 • FINLAND 358 90-372 144 • FRANCE 33 (1) 69077802 • HONG KONG 852 0-262707-852 0-262945 • IRELAND 353 042 72282 • ISRAEL 972 324298 • ITALY 39-2-98491071-2-3 • KOREA (02) 776-38 • MEXICO 52 660 4323 • THE NETHERLANDS 31 070-996360 • NEW ZEALAND 64 09 444-2645 • NORWAY 02-531250 • PORTUGAL 19545313 • SINGAPORE 65 29 11336 • SOUTH AFRICA 27 (011) 787-0473 • SPAIN 34 (1) 455 81 12 • SWEDEN 46 08 792 11 00 • SWITZERLAND 41 65 52 8949 • TAIWAN/THE REPUBLIC OF CHINA 886 (02) 7036280 • THAILAND 66 2349330 • UNITED KINGDOM 44 273 608 331 • WEST GERMANY 49 89 807081

Circle Reader Action No. 489



Research in electro-optical technology performed by E-Systems, Inc. of Dallas, TX, could lead to the development of signal processing systems that use laser-based computers. These 'optical computers' provide speed-of-light processing capabilities.

(Photo courtesy E-Systems, Inc.)

Manufacturing Technology

- **Austin-based Sematech has established 10 university-based Centers of Excellence around the country to conduct long-range semiconductor manufacturing research.**

Scores of American cities wanted it, but when the intense competition was over, Sematech selected Austin as its home base. The 14-member semiconductor manufacturing technology consortium, partially funded by the Department of Defense, was established in 1987 to develop leading-edge manufacturing capabilities.

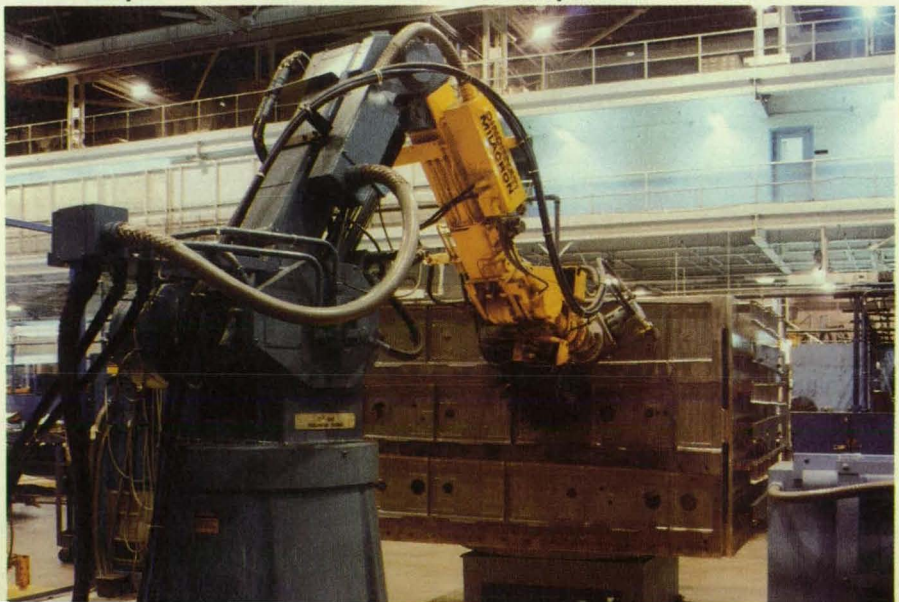
With Robert Noyce, co-founder of Intel and co-inventor of the integrated circuit as chairman, and with financial backing by the University of Texas System, Sematech built a 30,000-square-foot state-of-the-art production facility in just 32 weeks — about one-third the time normally required for such an undertaking. The consortium expects to produce its first working integrated circuits this spring.

Sematech will do more than manufacture chips, though. Through a subsidiary, Semi-Sematech, it is working with industry vendors to develop new procedures that will yield higher-quality manufacturing tools and equipment.

The San Antonio-based Southwest Research Institute (SwRI), the third-largest non-profit scientific research organization in the country, has devised several advanced manufacturing techniques for both military and civilian applications.

An SwRI-developed robotic system for removing surface defects from Air Force fighter canopies has been adopted at Hill Air Force Base,

A computer-controlled robot deburs aluminum parts for F-16 aircraft.



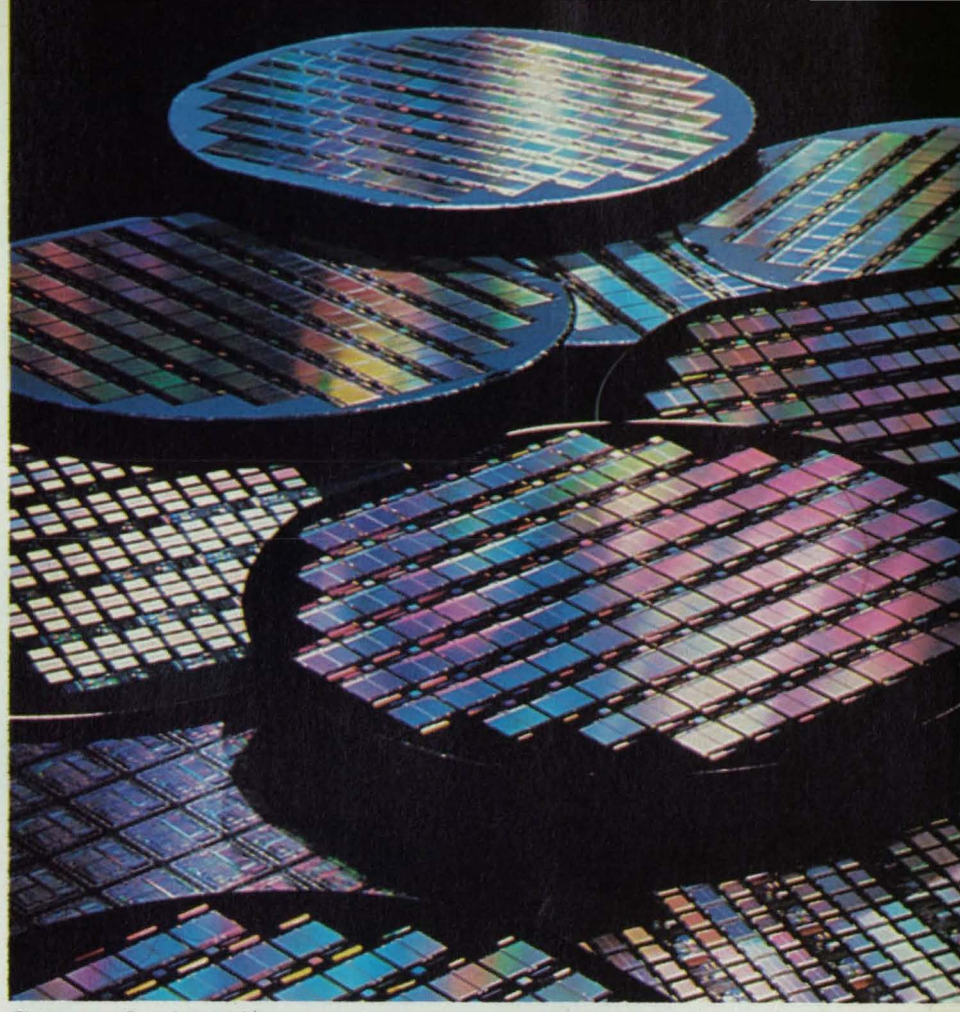
(Photo courtesy General Dynamics)

Texas' long-time participation in semiconductor research and production was rewarded with Sematech's selection of Austin as a home base.

Utah. One robot uses computer vision to locate flaws in F-4 and F-16 canopies, while two other robots buff away the defects and polish the canopies. This process is four times faster and more cost effective than manual polishing operations, according to the institute.

SwRI and a major aerospace manufacturer are developing a conceptual design for a computer-integrated manufacturing (CIM) facility capable of producing 30,000 jet engine vanes and blades per year. Using CIM and computer simulation techniques developed at SwRI, researchers are designing a plant where computers will control process planning, work scheduling, production accounting, and other chores.

Many Texas manufacturing innovations are already paying handsome dividends. One recent example is a computer chip etching process devised by Texas Tech University, Texas Instruments, and FSI International. The process, called Excalibur, uses gaseous acid to etch patterns on high-density memory chips. Widely used by semiconductor manufacturers in the U.S., Japan, and Korea, the process is cheaper and faster than other methods and produces less toxic waste.



(Photo courtesy Texas Instruments)

Marine Science

- **Texas A&M is the home base for the Engineering Research Center for Offshore Technology, the first National Science Foundation-sponsored engineering research center in the southwest.**

From Port Arthur to the Rio Grande River, the Texas tidewater coastline stretches 624 miles. With such inviting access to the marine environment, it's little wonder that Texas universities and state agencies have established extensive marine science programs.

These research efforts encompass an exhaustive range of topics, from the physiology of commercially-important shellfish to offshore drilling technology. Texas marine science programs aren't limited to Texas coastal areas, though; scientists scatter from the Bering Sea to the Antarctic to conduct advanced research.

(Photo courtesy Texas Instruments)

Shrimp research at the University of Houston contributes to the state's progress in the marine sciences.

The most extensive marine research effort is centered at Texas A&M University, which operates laboratories and research vessels at Galveston. The offshore technology center, which will receive $28 million over a five-year period, will bring together researchers from A&M, the University of Texas at Austin, and major oil companies and service firms to study ways to build offshore structures and recover oil at depths greater than 4,000 feet.

Texas A&M is scientific manager of the international Ocean Drilling Program (ODP), in which core samples are retrieved from the ocean floor. Scientists from 10 major United States oceanographic institutes and five foreign research centers participate in the program. In 1988, researchers aboard an ODP ship near Australia obtained 220 million-year-old marine rocks—the oldest yet recovered by scientific ocean drilling. The samples are expected to yield new clues about how Earth looked in the early days of the dinosaurs.

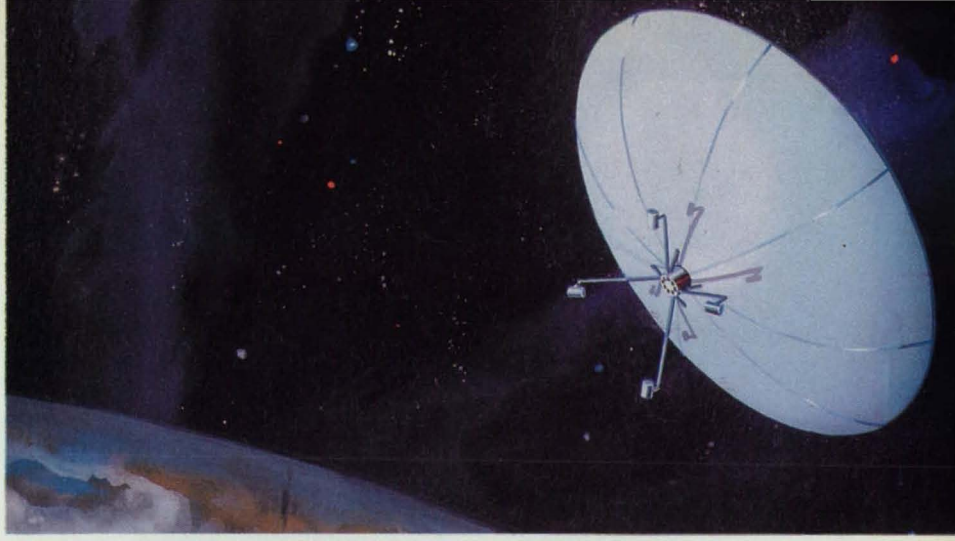
Scientists at the University of Texas Marine Science Institute at Port Aransas are conducting basic studies of the physiology and behavior of sciaenids, a group of coastal game fish that includes trout, black drum, and red drum (redfish). A better understanding of these fish should enhance efforts to establish commercial redfish hatcheries along the coast.

The mariculture research group also is trying to develop inexpensive food supplies for larval redfish, which is crucial if hatcheries are to prove economically viable.

To learn more about high tech opportunities in Texas, write to the Texas Department of Commerce, PO Box 12728, Austin, TX or call Phil Brewer, National Business Development Director, at (512) 320-9628.

Materials Science

- **With 200 staff members and a three-year, $30 million budget, the Texas Center for Superconductivity is the largest university-based superconductivity center in the United States.**



University of Houston engineers are developing the Space Ultra-Vacuum Research Facility (SURF), a wake shield useful for processing materials in orbit under ultra-high vacuum conditions.

In the universe of superconductivity, no star shines brighter than Dr. Ching-Wu "Paul" Chu, a physicist at the University of Houston. In February 1987, Chu and his research team achieved a major breakthrough when they produced a material that loses all electrical resistance at 98 degrees Kelvin—the first material to become superconducting at a temperature higher than that of liquid nitrogen (77°K).

Chu, director of the Texas Center for Superconductivity at the University of Houston, has continued his own important research while building an impressive team of scientists and engineers. Chu's center is working with several other organizations, including MCC in Austin, to continue superconductor development and explore possible applications for superconducting materials.

Before establishing the superconductivity center, Chu served as director of another University of Houston laboratory, the Space Vacuum Epitaxy Center (SVEC). Established in 1986 as a NASA CCDS, it is developing techniques to use the vacuum of space for materials processing.

SVEC hopes to use an umbrella-like shield to sweep the path of an orbiting instrument package, creating an ultra-vacuum. Experiments inside the instrument package would evaluate procedures, including molecular and chemical beam epitaxy, for producing new electronic, magnetic, and superconducting thin film materials and devices.

In more down-to-Earth programs, the Southwest Research Institute is evaluating ceramic materials for a variety of applications. Several projects are focusing on ceramic automobile engines; because ceramics can withstand higher temperatures than metals, ceramic engines could operate without oil or water and their requisite circulation systems. Early work with ceramic pistons and valves have brought promising results.

A chemist at the University of Texas at Austin has used a mineral called hydroxyapatite, which is found in tooth enamel and living bone, to create a synthetic bone material. Useful in both orthodontics and bone reconstruction, the material is stronger than previous bone substitutes and better able to withstand stress.

And a physicist at the University of Texas at San Antonio has created something many Texans will appreciate when the 100-degree heat of summer rolls in: an improved sunshield. The invention combines a synthetic version of melanin—a pigment found in hair, skin, and eyes—with plastic. Melanin filters out a broader range of solar energy than plastics, so sunglasses, car windshields, and other items made from the new material would provide greater protection than now available. □

1980

- BMC Software incorporates
- 5 employees
- 3270 OPTIMIZER/ IMS introduced
- 3270 OPTIMIZER/ CICS introduced

1981

- BMC sales top $1 million mark
- 7 employees

1982

- First product demonstration held outside U.S, (Frankfurt, West Germany)
- 21 employees
- DATA PACKER™/ IMS introduced
- SCREEN PLUS introduced
- SECONDARY INDEX UTILITY introduced

1983

- BMP RESTART introduced
- 40 employees

1984

- BMC's first international office opens in Frankfurt, West Germany
- First Technical Review held
- 55 employees
- DELTA IMS™ DB/ DC introduced
- LOADPLUS introduced

1985

- BMC office in Camberley, England opens
- 125 employees
- LOCAL COPY PLUS introduced
- 3270 OPTIMIZER/ VM introduced
- 3270 SUPEROPTIMIZER™/ CICS introduced
- 3270 SUPEROPTIMIZER™/ CICS for DOS/VSE introduced
- PREFIX RESOLUTION PLUS announced
- 3 ICP awards

1986

- BMC named to INC. MAGAZINE's ranking of the nation's fastest growing privately held companies
- 3 ICP Awards
- 141 employees
- 3270 SUPEROPTIMIZER™/ IMS introduced
- UNLOAD PLUS introduced
- DATA PACKER™/ FAST PATH introduced
- $17,966,000 in revenues

1987

- DELTA IMS VIRTUAL TERMINAL announced
- REORG PLUS for DOS/VSE introduced
- 3270 SUPEROPTIMIZER™/ TSO introduced
- DATA PACKER™/ DB2 introduced
- DATA PACKER™/ MSC introduced
- DB2 ALTER introduced
- BMC offices in Paris, France and Milan, Italy open
- 237 employees
- 7 ICP Awards
- BMC named to INC. MAGAZINE's ranking of the nations fastest growing privately held companies
- $28,043,000 in revenues

1988

- BMC office in Tokyo, Japan opens
- BMC European Support Center in Camberley, England opens
- DATA PACKER™/ VSAM announced
- U.S. Patent No. 4,750,137: First patent on BMC technology
- Awarded SOFTWARE MAGAZINE's "Top 50 Software Firms"
- 280 employees
- Initial public offering of BMC stock
- $41,550,000 in revenues

BMC Software calls Texas home

The best place for growth in the 80s; the right place to be in the 90s

Headquartered near Houston, BMC Software, Inc. (NASDAQ Market Symbol: BMCS), has become an international leader in the development, marketing and support of systems software products for IBM and compatible mainframe computers.

It's track record speaks for itself. Since incorporation in 1980, BMC has licensed its products to Fortune 500 and similarly sized corporations throughout the world. BMC is also recognized as the largest national and international software telemarketing firm.

In part, BMC's phenomenal growth is attributed to its tradition of leading-edge technology. In 1988 for example, BMC Software received a U.S. Patent for its original technologies, developed to increase the efficiency of data communications. Another reason for its growth is BMC's ability to attract top talents in every field. The major factor is location. The vitality of the southwestern lifestyle and proximity to Houston guarantee BMC employees a superior quality of life.

Add a state-of-the-art work environment for its employees and BMC is positioned as a corporation with a winning business strategy, global integrity and unlimited business potential.

BMC SOFTWARE

P.O. Box 2002
Sugar Land, Texas 77487-2002
713-240-8800

Circle Reader Action No. 481

Eight-Bit-Slice GaAs General Processor Circuit

Features include speed and adaptability to a variety of digital systems.

Goddard Space Flight Center, Greenbelt, Maryland

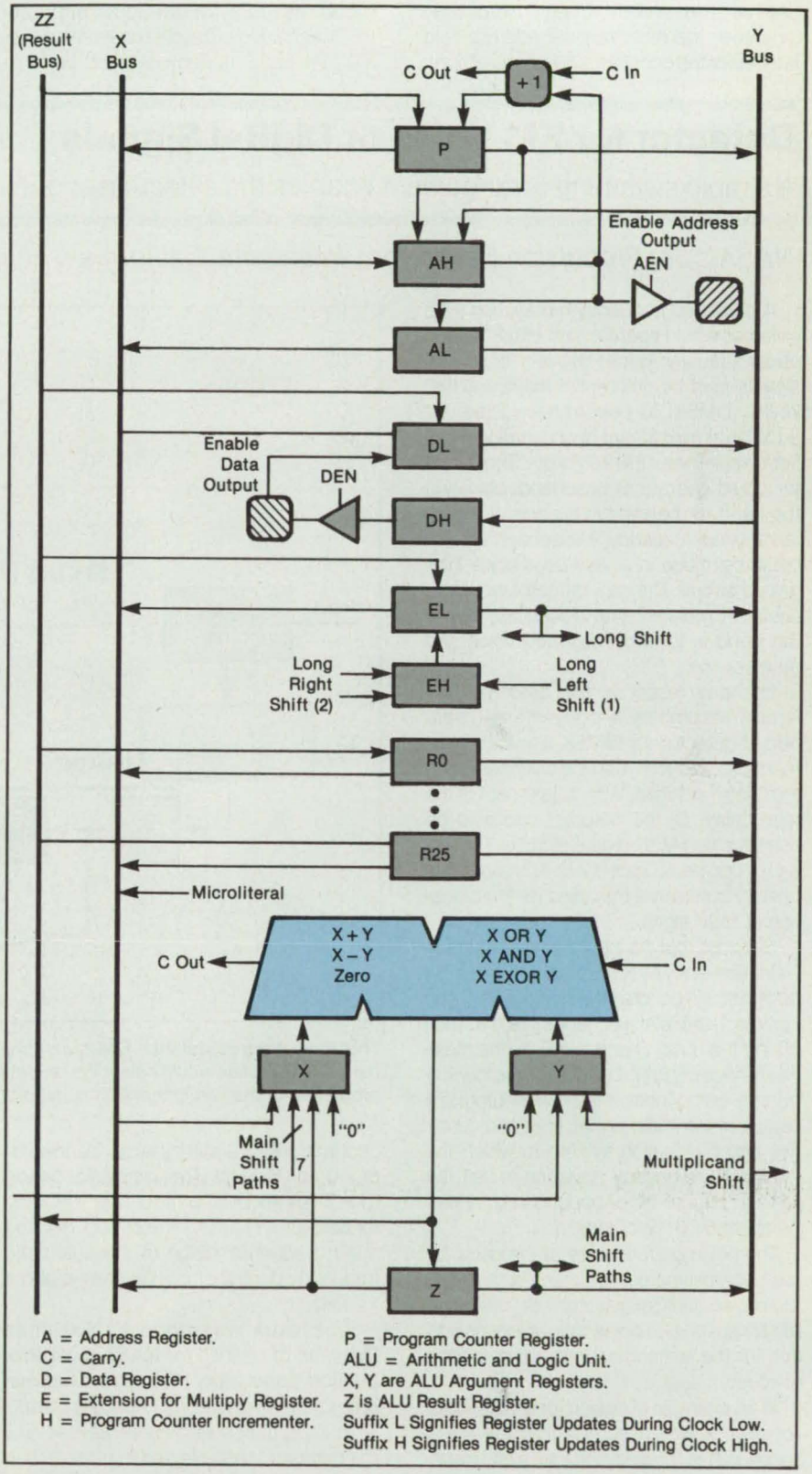
A novel GaAs 8-bit slice will enable the quick and efficient implementation of a variety of fast GaAs digital systems ranging from central processing units of computers to special-purpose processors for communications and signal-processing applications. With the GaAs 8-bit slice, designers can quickly configure and test the hearts of many digital systems that demand fast complex arithmetic, fast and sufficient register storage, efficient multiplexing and routing of data words, and ease of control.

The device itself is laid out with a bit-slice arrangement. One bit of each register, the arithmetic-and-logic unit, multiplexing logic, and the three major buses, is repeated eight times in the circuitry illustrated in the figure. The least-significant and the two most-significant 1-bit slices of the 8-bit slice are more complicated than is shown in the figure because of built-in multiplication and division functions and operations involving shifting and rotation (or cyclic shifting) of data.

Orthogonal to the eight 1-bit slices are the communication paths of a novel means of multiplexing shift paths for both right and left operations onto the same paths.

The 8-bit slice is made adaptable to slower asynchronous systems by an input called "MACK" (memory acknowledge) and some internal mode-control logic, which includes a small number of internal states. The logic interprets the condition of MACK = 1 as either a strobe preceding the data from a system-memory-reading operation by half a clock period or as an acknowledgement from system memory that it has latched the data to be written into it. For the quickest possible response to memory, the MACK input goes to both the system microprogram control and to all bit slices.

Modularity and high performance in multiplication and division are achieved by incorporating the special steps for a 2-bit-at-a-time multiplying algorithm and a nonrestoring dividing algorithm into the set of microcommands. Moreover, these special steps include the initialization of register contents for multiplication, the various cases of addition and subtraction with or without shift in division, steps that provide for the many different ways of forming the remainder in division, and the ability to modify the multiplying algorithm to cover all cases in which the multiplier and multiplicand are signed two's-complement binary words or unsigned positive binary words.



This **Data-Path Block Diagram** illustrates the functions of the 8-bit-slice circuit.

The 8-bit slice contains novel controls to enable the use of it in arithmetic-and-logic units of variable bit length. By use of this feature, any bit slice in the system can

be designated by microcode to be the least-significant-bit slice for the current arithmetic or logic operation. Carries and borrowings from other bit slices do not propagate into this bit slice, and shift paths for multiplication and division are automatically adjusted. One register address field is used as an immediate value (a microliteral) whenever the other register address field is a dedicated constant, and a special state enables the carry or borrowing to propagate through a very large number of bit slices (say 12 for a 96-bit computer arithmetic-and-logic unit) without requiring a slower clock.

The 9400-transistor chip has been fabricated in a 1.0-micrometer depletion-mode MESFET (Metal-Semiconductor FET) technology. The die measures 4.9 by 3.9 mm and has demonstrated performance above 150 million operations per second. The initial application for the device is a NASA data-compression system performing differential pulse code modulation.

This work was done by John Weissman and Robert V. Gauthier of Rockwell International Corp. for **Goddard Space Flight Center**. *For further information, Circle 71 on the TSP Request Card.*
GSC-13012

Detector for FM Voice or Digital Signals

A simple switching arrangement enables the selection of one or the other.

NASA's Jet Propulsion Laboratory, Pasadena, California

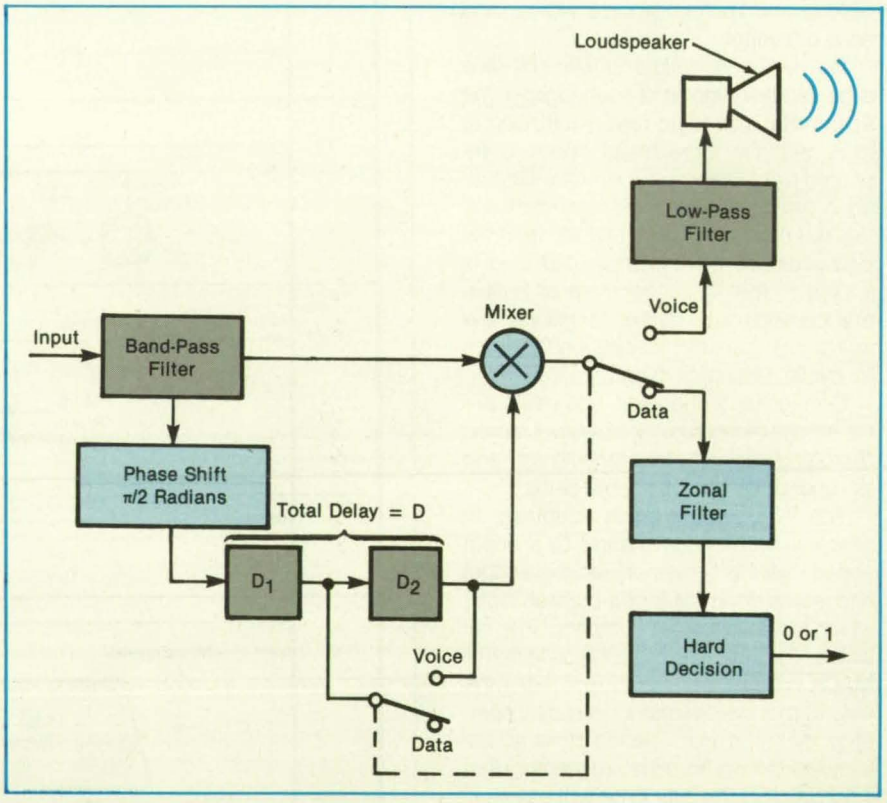
A proposed frequency-modulation (FM) detector would operate with either analog audio (usually voice) signals or digital signals sent by differential minimum-shift keying (DMSK). Its performance is expected to be similar to that of conventional limiter/discriminator FM detectors. The detector could operate at baseband, obviating the need for band-pass filtering at the intermediate frequency. A baseband version could be made in a very-large-scale integrated circuit. The new detector would be useful in mobile communications, where the trend is toward integrated voice and data service.

In many respects, the detector (see figure) resembles a conventional 1-bit-period detector for DMSK signals, and it functions as such when the switches are in the "data" position. With adjustment of the total delay, D, the detector can also be used for non-MSK digital signals. The detector can be equipped with automatic frequency control like that used for the reception of MSK signals.

Suppose that the input signal is modulated in frequency by $Ks(t)$, where K is the FM constant, $s(t)$ denotes the audio signal, and t is time. If the relative change in $s(t)$ is small during the delay D and if $[KD \times$ (the maximum value of $|s(t)|)] < \pi/10$, then the low-frequency component of the mixer output is a replica of the audio signal. In a representative communication system in which the maximum frequency deviation is half the speech bandwidth of about 3 kHz, D can be about 0.03 ms or less.

The noise performance of the detector has been estimated, assuming both amplitude noise and Gaussian phase noise. The resulting signal-to-noise ratio is identical to that for the limiter/discriminator detection of speech.

In an example of design for a voice/data receiver, it was assumed that the voice bandwidth is 3.5 kHz and the digital transmission rate is 9.6 kb/s. With a modulation index of 0.5, the optimum bandwidth of the receiver is approximately equal to the bit rate. However, in practice it is advantageous to select a slightly larger bandwidth of 10 to 11 kHz. The delay for voice ($D = D_1$) is about 0.03 ms or less; the delay for data ($D = D_1 + D_2$) is about 0.1 ms. The pull-in frequency range of the automatic frequency control of this receiver is about 1.2 kHz.



This **Frequency-Modulation Detector** would demodulate analog (voice) or binary data signals. The switches would select the operating mode according to the bandwidths and other properties of the two types of modulation.

This work was done by Faramaz Davarian of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 94 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 the commercial use of this invention should be addressed to

Edward Ansell
Director of Patents and Licensing
Mail Stop 305-6
California Institute of Technology
1201 East California Boulevard
Pasadena, CA 91125

Refer to NPO-16788, volume and number of this NASA Tech Briefs *issue, and page number.*

ENGINEERING...
Online on
STN International®

For more information about STN International, write or call: STN International, Marketing, Dept. 30689, P.O. Box 02228, Columbus, OH 43202. Phone 800-848-6538

STN International is operated in North America by Chemical Abstracts Service, a division of the American Chemical Society; in Europe, by FIZ Karlsruhe; and in Japan, by JICST, the Japan Information Center of Science and Technology.

Circle Reader Action No. 385

Physical Sciences

Hardware Techniques, and Processes

68 Cladding for Transversely-Pumped Laser Rod
68 Making Displaced Holograms at Two Wavelengths
70 Electron/Ion-Scattering Apparatus
72 Measurement of Composition in Transparent Model Alloy
73 Modified Technique for Chemisorption Measurements
74 Measurement of Molecular Mobilities of Polymers
74 Measuring Shapes of Reflectors by Microwave Holography

Books and Reports

76 Review of Fiber-Optic Electric-Field Sensors
76 Theory of a Pyrotechnically Driven Device

Cladding for Transversely-Pumped Laser Rod

Pump power would be coupled in more effectively.

NASA's Jet Propulsion Laboratory, Pasadena, California

The proposed combination of suitable dimensioning and cladding of a neodymium:yttrium aluminum garnet or similar solid-state laser would provide for the more efficient utilization of transversely-incident pump light from diode lasers. The new design would overcome some of the limitations of longitudinal- and older transverse-pumping concepts and thereby promote operation at higher output powers in the TEM_{00} mode.

The geometry of longitudinal pumping makes it difficult to scale to higher power. Transverse pumping permits the use of multiple diode-laser pumps to increase power, but, in the conventional design, transverse pumping is inefficient because much of the pump power is absorbed near the surface of the gain medium, outside the Gaussian diameter of the TEM_{00} mode (the effective diameter of the laser beam).

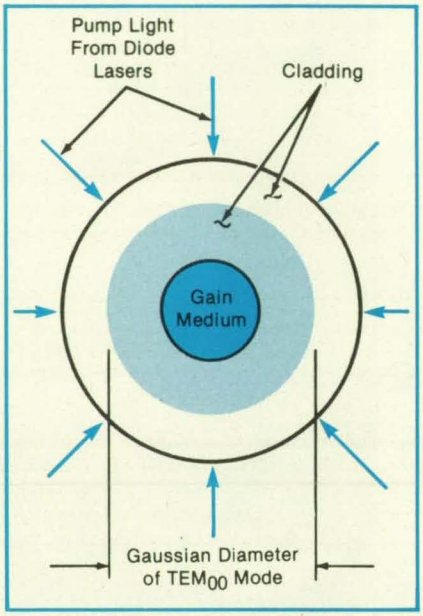
The improved laser resonator (see figure) would consist of an inner gain medium surrounded by a cladding that does not absorb at the pump or laser wavelengths and has no gain at the laser wavelength. The index of refraction of the cladding should be close (preferably equal) to that of the gain medium. The gain medium would be wide enough (typically one or more absorption lengths) so that it could absorb most of the pump energy.

One of the principal features of the new concept is that the resonator would be designed to make the Gaussian diameter of the TEM_{00} mode greater than the diameter of the gain medium, so that a significant portion of the laser beam would extend out into the inner portion of the cladding. In addition, the cladding would be made thick enough to make the TEM_{00} mode essentially zero outside the cladding. Thus, the laser beam would still be kept safely within the diameter of the resonator, but the outer portion of the beam could be reached by the pump light.

Because the pump light would be absorbed only by the gain medium and not by the cladding, all of the excitation would take place inside the Gaussian diameter. Thus, the pump power would be extracted efficiently. If the resonator is aligned correctly, it should operate only in the TEM_{00} mode because the overlap between the pump light and the TEM_{00} mode is greater than the overlap between the pump light and any higher-order transverse mode.

While the figure shows a simple round configuration, others are possible. For example, the TEM_{00} could be centered in a slab of gain medium between two slabs of cladding. Also, the laser could be pumped from only one side and a mirror used to reflect light back into the gain medium from the other side.

This work was done by Robert L. Byer and Tso Yee Fan of Stanford University for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 102 on the TSP Request Card.*



The **Improved Laser Resonator Rod for Transverse Pumping** would include a central gain medium and a transparent, gainless cladding that has (preferably) the same index of refraction.

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 14]. Refer to NPO-17355.

Making Displaced Holograms at Two Wavelengths

Two types of gradients in refraction can be measured simultaneously.

Marshall Space Flight Center, Alabama

A two-wavelength holographic system can be augmented with a pair of prisms to introduce a small separation between the holograms formed simultaneously at the two wavelengths on the holographic plate. Previously, the two holograms were overlapped on the plate, and the two images were obtained in a cumbersome two-step process: First, a photograph was taken of the reconstruction of the scene from the hologram of the first wavelength; then a second photograph was taken while reconstructing at the second wavelength. Great care had to be taken in obtaining these photographs because the differences between the spacings of the interference fringes in the two photographs were sometimes very small.

The principal use of this type of holography is in the study of flows. Gradients in the index of refraction of a fluid can be

Thomson Saginaw ball screw actuators... when only the best will do.

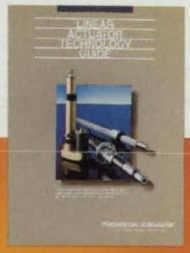
A machine's performance is only as good as its components. That's why Thomson Saginaw ball screws have been specified most in demanding aviation and aerospace applications since 1941.

Today, Thomson Saginaw is the new name for high-efficiency linear actuators – products formerly manufactured by the Actuator Products Group, Saginaw Division, General Motors Corporation. Now Thomson Saginaw is making machines more reliable in the manufacturing plant as well.

Operating at over 90 percent efficiency, Thomson Saginaw ball screws convert rotary motion to linear motion. Assemblies come in telescoping or miniature designs, with ground or rolled threads, or even lightweight tubular screws. Diameters range from 3/16 inch to 4 inches.

From milling machines to flying machines, the names "Thomson" and "Saginaw" are synonymous with reliable, quality performance. We welcome your inquiries. For a copy of our new catalog – or for expert application assistance – call us at (517) 776-4123.

Or write Thomson Saginaw Ball Screw Company, Inc., Box 9550, Saginaw, MI 48608. Telex: 71425543. Fax: (517) 776-3632.



Circle Reader Action No. 413

THOMSON SAGINAW

First in Linear Actuator Technology

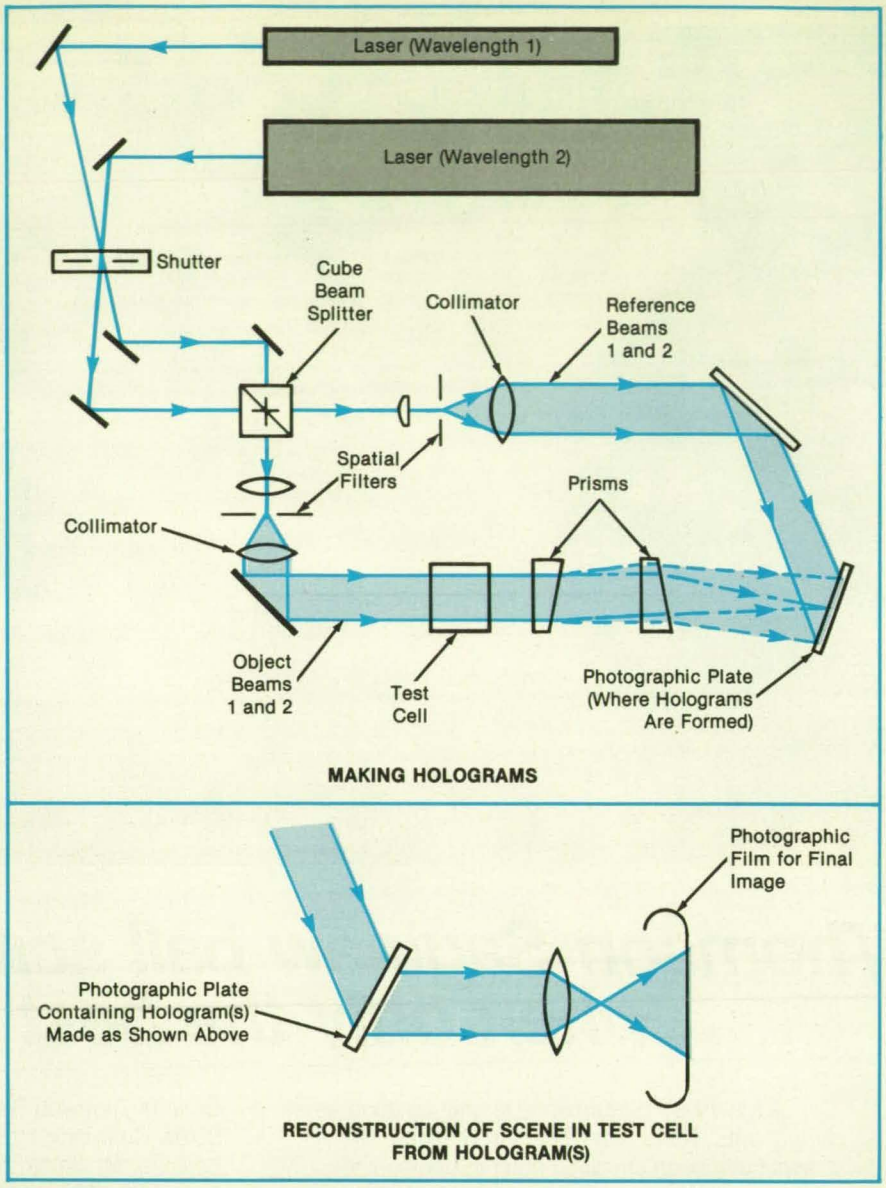
caused by variations in temperature, concentration, or both. Holography at one wavelength cannot be used to distinguish between the two types of variations. However, the difference between the spacings of fringes in photographs reconstructed from holograms that were taken simultaneously at two different wavelengths can be manipulated mathematically to determine the type of variation.

Two laser beams of different wavelengths (e.g., 623.8 and 442.0 nm) are passed through a cube beam splitter to generate an object beam and a reference beam at each wavelength. The beams are spatially filtered and collimated. The reference beams are reflected onto the photographic plate. The object beam passes through the test cell that contains the fluid, then through the prisms, which disperse the two beams to slightly different angles. Thus, the two object beams strike the photographic plate at slightly separated positions, forming two slightly separated holograms (see figure).

During reconstruction, the two images are sufficiently displaced so that one large photograph containing both can be made. Because both photographs are taken simultaneously, the sensitivity of the system is greatly increased. This system can also be used in the real-time analysis of fluid flow.

This work was done by William K. Witherow and Andreas Ecker of **Marshall Space Flight Center**. *No further documentation is available.*

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, Marshall Space Flight Center [see page 14]. Refer to MFS-28242.



Holograms at Two Different Wavelengths are displaced slightly from each other because the object beams are dispersed by the two prisms.

Electron/Ion-Scattering Apparatus

Electron and ion beams are merged, then separated for analysis.

NASA's Jet Propulsion Laboratory, Pasadena, California

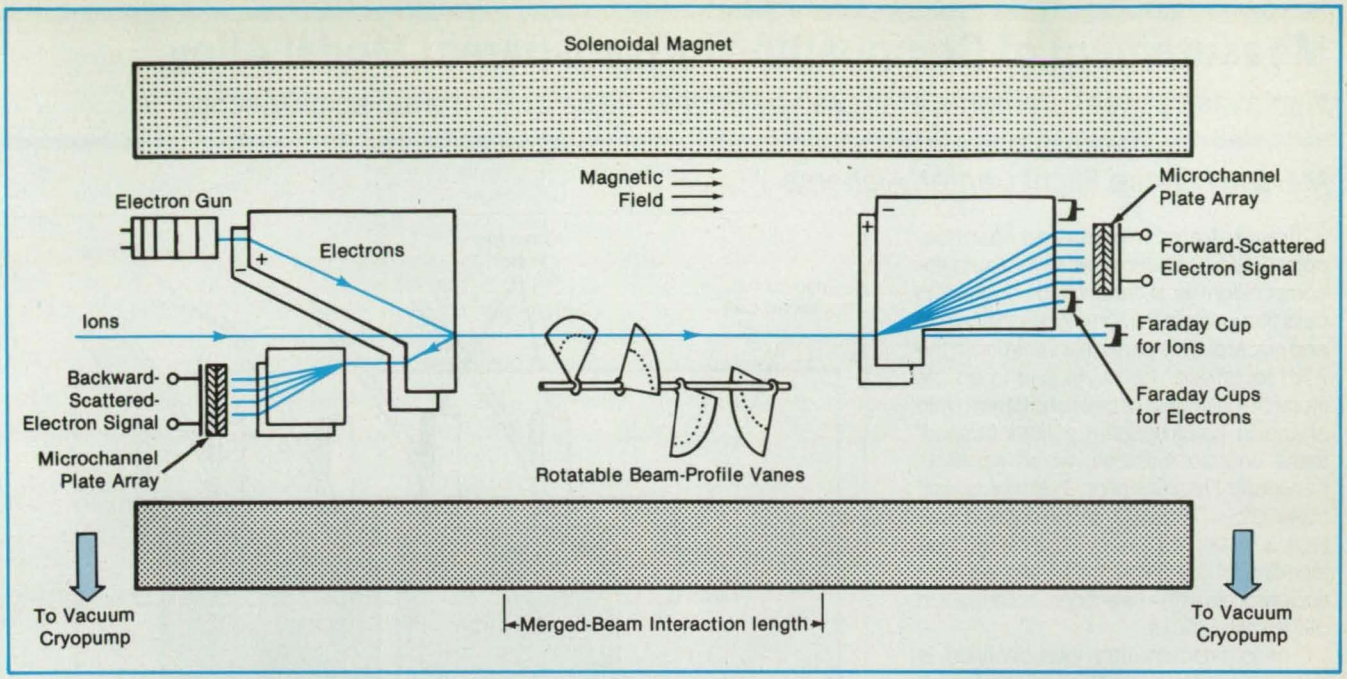
An apparatus measures cross sections and energies for inelastic scattering of low-energy electrons from positive or negative ions. Previous scattering techniques have involved angle-by-angle sequences of measurements in which only about 1 percent of the scattered electrons could be measured at each setting. In the new apparatus, most of the electrons scattered inelastically over a wide range of angles are measured simultaneously, with a consequent increase in the signal-to-noise ratio by a factor of about 10^4.

As shown in the figure, a beam of electrons and a beam of ions are aimed along a low-intensity magnetic field between a pair of electric-field plates. The crossed electric and magnetic fields hardly affect the ions but cause the electrons to drift toward the ions by trochoidal motion.

The uniform magnetic field causes the beams to remain merged in a region about 20 cm long, where they interact. At the other end of the interaction region, the beams are separated by a second set of electric-field plates. The drift angles of the electrons (or, equivalently, the positions at which the electrons strike a detector plane) depend in part on the energies left after the inelastic collisions with the ions.

Two sets of microchannel-plate, position-sensitive detectors are used to measure the electron scattering signal as a function of position (or energy loss). One set, in the forward direction, measures the signal from electrons scattered in the forward direction (scattering angles from 0° to 90°); while the second set, in the backward direction, measures the electron signals from scattering in the angular range from 90° to 180°. The scattering cross section as a function of the electron energy loss is then obtained, in part, from the incident electron and ion-beam currents and the scattered currents as measured by signals at the forward and back microchannel plates.

Rotatable vanes containing small holes



This **Merged-Beam, Trochoidal-Analysis** apparatus measures cross sections for inelastic scattering of electrons by ions.

are used to measure the overlap of the electron and ion beams in four planes, yielding an approximate three-dimensional representation of the degree of overlap. With modifications, the apparatus can also be used for measurements of excitation cross sections in neutral atoms, molecules, radicals, and excited states of atoms and molecules.

This work was done by Ara Chutjian of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 70 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 14]. Refer to NPO-16789.

Measurement of Composition in Transparent Model Alloy

Noninvasive measurements are taken by Fourier-transform infrared spectroscopy.

Marshall Space Flight Center, Alabama

Fourier-transform infrared spectroscopy (FTIR) has been used to measure the composition as a function of position in cells that contain mixtures of succinonitrile and glycerol. This particular variation of the FTIR technique was developed to enable study of the growth of cells of different solid phase in unidirectional solidification of these organic mixtures, which serve as transparent analogs of opaque monotectic metal alloys. The study of the organic analogs is expected to contribute to understanding of the formation of aligned rods and particles in the directional solidification of the metal alloys.

The organic mixture was confined in each cell between two glass cover plates 2 cm wide and 5 cm long, held 10 to 50 μm apart. The cell was pushed across the gap between a hot and a cold plate to effect directional solidification (see Figure 1). Cells were quenched rapidly at various stages of progress of the solidification front to enable subsequent determination of compositions as functions of position at those stages.

FTIR measurements were taken at a sequence of locations along the cell both before and after unidirectional solidification to reveal the changes that occur during solidification. The FTIR observation area at each location had a diameter of 100 μm. The spectral absorption peak of glycerol at a wave number of 3,359 $(cm)^{-1}$ and that of succinonitrile at 3,096 $(cm)^{-1}$ were selected to obtain the concentration of each constituent at each location (see Figure 2).

The advantage of this FTIR technique is that the redistribution of material caused by solidification can be determined after the fact, to a very fine scale. Unlike in metallographic techniques, this one is nondestructive: it is not necessary to section the specimens or even to open the cells at all. Direct correlations can be made between the FTIR observations and the microstructures visible under microscopes at the same positions. Because the specimens are not destroyed, interesting regions can be rescanned at other wavelengths or different parameters.

One disadvantage is that the glass in the cover plates might not be transparent at a wavelength of interest. This can be overcome by selection of a different glass or wavelength. The use of more than one absorption peak for each compound would increase the sensitivity. If the absorption peaks of impurities are known, the segregation of impurities caused by unidirectional solidification or zone refining could also be measured by this technique.

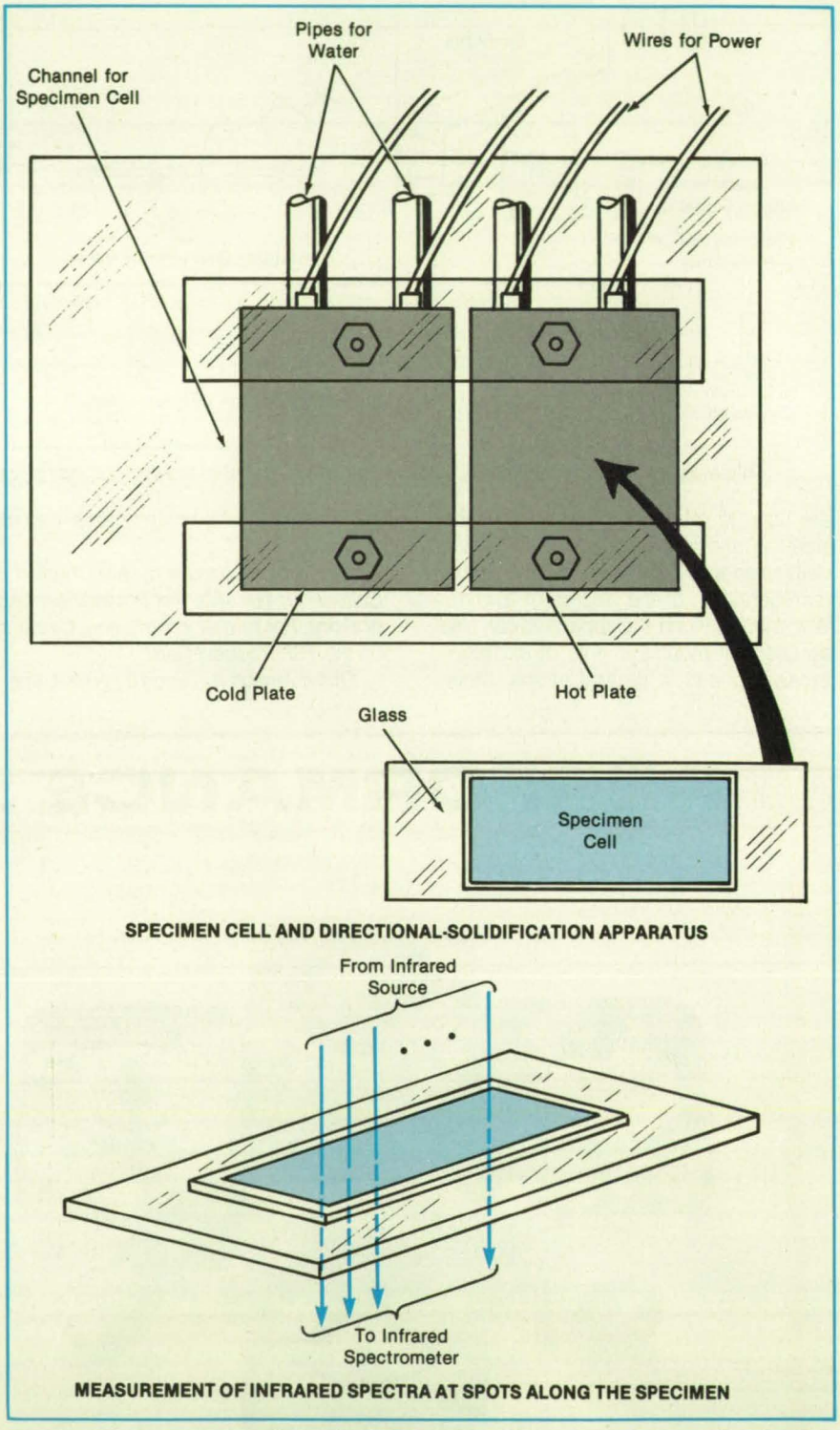


Figure 1. A **Thin Specimen of Succinonitrile/Glycerol Mixture** is probed by FTIR spectroscopy before and after directional solidification.

This work was done by William F. Kaukler, Gretchen L. Perry, and Peter A. Curreri of the University of Alabama for **Marshall Space Flight Center**. *Further information may be found in NASA TM-100317 [N88-15027], "Cellular Solidification in a Monotectic System — Center Director's Discretionary Fund Final Report."*

Copies may be purchased [prepayment required] from the National Technical In-

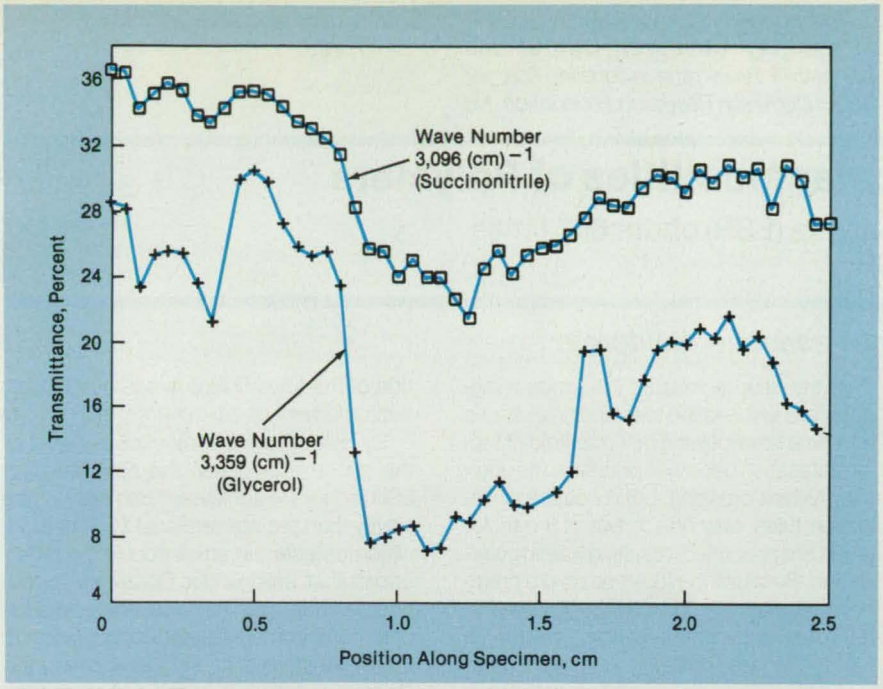


Figure 2. The **Transmittance of a Specimen at Two Wavelengths** as was measured at various positions along a specimen. Because each wavelength lies at a spectral absorption peak of one of the compounds in the specimen, these data can be used to infer the composition of the specimen as a function of position.

formation Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 14]. Refer to MFS-26079

Modified Technique for Chemisorption Measurements

A greater number of smaller adsorbate volumes yields more-accurate measurements.

Langley Research Center, Hampton, Virginia

It is frequently desirable to measure the amount of a particular gas, or adsorbate, that will chemisorb, or adsorb with chemical bonding, on a sample of some solid material. Usually, a known volume of adsorbate gas is passed through the sample to be tested, and the amount of this gas that leaves the sample is measured. Although pure adsorbate gas may be used, the adsorbate is often contained in an inert carrier like helium. When the concentration of adsorbate gas leaving the sample is very nearly equal to its initial concentration, the measurement is terminated. The amount of adsorbate chemisorbed is measured as the total amount put into the sample minus the total amount that leaves the sample. The size of the adsorbate sample volume is usually selected so that only a few samples are required to complete this measurement.

In measurements of the chemisorption of CO on a Pt/SnO_2 catalyst it has been observed that if small numbers of relatively large volumes of adsorbate gas are passed through the sample, very little removal of CO is detected. Therefore, it appears in these cases as if little or no CO has been chemisorbed on Pt/SnO_2.

However, if much smaller volumes of adsorbate gas are used, the small amount of CO that is removed is readily detected, and chemisorption can be seen clearly to have occurred. If the catalyst sample is exposed to repeated injections of adsorbate (e.g., 50 or more times), the cumulative removal of CO is found to be significant. Thus, it was found possible to measure quantitatively the chemisorption of CO on Pt/SnO_2 by means of a large number of small injections of CO, whereas the traditional use of a few fairly large volumes of gas erroneously indicated that little or no chemisorption had occurred.

This technique of using a large number of small volumes of adsorbate gas to measure chemisorption should be applicable to many gas/material combinations

other than CO on Pt/SnO_2. The volume used should be chosen so that at least 10 percent of the adsorbate gas is removed during each exposure.

This work was done by David R. Schryer of **Langley Research Center** *and Kenneth G. Brown and Jacqueline Schryer of Old Dominion Research Foundation. No further documentation is available.*
LAR-13725

Measurement of Molecular Mobilities of Polymers

Time-resolved electron-spin resonance (ESR) offers 667 times the sensitivity of conventional ESR.

NASA's Jet Propulsion Laboratory, Pasadena, California

A new molecular-probe technique is used to measure the molecular mobility of a polymer. The method is based on the use of time-resolved electron-spin resonance (ESR) spectroscopy to monitor the decay of transient nutation amplitudes from photoexcited triplet states of probe molecules with which the polymer is doped. The higher the molecular mobility of the polymer matrix, the faster the nutation amplitudes of the probe molecules decay.

It has been hypothesized that in polymer matrices, microscopic molecular mobilities are directly related to macroscopic mechanical properties. For example, the aging processes of polymers, which include cross-linking between polymer chains caused by ultraviolet radiation and the collapse of free volumes by isothermal relaxation processes, reduce molecular mobilities.

In the new technique, the probe molecules are first excited to their singlet states by a 5-ns laser pulse. Their manifold of triplet states then becomes populated through intersystem crossing, but, because of selection rules, only one or two of the triplet levels are populated, resulting in spin polarization. Because the triplet spins are created in a relatively short time, they have a high degree of coherence immediately following the laser pulse.

As time goes on, relaxation processes cause the coherence of the spins to decrease. One important relaxation process is the motion of the probe molecules caused by interaction with the surrounding polymer matrix. The higher the molecular mobility of the polymer, the faster the coherence and the related transient nutation amplitudes decrease. The transient nutation amplitude is a measure of the evolution of the ensemble average of the magnetic moment of the coherent spins.

By detecting the photoexcited states of the probe molecules, the time-resolved ESR technique achieves much higher sensitivity than the conventional ESR method, which detects the small population differences that exist under Boltzmann equilibrium conditions. The fractional population difference immediately after population of the triplet state is nearly 1.0, whereas the Boltzmann equilibrium value at room temperature is approximately 0.0015. Thus, the sensitivity of the time-resolved detection method is approximately $1.0/0.0015 \approx 667$ times that of the conventional method.

With phenazine as the probe, the new technique has been used to measure the differences in the molecular mobilities of polymethylmethacrylate samples of different average molecular weights. The differences in mobilities were correlated with the glass-transition temperatures of the samples.

This work was done by Soon Sam Kim and Fun-Dow Tsay of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 124 on the TSP Request Card.*
NPO-17216

Measuring Shapes of Reflectors by Microwave Holography

Theoretical and practical aspects of microwave holographic metrology are discussed.

NASA's Jet Propulsion Laboratory, Pasadena, California

A pair of reports discusses the theoretical foundation and recent theoretical and practical developments in the use of microwave holography to measure the surfaces of microwave antennas. (The sec-

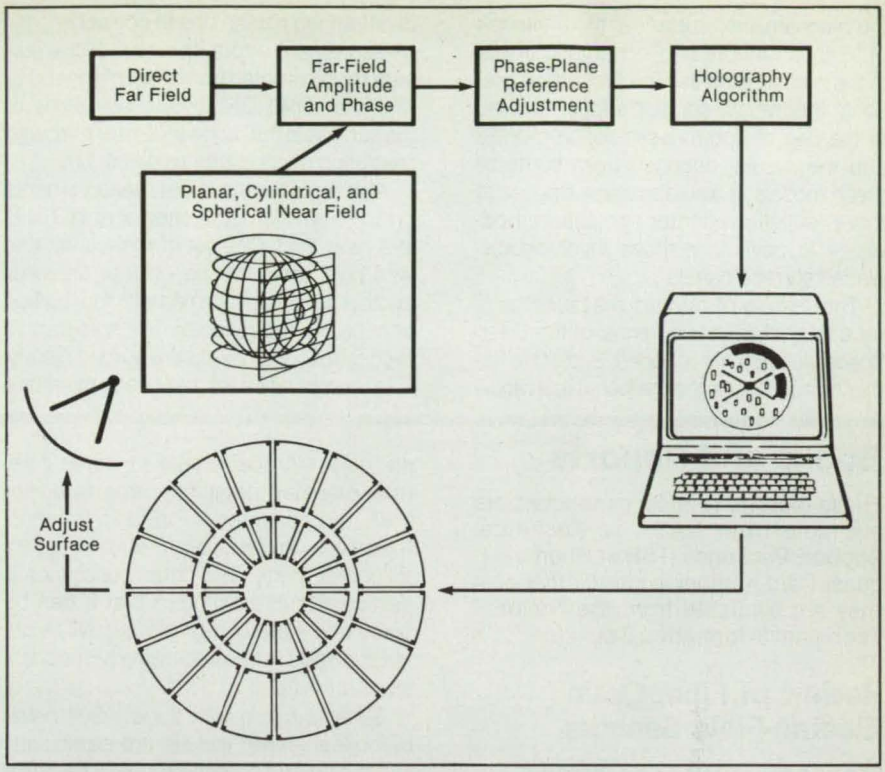
ond report is an abbreviated version of the first report.) Microwave holographic measurements provide acceptable accuracy and are more convenient and less time consuming than optical and mechanical measurements, especially where measurements have to be repeated. The microwave holographic metrology of large reflectors, first reported in 1976, has been improved into an accurate technique with potential industrial applications.

In microwave holographic metrology, one first measures the far-field amplitude and phase (or Fresnel-zone) pattern of the radiation from the antenna or else constructs the far-field quantities from near-field measurements (see figure). One then uses the Fourier-transform relationship between the far-field pattern and a function related to the distribution of electric current on the reflector or on an equivalent aperture to reconstruct that function. From the phase information in the reconstructed function, one can determine the local deviation of the surface of the reflector from the assumed paraboloid.

The first report derives the fundamental equations of the holographic technique, using the customary formulation of physical optics. It describes the conditions under which the Fourier-transform relationship applies and shows the inverse Fourier transform that yields the deviation of the surface. In practice, an approximate numerical inversion is performed by a suitable algorithm that incorporates a discrete or fast Fourier transform. The choice of algorithm depends on the nature of the available measured or simulated data; for example, if the measurements are taken at nonuniformly spaced points, one must incorporate a nonuniform-sampling interpolation formula. The texts discuss these and the related topics of choosing sampling positions and intervals to suppress spurious results.

It is also necessary to account for the infinite extent of the Fourier transform of a function that, like the current density, has finite support. Toward this end, the reports discuss an iterative procedure to synthesize far-field measurements outside the region around the antenna boresight where measurements are taken. This extrapolation may be required to increase the spatial resolution of the reconstructed current and deviation of the surface.

The first step in the iterative procedure is to extend the domain of the field-measurement region by pretending that the field is zero out there. The inverse transform is performed over the enlarged domain, and the resulting function is truncated at the edge of the antenna. The forward Fourier transform of the truncated function extends out to the unmeasured domain and there constitutes the extrapolation. Using the measured field in the measurement domain and the extrapolated field elsewhere,



Methodology of Applying Microwave Holographic Diagnosis to complex (amplitude and phase) far-field data, either directly measured (using far-field or compact ranges) or constructed from near-field measurements.

the procedure is repeated until the desired improvement is obtained.

The next topic is methods of numerical simulation of possible measurement scenarios. The objective of such studies is to establish the bounds on the accuracy of

the reconstructed surface in the presence of various random and systematic errors in the measurements. The first report presents theoretical considerations involved in the use of aperture-simulation models and the results obtained from some of these models. It also discusses the use of more-realistic reflector-simulation models — in particular, those involving displaced surface panels.

The results of far-field measurements on a 64-m-diameter antenna of the Deep Space Network are reported. Subject to further refinements in the mathematical model of diffraction effects and to corrections for measurement errors, the map of the surface reconstructed from a set of measurements at 11.45 GHz shows deviations of the surface in the range of ±5.09 mm, with resolution of panels as small as 1 m.

Also reported are novel measurements on a 156-cm-diameter reflector at 11.3 GHz in a near field. One set of measurements was performed on the original antenna; another set was performed with four bumps attached to the reflector. The holographic reconstruction showed the bumps clearly. This combination of near-field measurement and holographic reconstruction can be a very powerful diagnostic tool.

This work was done by Y. Rahmat-Samii of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain copies of the reports, "Antenna Diagnosis by Microwave Holographic Metrology" and "Microwave Holographic Metrology for Antenna Diagnosis," Circle 13 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 14]. Refer to NPO-17382 and NPO-17268.

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.

Review of Fiber-Optic Electric-Field Sensors

Piezoactive plastics stress glass fibers, causing phase shifts.

A tutorial paper reviews the state of the art in fiber-optic sensors of alternating electric fields. Because such sensors are made entirely of dielectric materials, they are relatively transparent to incident electric fields; that is, they do not distort the fields significantly.

To form a sensor, a piezoactive plastic is bonded to a single-mode cylindrical glass fiber approximately 100 μm in diameter. The reviewed configurations include a fiber bonded to the face of a plastic ribbon, a fiber embedded in a plastic ribbon, and a fiber concentrically jacketed by the plastic. The thickness of the plastic ribbon or jacket can range from 25 to 100 μm. The sensor is used as one arm of a Mach-Zehnder interferometer.

To achieve high sensitivity, the plastic used in the sensor must be permanently polarized (poled). The changes in polarization induced in the piezoactive plastic by the applied electric field result in stresses on the fiber. The resulting strains in the fiber cause optical phase shifts that are measured with the interferometer. Assuming a fiber 1 km in length and a phase-shift-detection threshold of 10^{-6} radian, the minimum detectable electric field alternating at a frequency of about 1 kHz ranges from 43 to 330 μV/m, the exact value depending on the configuration in use.

The paper presents equations that express the relationships among stress, strain, and the electric field in a piezoactive plastic and equations for the phase shift in terms of the photoelastic coefficients and strains in an optical fiber. A table lists piezoelectric coefficients for three plastics: oriented poly(vinilidene fluoride) (PVF_2), a copolymer of PVF_2 with tetrafluoroethylene, and a copolymer of PVF_2 with trifluoroethylene. The latter copolymer is particularly interesting in that it can be poled to a state of high piezoactivity without such additional processing as mechanical stretching.

Sensors made with transversely-poled cylindrical plastic jackets are particularly interesting and potentially useful because they are compact and light in weight. The useful sensitivity of such sensors is expected to extend to frequencies of several hundred megahertz. The peaks and valleys in the sensitivity of this kind of sensor as a function of frequency have been projected on the basis of previous theoretical and experimental studies of axial and radial mechanical resonances and damping in the jacket and core materials.

This work was done by Ramon P. De Paula of Caltech and Jacek Jarzynski of Georgia Institute of Technology for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Fiber Optic Electric Field Sensor Technology," Circle 130 on the TSP Request Card.*
NPO-17242

Theory of a Pyrotechnically Driven Device

Predictions and measurements of operation are presented.

A report presents relations that predict the behavior of a pyrolytically operated device. This mathematical analysis was motivated by the need to evaluate the performances of squib-driven release nuts. The analysis takes into account the most significant of the complicated interrelated processes involved in the operation of pyrotechnically driven devices and as such can aid in their design and in the evaluation of test data.

The gas mixture generated by the pyrotechnic squib is assumed to obey the ideal-gas law, from which a differential equation for the pressure is derived. The rate at which high-pressure gas is generated is assumed to be governed by a reaction-rate model, while the rate of condensation of condensable material is attributed to diffusion to the wall, governed by a simple diffusion-rate model.

The heat load of the wall is a function of heat transfer from the gas, as determined by the temperature difference between the gas and the wall, the exposed wall area, and the heat transfer coefficient of the gas mixture, as well as by radiation from the combustion products. The rate of thermal energy release by the pyrolytic gas generator is taken as the product of the heat of reaction and the rate of reaction. The change of pressure due to the work done on the piston is assumed to be that of an expanding ideal gas. Equations are also introduced to express the rate of change of volume as a function of the speed and the acceleration of the piston, as determined by the pressure, the friction forces, and the inertia of the piston.

All of these relations are combined for the numerical solution, enabling the evaluation of any or all of the physical parameters that affect the operation of the pyrotechnically driven device. These include the rates of combustion, diffusion, and conduction of heat; the area of the combustion chamber; the characteristic diffusion length; the initial volume; the mass of the piston; the static and sliding frictional forces; the travel of the piston before and after release; the ambient temperature during operation; and the ambient temperature and humidity during assembly.

The analysis yields correlations among pressure, piston travel, piston speed, gas temperature, well temperature, and heat load on the wall, as a function of time. For test cases of two types, a locked piston and a piston allowed to travel its full distance, the computed and measured correlations between pressure versus time were in good agreement.

This work was done by Robert Richter of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Analysis of the Operation of a Squib Driven Release Nut," Circle 6 on the TSP Request Card. NPO-17117*

CONTROLLING CHANGE

Lock Into Dynamic Design, Material And Processing Creativity With GE.

Total solutions from a single source. A spectrum of resin technologies. Advanced alloys, composites, copolymers. Leading-edge process development and expertise. The exclusive Engineering Design Database—unique design and analysis tools in a total system for plastics engineering.

The innovative Intelligent Automation Series from Foxboro. Enclosures of injection-molded LEXAN® resin. Cell brackets of foam-molded LEXAN resin. Internals of NORYL® and VALOX® resins. Over 300 parts in all.

Diverse technologies and application development resources—only from GE.

For more information call:
(800) 845-0600

GE Plastics

® Registered Trademarks of General Electric Company.

Circle Reader Action No. 615

Materials

Hardware Techniques, and Processes

78 Alumina-Enhanced Thermal Barrier
80 Better PFAE's From Direct Fluorination
80 Additives Lower Pickup of Moisture by Polyimides
81 Metal Oxide/Zeolite Combination Absorbs H_2S

Books and Reports

82 CdO Pretreatment for Graphite Lubricant Films
82 Degradation of Carbon/Phenolic Composites by NaOH
83 Effects of Aging on Embrittlement by Hydrogen

Alumina-Enhanced Thermal Barrier

Improved fibrous refractory composite material raises the temperature limit.

Ames Research Center, Moffett Field, California

A rigid, fibrous ceramic tile material called "alumina-enhanced thermal barrier" (AETB) extends the high-temperature capability of insulating materials. Although it is intended primarily for use in the heat shield of the Space Shuttle orbiter, the new material has obvious potential for terrestrial use in kilns, furnaces, heat engines, and other applications in which light weight and high operating temperature are specified.

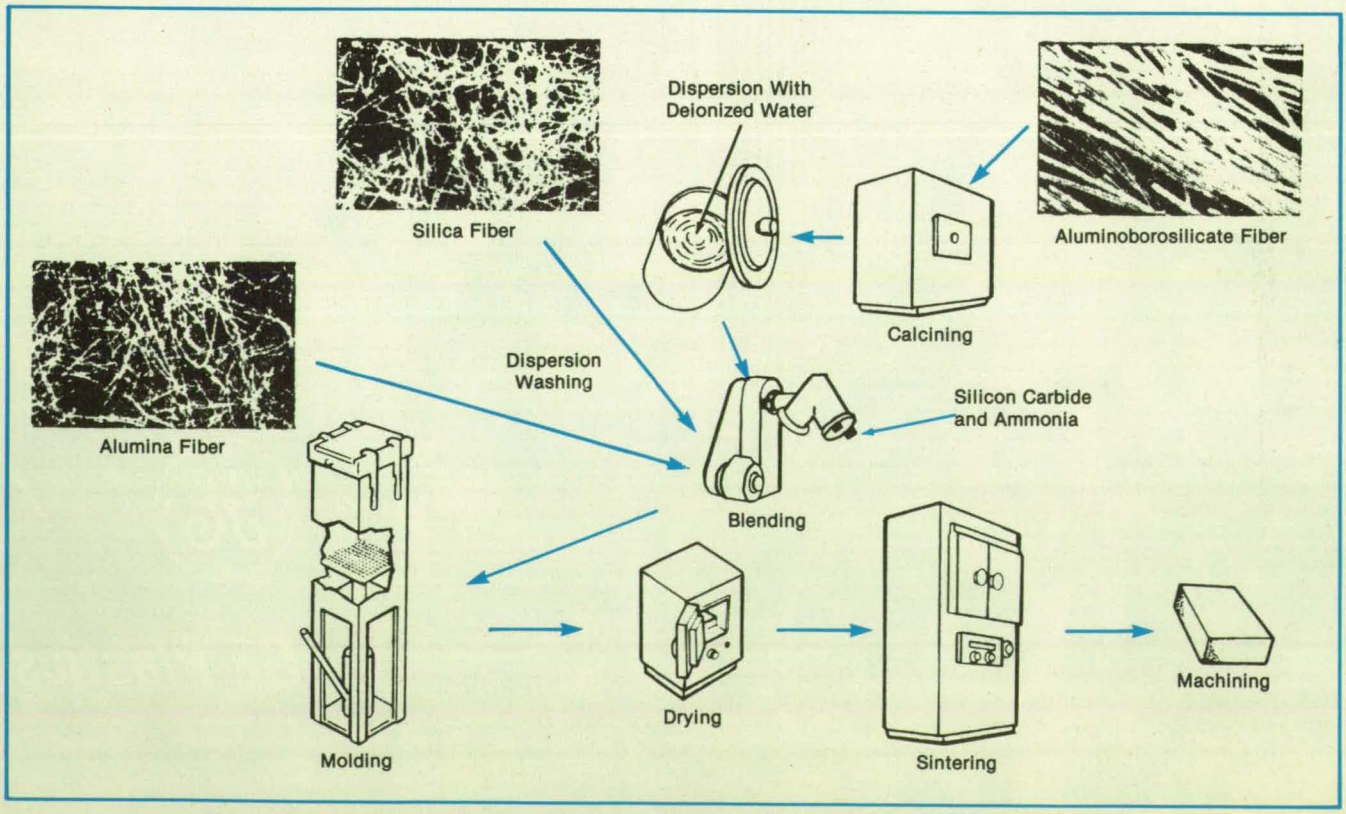
AETB results from a modification of FRCI, a lightweight aluminoborosilicate (ABS)/silica material developed to replace much of the denser all-silica high-temperature reusable surface insulation (HRSI) originally used on the Space Shuttle. AETB is made from high-purity silica fibers 1 to 3 μm in diameter, alumina fibers 2 to 4 μm in diameter, and ABS fibers 2 to 4 μm in diameter with a nominal composition of 62 percent Al_2O_3, 14 percent B_2O_3, and 24 percent SiO_2 by weight.

The proportions of ABS to silica and of alumina to the ABS/silica combination can be varied to change the properties of the AETB. With an ABS/silica ratio of less than 0.15, the AETB becomes unstable and devitrifies at high temperatures. With an ABS/silica ratio of more than 0.3, the boria from the ABS softens the silica so much that the AETB loses its high-temperature strength and insulating properties. The alumina fibers inhibit shrinkage at high temperatures, but if present at more than 30 percent by weight, they reduce the ability of the AETB to withstand thermal shock.

Tiles of AETB are now being manufactured (see figure) with a composition of 14 percent ABS, 66 percent silica, and 20 percent alumina. The fibers are processed into homogeneous billets 8.5 by 8.5 by 5.5 in. (21.6 by 21.6 by 14.0 cm) and fired at 2,425 °F (1,329 °C) for 90 min to yield rigid tiles having a density of 12 lb/ft^3 (190 kg/m^3). These have 20 percent more tensile strength than that of comparable FRCI tiles of 20 weight percent ABS and equal density. The AETB tiles provide thermal insulation at 2,700 °F (1,480 °C) — more than 300 °F (170 °C) above the maximum operating temperatures of HRSI and FRCI. The thermal conductivity of the AETB is the same as that of the FRCI. The only disadvantage of the AETB over the FRCI appears to be a slight increase in thermal expansion.

This work was done by Marnell Smith, Dan Leiser, and Howard Goldstein of **Ames Research Center**. *For further information, Circle 163 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center [see page 14]. Refer to ARC-12135.



Three Kinds of Ceramic Fibers are blended, molded, and sintered to make refractory tiles.

WE INVENTED THE SUPERALLOYS THAT WILL BUILD TOMORROW'S TECHNOLOGY.

It used to be that emerging technologies had to wait for the availability of metals and alloys to turn research projects into reality. We changed all that when we invented and developed a revolutionary, high-technology process which makes unique alloys that can't be produced by conventional melting or powder metallurgy. Inco's proprietary mechanical alloying process produces oxide dispersion strengthened superalloys — and other metal systems — that challenge tomorrow's technology instead of the other way around.

The mechanically alloyed O.D.S. products offer many advantages over conventional materials. They tolerate higher temperatures. They offer long-term metallurgical stability, corrosion resistance, and unique strength/temperature characteristics.

In aerospace, marine, chemical, nuclear, and heat treatment engineering, you can push the boundaries of your technology. And you can do it now, because we're already making the superalloys that will meet new design demands: INCONEL alloy MA 754, INCOLOY alloy MA 956, and INCONEL alloy MA 6000. We also produce aluminum and aluminum-lithium alloys by mechanical alloying.

Find out about these high-performance alloys and others under development. Write or call for our free publication, "Exceptional Alloys for Demanding Applications." In the U.S., Inco Alloys International, Inc., Huntington, West Virginia 25720. Telephone (304) 526-5755. Telex 886413. Telefax (304) 526-5441. In Europe, Inco Alloys International Ltd., Wiggin Works, Hereford, England HR4 9SL. Telephone (0432) 272777. Telex 35101. Telefax (0432) 264030.

INCO ALLOYS INTERNATIONAL

Better PFAE's From Direct Fluorination

The process yields stable and effective lubricants under proper conditions.

Lewis Research Center, Cleveland, Ohio

New low-molecular-weight perfluoroalkylethers (PFAE's) were synthesized by direct fluorination in an experimental study. The study correlated the viscosity and oxidation characteristics of the PFAE's with their structures to evaluate their suitability as high-temperature lubricants and hydraulic fluids.

PFAE's are generally well suited for these applications because of their thermal and oxidative stabilities, viscosity-vs.-temperature characteristics, elastohydrodynamic film-forming capabilities, boundary-lubricating abilities, and nonflammability. The study was aimed at determining these properties in compounds made by the direct fluorination process.

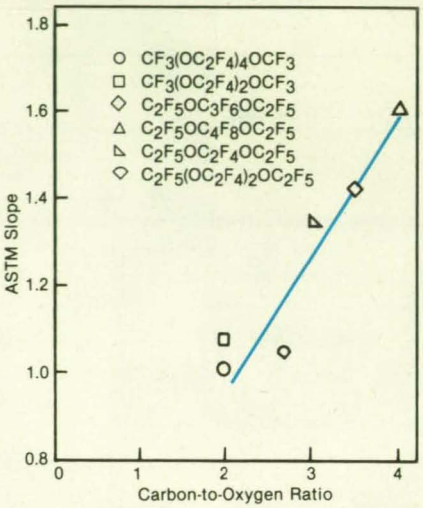
The direct fluorination process is attractive because it often involves a single-step reaction and uses cheap starting materials. Moreover, it is versatile: it can produce highly branched ethers as well as polyethers containing more than two sequential carbon atoms in the polymer chains. Such molecules cannot be made by conventional techniques.

In a typical direct fluorination process, the liquid to be treated is reacted with an atmosphere that contains fluorine. The products of the reaction are collected in a cold trap, and the desired product is separated from the others by atmospheric distillation.

The study showed that for the best viscometric properties (that is, the least variation of viscosity with temperature), a PFAE should have a low carbon-to-oxygen ratio (see figure) and a low degree of branching. In addition, the more-highly-branched PFAE fluids are less resistant to oxidation than are those containing single pendant trifluoromethyl groups or those containing no branching at all. It is postulated that a single pendant group attached to a carbon atom adjacent to an oxygen atom in a PFAE may stabilize the polymer by sterically protecting the oxygen in the backbone of the molecule.

This work was done by W. R. Jones, Jr., of **Lewis Research Center** *and T. R. Bierschenk of Exfluor Research Corp. Further information may be found in NASA TM-87284 [N86-25475/NSP], "The Preparation of New Perfluoroether Fluids Exhibiting Excellent Thermal-Oxidative Stabilities."*

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-14613



The **ASTM Slopes of Unbranched PFAE's Increase** with increasing carbon-to-oxygen ratio of PFAE's made by direct fluorination. (The ASTM slope is a measure of the decrease of viscosity with temperature: a lower slope indicates a viscometrically superior lubricant.)

Additives Lower Pickup of Moisture by Polyimides

Positron-annihilation tests show increased densities.

Langley Research Center, Hampton, Virginia

A series of new polyimide-processing additives decrease the free volume and the pickup of moisture in a new 422 copolyimide. The physical properties of several copolyimides synthesized from linear BDSDA/ODA/MPD (see table) homopolymers have been investigated previously, by positron-annihilation spectroscopy, with results indicating that the copolyimides have a unique transition molecular structure characterized by higher electron densities and stronger bonds. The transition structure permits both physical and chemical entry of water molecules into it.

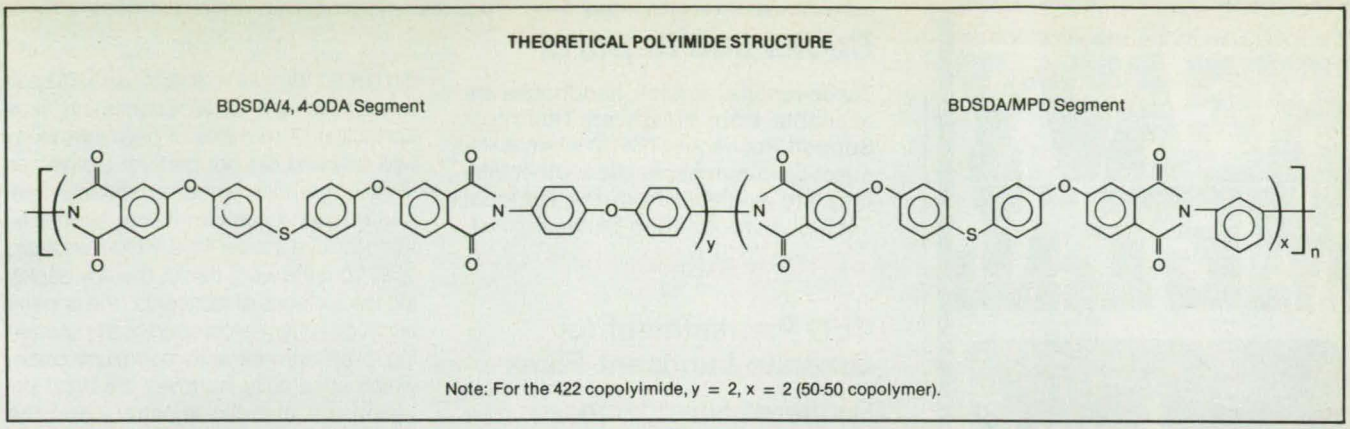
Following these discoveries, we decided to study the effects of several short-chain processing additives on the properties of the optimal BDSDA/ODA/MPD [422] copolyimide (see figure). The compositions were prepared by imidizing a mixture of a high-molecular-weight copoly(amic acid) of the BDSDA/ODA/MPD [422] resin with various amic acid additives at a concentration of 5 to 10 percent by weight.

An examination of the saturation moisture contents shows that the free volume in the [422] copolyimide decreases systematically as 5 percent BDSDA/AN, ODA/PA, and MPD/PA are added, respectively. It thus appears that MPD/PA is the most effective short-chain additive for making the [422] copolyimide more compact and, consequently, denser; but doubling the concentration of BDSDA/AN appears to have a disproportionately large effect on free volume in the base polymer. Positron-annihilation results are also consistent with this large reduction in free volume. A concomitant increase in the intensity of the long-lifetime component suggests that most of the free electrons have been engaged in strengthening the electronic bonds between various segments of the molecular chains.

BDSDA	4′4′-bis(3,4-dicarboxyphenoxy)diphenylsulfide dianhydride
ODA	4,4′-diaminodiphenyl ether
MPD	1,3-diaminobenzene(m-phenylene diamine)
PA	phthalic anhydride
AN	aniline
BDSDA/AN	BDSDA end-capped with aniline
ODA/PA	ODA end-capped with phthalic anhydride
MPD/PA	MPD end-capped with phthalic anhydride
BDSDA/ODA/MPD	a copolyimide of BDSDA and ODA plus MPD in a molar ratio of 4:2:2, hence [422]

The **Abbreviations Used in the Text** are defined above.

This work was done by Terry L. St. Clair and Jag J. Singh of **Langley Research Center** *and J. Richard Pratt of Planning Research Corp. Further information may be found in NASA TM-89023 [N87-12614], "In-*



The BDSDA/ODA/MPD Copolyimide exhibits a decrease in free volume after a small addition of BDSDA end-capped with aniline and of ODA and MPD, both end-capped with phthalic anhydride.

vestigation of the Effects of Short Chain Processing Additives on Polymers."

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.

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 14]. Refer to LAR-13679

Metal Oxide/Zeolite Combination Absorbs H_2S

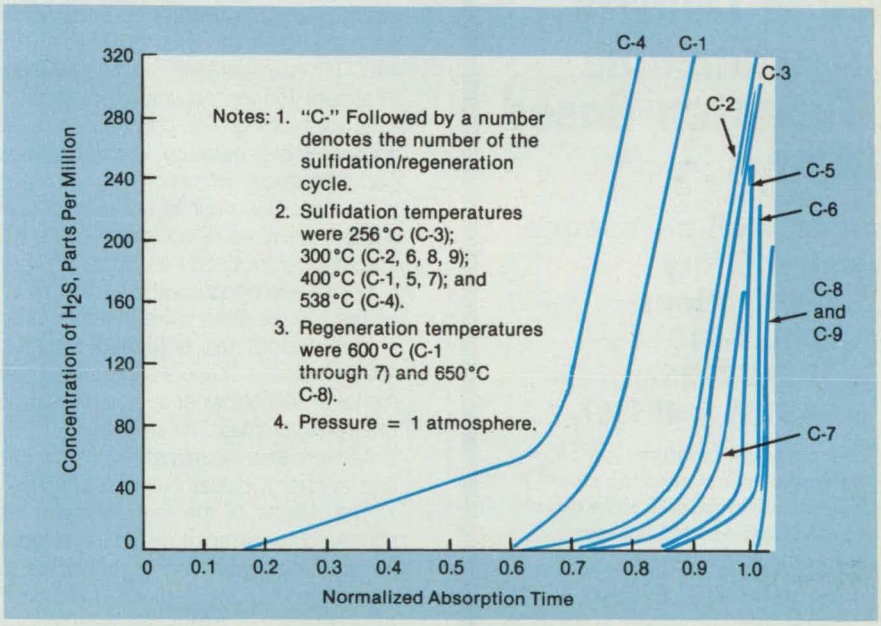
A regenerable absorber cleans up hot gas streams.

NASA's Jet Propulsion Laboratory, Pasadena, California

Mixed copper and molybdenum oxides supported in the pores of zeolite have been found to remove H_2S from a mixture of gases rich in hydrogen and steam, at temperatures from 256 to 538 °C. Such an absorber of H_2S is needed to clean up gas streams from fuel processors that incorporate high-temperature steam reformers or hydrodesulfurizing units.

Zeolites were chosen as the supporting materials because of their high porosity, rigidity, alumina content, and variety of both composition and form. The zeolite pellets were impregnated with basic cupric carbonate and ammonium molybdate dissolved in concentrated ammonium hydroxide. After drying in an oven at 110 °C, the pellets were impregnated again. This process was repeated 8 to 10 times. The material was then calcined in an oxygen-rich atmosphere in a muffle furnace at 600 °C for 3 hours, yielding zeolite impregnated with $CuO \cdot \frac{1}{3}MoO_3$.

The sorbents were alternately exposed at various temperatures to a flowing sulfidation-gas mixture of $1H_2S/20H_2/25H_2O/54N_2$, then regenerated at a temperature of 600 to 650 °C in a mixture of $70N_2/30$ air (numbers indicate molar percentages). Of the supporting materials tested, the best H_2S-removal performance was shown by 4Å zeolite (see figure). Most of the sulfidation reactions involve the conversion of CuO to Cu_2S; molybdenum sulfides are usually not seen. The sorbent maintains a high capacity for sulfur — in stoichiometric proportion to the copper content — for as many as 12 sulfidation/regeneration cycles.



The **Concentration of H_2S** in the gas after passage through the zeolite/$CuO \cdot \frac{1}{3}MoO_3$ sorbent is much lower than the concentration (1 percent) in the entering gas. The normalized absorption time is defined as the time divided by the time that corresponds to the theoretical conversion of all of the CuO to Cu_2S.

This work was done by Gerald E. Voecks and Pramod K. Sharma of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 150 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

Edward Ansell
Director of Patents and Licensing
Mail Stop 301-6
California Institute of Technology
1201 East California Boulevard
Pasadena, CA 91125

Refer to NPO-17099, volume and number of this NASA Tech Briefs *issue, and the page number.*

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.

CdO Pretreatment for Graphite Lubricant Films

Sputtered films decrease friction and increase endurance.

The lubrication of rubbing steel surfaces with graphite can be improved by sputtering cadmium oxide onto the surfaces, according to a report. Previous investigations of surface pretreatments and of the tribological effects of cadmium oxide had prompted speculation as to whether cadmium oxide might enhance the lubricant effect of graphite by increasing the adherence of the graphite to the metal surface or by contributing to the film-forming properties of the graphite.

In the investigation described in the report, sputtered films of cadmium oxide were applied to sandblasted disks of AISI 440C HT stainless steel, as a surface pretreatment for the application of graphite films by rubbing. For comparison, other disks were pretreated by rubbing the sandblasted surfaces with cadmium oxide prior to the rubbing of graphite. For another comparison, mixtures of cadmium oxide and graphite were rubbed into the sandblasted but otherwise nonpretreated surfaces.

The treated disks were tested in a pin-on-disk tribometer, equipped with SAE 1045 steel pins. These tests yielded coefficients of friction, wear lives, and pinwear rates and volumes. The wear tracks on the disks were also examined microscopically and by energy-dispersive x-ray analysis.

The results of the tests showed that sputtered cadmium oxide films and graphite lubrication gave mean endurance (as measured in sliding distance until a coefficient of friction of 0.25 is reached) about 20 times as long and mean pinwear rates about one one-hundredth of those of the same surfaces with graphite lubrication alone but without pretreatment. Pretreatment with cadmium oxide also proved better than the best commercial pretreatment (zinc phosphate), with endurance and pinwear rates increased by a factor of 7 and decreased by a factor of 10, respectively. While the various pretreatments had pronounced effects on endurance, they gave nearly equivalent coefficients of friction.

The disks that were pretreated by rubbing with cadmium oxide exhibited improvements over nonpretreated disks but did not perform as well as those with sputtered cadmium oxide. Lubricating films consisting of mixtures of cadmium oxide and graphite did not perform as well as films of graphite alone on surfaces pretreated with cadmium oxide; such mixtures formed thicker films, which tended to spall from the wear tracks, thereby depleting the surfaces of lubricants. The primary beneficial effect is obtained by the sputtering pretreatment with cadmium oxide, which apparently improves the bond between the metallic substrate and the graphite.

This work was done by Robert L. Fusaro of **Lewis Research Center**. *Further information may be found in NASA TM-87300 [N86-25473], "Sputtered Cadmium Oxide as a Surface Pretreatment for Graphite Solid Lubricant Films."*

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-14635

Degradation of Carbon/Phenolic Composites by NaOH

NaOH degrades both the carbon and the phenolic components of carbon/phenolic laminates.

The effects of the sodium hydroxide contamination level on physical and chemical properties of phenolic resin and carbon/phenolic composites are described in a report. Prior studies focused on the effect of sodium contamination on the carbon fibers in these materials.

As the concentration of sodium hydroxide in one-stage (Borden's SC-1008 or equivalent) phenolic resin is increased, the gel times are reduced, the polymerization onset temperature is lowered (according to differential scanning calorimetry), and the polymerization reaction rate is increased. These results are consistent with the known ability of sodium hydroxide to convert phenol to the more reactive phenolate anion, which perhaps results in an increased incidence of parasubstitution. According to gel-permeation chromatography, the average molecular weight of the polymer decreases, perhaps because of sodium hydroxide-catalyzed breakdown of the oligomers. Finally, the resin viscosity increases with the sodium content.

When resin-impregnated laminated cloths (prepregs) are squeezed in a hot press, the flow of resin out of the prepregs decreases with increasing sodium con-

tent. This decrease is consistent with the reduction in gel time caused by the sodium hydroxide. A greater sodium hydroxide concentration also leads to an increase in moisture absorption by the prepreg under ambient conditions and to an increase in the phenol efflux measured during the tests for volatiles.

Thermogravimetric analyses of carbon broad goods and of carbon/phenolic laminates show a striking increase in weight loss with increasing sodium concentration. In the case of the laminates, the weight loss is much greater in the presence of a normal (50 ml/min) airflow than in the absence of an airflow.

Mechanical-property tests showed that an increase in sodium content apparently decreases the compressive modulus and flexural strength and increases the shear strength of the composites. The failure mechanism (shown by optical and scanning-electron microscopy) is related to sodium concentration, and transitions among failure mechanisms are observed in the cases of shear and flexural modes. Results from thermogravimetric analyses indicate that higher levels of sodium may also lead to matrix degradation at lower temperatures.

This work was done by H. M. King, M. L. Semmel, and B. E. Goldberg of **Marshall Space Flight Center** *and Raymond G. Clinton, Jr., of Georgia Institute of Technology for Marshall Space Flight Center. To obtain a copy of the report, "Investigation of the Effects of NaOH Dopant Level on the Physical and Mechanical Properties of Carbon/Phenolic Composite Material," Circle 55 on the TSP Request Card. MFS-27099*

Effects of Aging on Embrittlement by Hydrogen

Concentration of hydrogen at grain boundaries determines the mode of fracture.

A report discusses a study of grain-boundary fracture of hydrogen-charged nickel under conditions in which the hydrogen is immobile. Thermally-charged nickel specimens were aged at several temperatures for various periods of time to allow hydrogen to diffuse. The specimens were then quenched and tested in liquid nitrogen (at a temperature of 77 K) so that the distribution of hydrogen produced by aging would be maintained.

The study showed that embrittlement is a function of bulk hydrogen concentration and the thermal history of the hydrogen-charged nickel. The bulk concentration and the thermal history apparently control the concentration of segregated hydrogen at grain boundaries and thus govern intergranular fracture.

The test data show that the equilibrium concentration of hydrogen at grain boundaries can be expressed by Fermi-Dirac statistics. The mathematical model of concentration as a function of aging time can be developed from classical diffusion theory.

The binding enthalpy of hydrogen to grain-boundary trapping sites is 11.6 kJ/mole (0.12 eV/atom). The transition from ductile fracture to completely intergranular fracture occurs at hydrogen concentrations from 5 to 15 percent at the grain boundaries. Hydrogen-rich layers about 300 Å thick develop at nickel grain boundaries.

This work was done by D. H. Lassila of **Ames Research Center** *and H. K. Birnbaum of the University of Illinois. Further information may be found in NASA TM-88207 [N86-26416], "Hydrogen Embrittlement of Nickel: Modeling of the Effect of Diffusive Segregation of Hydrogen on Intergranular Fracture."*

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.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center *[see page 14].* *Refer to ARC-11762.*

Computer Programs

84 Calculating Buckling and Vibrations of Lattice Structures

85 Optimization of Simulated Trajectories

86 Optimizing Simulated Trajectories of Rigid Bodies

87 Computing Flutter Boundaries

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 1988 *COSMIC Software Catalog*, containing descriptions and ordering information for available software.

COSMIC is part of NASA's Technology Utilization Network.

COSMIC® — *John A. Gibson, Director*, (404) 542-3265
The University of Georgia, 382 East Broad Street, Athens, Georgia 30602

Computer Programs

These programs may be obtained at a very reasonable cost from COSMIC, a facility sponsored by NASA to make computer programs available to the public. For information on program price, size, and availability, circle the reference number on the TSP and COSMIC Request Card in this issue.

Mechanics

Calculating Buckling and Vibrations of Lattice Structures

Exact member theory accounts for distributed masses and axial forces.

The BUNVIS-RG computer program is designed to calculate vibration frequencies or buckling loads of prestressed lattice structures that might be used in outer space. For buckling and vibration problems, BUNVIS-RG can calculate the dead-load axial forces caused in the members by any combination of externally-applied static point forces and moments at the nodes, axial preload or prestrain in the

members, and such acceleration loads as those due to gravity.

In effect, such preload and prestrain calculations are conducted under the assumption that a structure is assembled with the preloads and prestrains in its members (given by data) and with its nodes clamped and that the nodes are then released to distribute the prestress through the structure. Gravity or any other acceleration loading of a structure is accounted for by sharing the mass of each member or substructure according to the location of its center of gravity between the nodes at its ends and converting to forces by using the appropriate acceleration.

The program uses exact member theory for beams and taut cables to account correctly for distributed mass and axial force. The algorithm involves a stiffness matrix that is a function of the eigenparameter. Gauss elimination is applied to this matrix at a trial value of the eigenparameter to enable the algorithm to determine the number of eigenvalues exceeded, and this is repeated for successive trial values of the eigenparameter.

In previous applications, these trial values have often been chosen by a bisection routine. However, BUNVIS-RG has a new accelerated-convergence routine that uses the determinant of the stiffness matrix and retains the certainty of the algorithm, but is about twice as fast. Member equations used are the classically exact ones obtained by solving the appropriate differential equations.

The BUNVIS-RG program can do the following:

- Find a set of data-specified eigenvalues;
- Determine static loading, including prestress and acceleration;
- Do a preliminary calculation to determine that the structure is stable under dead load alone;
- Use a random-force-vector method to find the shapes of vibrational modes;
- Resequence nodes to minimize bandwidth and thus reduce solution times;
- Treat stayed columns as substructures in a very rapid and efficient manner from a point of view of input and execution;
- Treat repetitive geometry in an efficient manner by analyzing only the basic repeating portion; and
- Treat elastic and offset connections between members and nodes.

Complex and real versions of BUNVIS-RG can be created with a one-line change in the main program source code — activate or deactivate, respectively, the FORTRAN COMPLEX type statement that declares several entities as complex. The real version of the program executes three to five times faster and will put out a message when the complex version, which uses complex arithmetic for some calculations, must be used to obtain the solution to a given problem.

BUNVIS-RG is a FORTRAN 77 computer program that has been implemented on a CDC CYBER computer under NOS 2.+ and on a VAX computer under VMS 4.5. The central memory required for CDC versions with active graphics routines is specified in CDC words (one CDC word = sixty 6-bit bytes): complex version, 225,726 (octal) words; real version, 205,663 (octal) words. The NASA-Langley graphics routines use at least 7,423 (octal) words of these field lengths. The virtual memory allotted for VAX versions with dummy graphics routines is as follows: complex version, 1,041,408 8-bit bytes; real version, 639,488 8-bit bytes. The program was released in 1988.

This program was written by M. S. Anderson, B. J. Durling, and C. L. Herstrom of **Langley Research Center**; *F. W. Williams, J. R. Banerjee, and D. Kennedy of the University of Wales Institute of Science and Technology; and D. B. Warnaar of Delft University of Technology. For further information, Circle 69 on the TSP Request Card.*

LAR-13876 (CDC version) and LAR-13791 (VAX version)

Optimization of Simulated Trajectories

A program has the flexibility to treat a variety of problems.

The Program To Optimize Simulated Trajectories (POST) provides the ability to target and optimize trajectories of a point-mass powered or unpowered vehicle operating at or near a rotating planet. The program has been used successfully to solve a wide variety of problems in the mechanics of atmospheric flight and transfer between orbits. The generality of the program is demonstrated by its capability to simulate up to 900 distinct trajectory phases, including generalized models of planets and vehicles. This flexible simulation capability is augmented by an efficient discrete-parameter-optimization capability that includes equality and inequality constraints.

The basic flexibility of simulation is achieved by decomposing the trajectory into a logical sequence of simulation segments. Segments of trajectories, referred to as phases, enable the accurate and efficient mathematical modeling of both the physical and the nonphysical aspects of the simulation.

The computational routines can be categorized according to five basic functional elements. These elements are the planet module, the vehicle module, the trajectory-simulation module, the trajectory auxiliary calculations module, and the targeting/optimization module.

The planet module is composed of a surface model, a gravitational model, an atmospheric model, and a winds model. The

Circle Reader Action No. 382

shape of the planet is oblate. These models define the environment in which the vehicle operates.

The vehicle module comprises the mass-properties, propulsion, aerodynamic, aeroheating, and steering (guidance) models. These models define the basic vehicle-simulation characteristics.

The trajectory-simulation module consists of the event-sequencing module that controls the cycling of the program, the table-interpolation routines, and several standard numerical integration techniques. These models are used in numerical solutions of the equations of motion.

The trajectory auxiliary calculations module provides such output calculations as conic parameters; Keplerian-orbit error calculations; auxiliary position, velocity, and range calculations; determination of Sun shadows; simulation of multiple vehicles; radio guidance coordinates; and tracking data.

The targeting/optimization module provides a general discrete-parameter-iteration capability. The user selects the optimization variable, the dependent variables, and the independent variables from a list of more than 400 program variables. An accelerated projected-gradient algorithm is used as the basic optimization technique. This algorithm is a combination of Rosen's projection method for nonlinear programming and Davidson's variable-metric method for unconstrained optimization.

The documentation includes a complete troubleshooting guide, including error messages and three sample problems: (1) Space-Shuttle ascent, (2) Space-Shuttle entry, and (3) orbital maneuvers. POST has been implemented as a batch program on a CDC CYBER 170/175 computer under NOS and a DEC VAX computer under VMS 4.x. The VAX version, written in FORTRAN 77, has a central-memory requirement of 608,000 bytes. The CDC version, written in FORTRAN V, requires 216,404 octal words.

This program was written by Garry L. Brauer, David W. Olson, and Robert Stevenson of Martin Marietta Corp. for **Langley Research Center**. *For further information, Circle 68 on the TSP Request Card.*

LAR-13938 (VAX version) and LAR-13953 (CDC version)

Optimizing Simulated Trajectories of Rigid Bodies

A three-degree-of-freedom program is extended to six degrees of freedom.

6D POST is a general-purpose, six-degree-of-freedom computer program for the optimization of simulated trajectories of rigid bodies. It is a direct extension of the three-degree-of-freedom POST program described in the preceding article (LAR-13938 and LAR-13953). The 6D POST program models the trajectory of a powered or unpowered vehicle operating at or near a rotating planet. The program can be used to solve a variety of performance, guidance, and flight-control problems for atmospheric and orbital vehicles.

The principal features of 6D POST are an easy-to-use namelist-type input procedure (which significantly reduces input-file-setup time for studies requiring the normal large amount of input data), an integrated set of flight-control-systems (FCS) modules, and a general-purpose discrete-parameter targeting and optimization that includes equality and inequality constraints.

Typical applications of 6D POST include the simulation and analysis of guidance and flight-control systems, analyses of loads and types of dispersion, general-purpose six-dimensional simulation of controlled and uncontrolled vehicles, and validation of six-dimensional performance.

As in POST, the basic flexibility of simulation is achieved by decomposing the trajectory into a logical sequence of simulation segments called "phases." Also as in POST, computational routines are categorized according to five basic functional elements; namely, the planet module, the vehicle module, the trajectory-simulation module, the trajectory auxiliary calcula-

tions module, and the targeting/optimization module. The planet module is similar to that in POST. The vehicle module is similar to that in POST, but also includes an airframe model, a navigation-and-guidance model, and a flight-control-system model. The planet, trajectory-simulation, trajectory auxiliary calculations, and targeting/optimization modules are similar to those in POST.

The documentation includes a complete troubleshooting guide, including error messages and a Space Shuttle reentry sample problem. 6D POST has been implemented as a batch program on a CDC CYBER 170/175 computer under NOS and a DEC VAX computer under VMS 4.x. The VAX version, written in FORTRAN 77, requires 660,000 bytes of central memory. The CDC version, written in FORTRAN V, requires 227,733 octal words.

This program was written by Garry L. Brauer, David W. Olson, and Robert Stevenson of Martin Marietta Corp. for **Langley Research Center**. *For further information, Circle 67 on the TSP Request Card.*
LAR-13939 (VAX version) and
LAR-13954 (CDC version)

Computing Flutter Boundaries

This program calculates aeroelastic responses of mistuned airfoils.

The MISER2 computer program calculates the flutter boundaries and aeroelastic response of a cascade of arbitrarily mistuned airfoils. This program is based on a typical section formulation incorporating incompressible, subsonic and supersonic cascade, unsteady aerodynamic theories. Each blade is modeled as a two-degree-of-freedom oscillator that has inertial coupling between the bending and torsional motions.

It is possible to consider any type of mistuning; for example, blade-to-blade variations of the uncoupled bending and torsional frequencies of the blade, damping ratios, mass ratios, elastic axes, and positions of centers of gravity. Both the tuned and mistuned, uncoupled bending and torsion cases, in addition to the tuned, coupled bending and torsion case, can be treated as special cases of this program.

This program now operates on the NASA Lewis Research Center IBM 370/333 computer with time-sharing system (TSS). The source code is written in FORTRAN 4. Subroutine calls are made to the IMSL package.

This program was written by Robert E. Kielb and Krishna Rao V. Kaza of **Lewis Research Center**. *For further information, Circle 65 on the TSP Request Card.*
LEW-14380

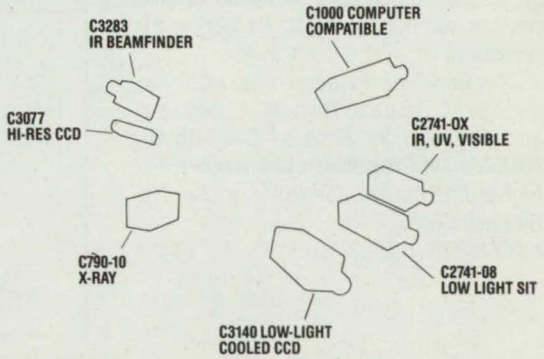
Critical problems demand critical solutions. At Hamamatsu, we provide solutions with our line of video problem solvers.

From "standard" infrared and x-ray imaging cameras to "custom" OEM cameras, Hamamatsu's advanced video technology helps you meet a universe of challenges — solving critical measurement and inspection requirements for scientific and industrial applications. And we've done it with a quality of design, a quality of performance and a quality of support unprecedented in the industry.

In industrial microscopy, IC inspection, real-time x-ray, laser and LED beam profiling and low-light phosphor imaging, to mention just a few, Hamamatsu cameras are leading the exploration of new video frontiers.

When you're working at the leading edge of technology, you need equipment that's already there. And it's available today...

From the systems company of Hamamatsu Photonics!



HAMAMATSU
PHOTONIC SYSTEMS

Video Products Division
Suite H, 40 Bear Hill Road, Waltham, MA 02254
(617) 890-3444

Japan: 0534/35-1562 Sweden: 0760-32190
France: (1) 46 55 47 58 UK: 01-367-3560
West Germany: 08152/375-55

Circle Reader Action No. 532

Sensing the Position of a Piston in a Cylinder

A moving piston covers and uncovers pressure taps.

NASA's Jet Propulsion Laboratory, Pasadena, California

The position of a piston in a cylinder is determined by a series of ports and pressure-actuated electrical switches. The position-sensing scheme was developed to help control the movement of the piston, which delivers fist-size objects to an automatic mechanism at a rate of less than 1 per second. The piston can be driven by either pressurized gas or hydraulic fluid.

The position sensors have only fluid connections to the cylinder. If the cylinder or piston has to be removed, it is not necessary to disturb the electrical connections to the switches. The scheme is also useful when electrical sensors would create a hazard or cause interference.

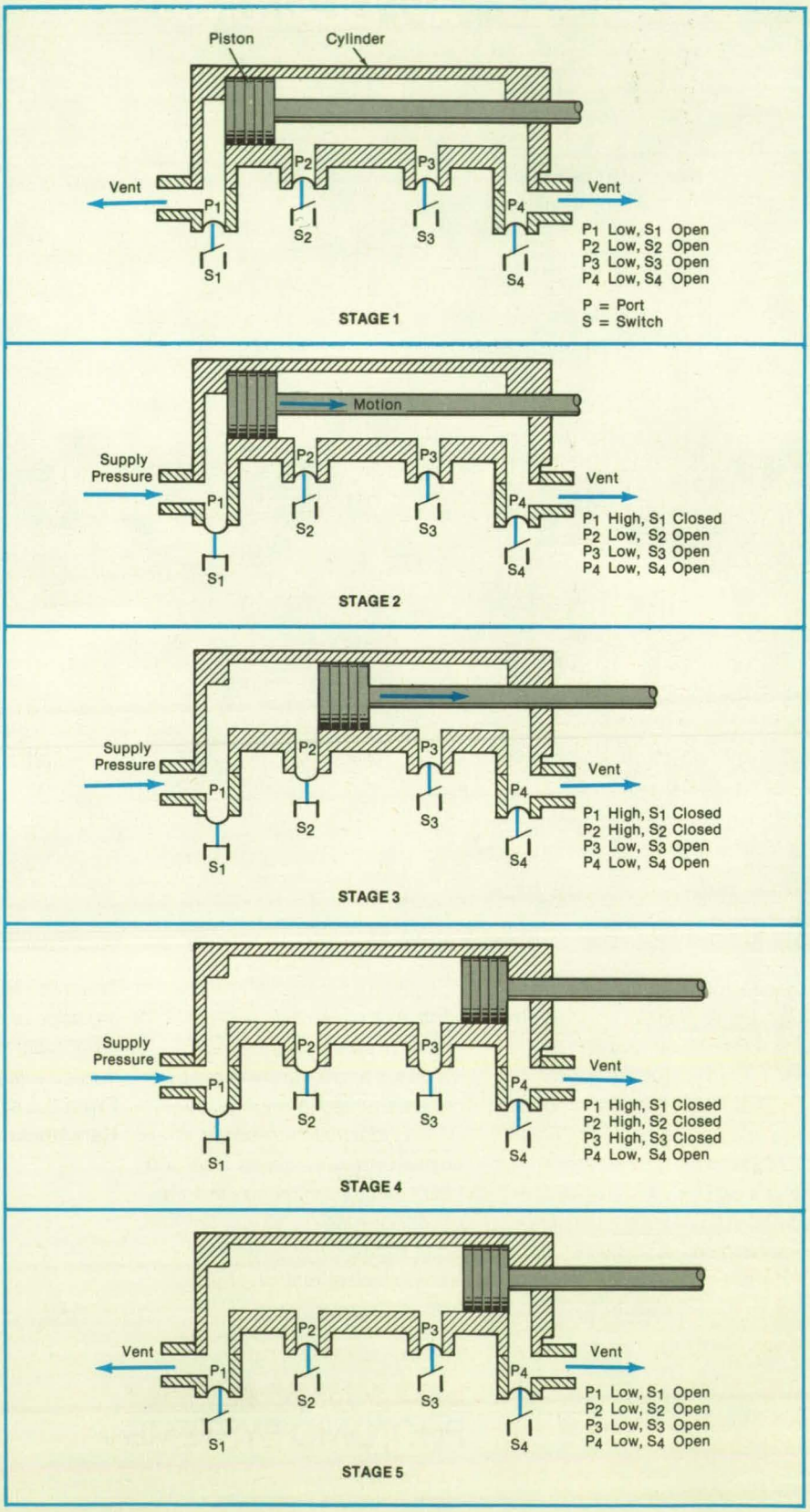
When the piston is at the left end of the cylinder (see figure), and pressure is not applied, position-sensing switches S_1 through S_4 are open. When pressure is applied to port 1, switch S_1 closes, while the other switches remain open. This indicates that the piston is ready to move toward the right. As the piston moves, it progressively exposes ports 2 and 3 to the supply pressure so that switches S_2 and S_3 close progressively.

After the piston reaches the right limit of its travel, both ends of the cylinder are vented, and all switches open under the low cylinder pressure. Pressure is then applied to port 4 so that the piston starts moving left, and the switch-closing sequence occurs in the reverse direction.

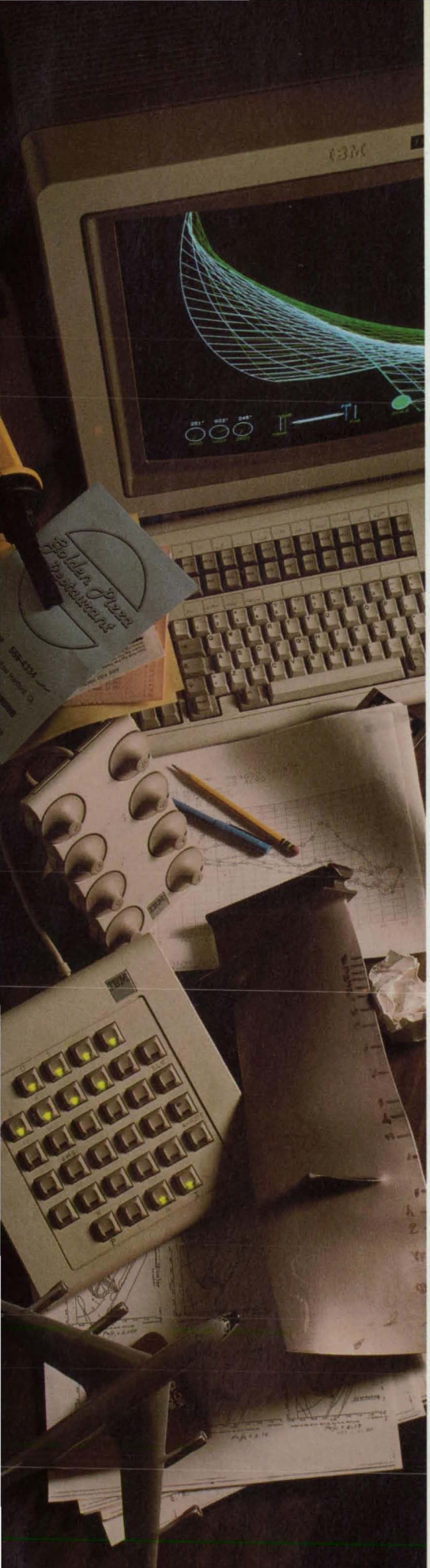
The resolution of the position measurement depends only on the distance between ports (which may number more than four). The precision of static measurements depends on the mechanical precision of the sizes and locations of the ports and piston seal. The precision of dynamic measurements depends on the speed of the piston and the lengths of the connecting lines to the switches.

Electrical switches can be eliminated entirely if necessary. The ports could then be connected directly to fluidic control devices without having to transduce the pressures into electrical signals.

This work was done by Gordon A. Wiker, George M. Tetsuka, Thomas W. Andrews, and Richard W. Rice of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 74 on the TSP Request Card.*
NPO-16956



The **Progress of a Piston** from left to right is detected by pressure switches at ports along the cylinder wall. The switches close when they are subjected to a high pressure and open when the pressure falls.



Take a job that's nothing but problems.

1. How do you design an engine that increases aircraft performance while improving fuel consumption?

2. Create an engine that boosts thrust by 12,000 pounds with just a software change.

3. Design the optimum engine for Advanced Short Takeoff or VTOL aircraft.

4. Can turbine blades be manufactured as single crystals?

If you love solving problems like these, we need you. We'll put you side by side with engineers who are making aviation history. Working on programs like the National Aerospace Plane. The Advanced Tactical Fighter. Or the engines on the new super-twin jetliners that are transforming commercial aviation.

Your biggest problem could be choosing between Pratt & Whitney's Florida or Connecticut locations. We offer the diversity you'd expect from United Technologies, the world's seventh-largest manufacturing company. Naturally, you'll get good pay and solid benefits. But you'll get something more: a chance to put your energy into things that matter.

Send your resume to Pratt & Whitney Professional Recruitment, Mail Stop NB 999-902, 400 Main Street, East Hartford, CT 06108.

You want more challenge and recognition. **We read you loud and clear.**

UNITED TECHNOLOGIES
PRATT&WHITNEY

An equal opportunity employer.

Circle Reader Action No. 419

Hatch Cover Slides Through Hatch

Internal pressure aids sealing in a simple cover.

Lyndon B. Johnson Space Center,
Houston, Texas

A hatch cover for a pressurized vessel provides a tight seal but can be opened quickly from either side. In opening or closing, the cover sweeps out relatively little volume within the vessel, so that it does not hinder the movement of people or objects from the vessel to the outside or the placement of people or objects near the hatch.

The cover uses the internal pressure to create a seal when it is closed. It does not need bolts or latches to keep it closed (though simple latches could be used to hold it in place before the application of sealing pressure). The design of the cover therefore eliminates leakage paths, and the cover is immune to the hazards of sudden decompression or jamming when bolts and latches fail.

The cover is an elliptical plate that seats against a slightly smaller elliptical hole. The seal is a bead of compressed elastomer on the periphery of the hole. To open the hatch, someone inside or outside the vessel rotates the cover through an angle of 90° around the axis of the hole, creating clearance zones at the ends of the ellipse (see Figure 1). The opener then shifts the cover to one side along its major axis, creating a third clearance zone at the opposite edge (Figure 2). The opener then tilts that edge through the opening, continuing the motion until the trailing edge is clear of the hole, then moves the entire cover away from the chamber. The minor axis of the rotated cover easily passes through the major axis of the hole.

The hatch is closed by the reverse procedure. Whether opening or closing the hatch, the user keeps the hands on grips on the cover. Either operation can therefore be executed quickly.

This work was done by Charles Allton and James H. O'Kane of **Johnson Space Center**. *No further documentation is available.*

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 14]. Refer to MSC-21356.

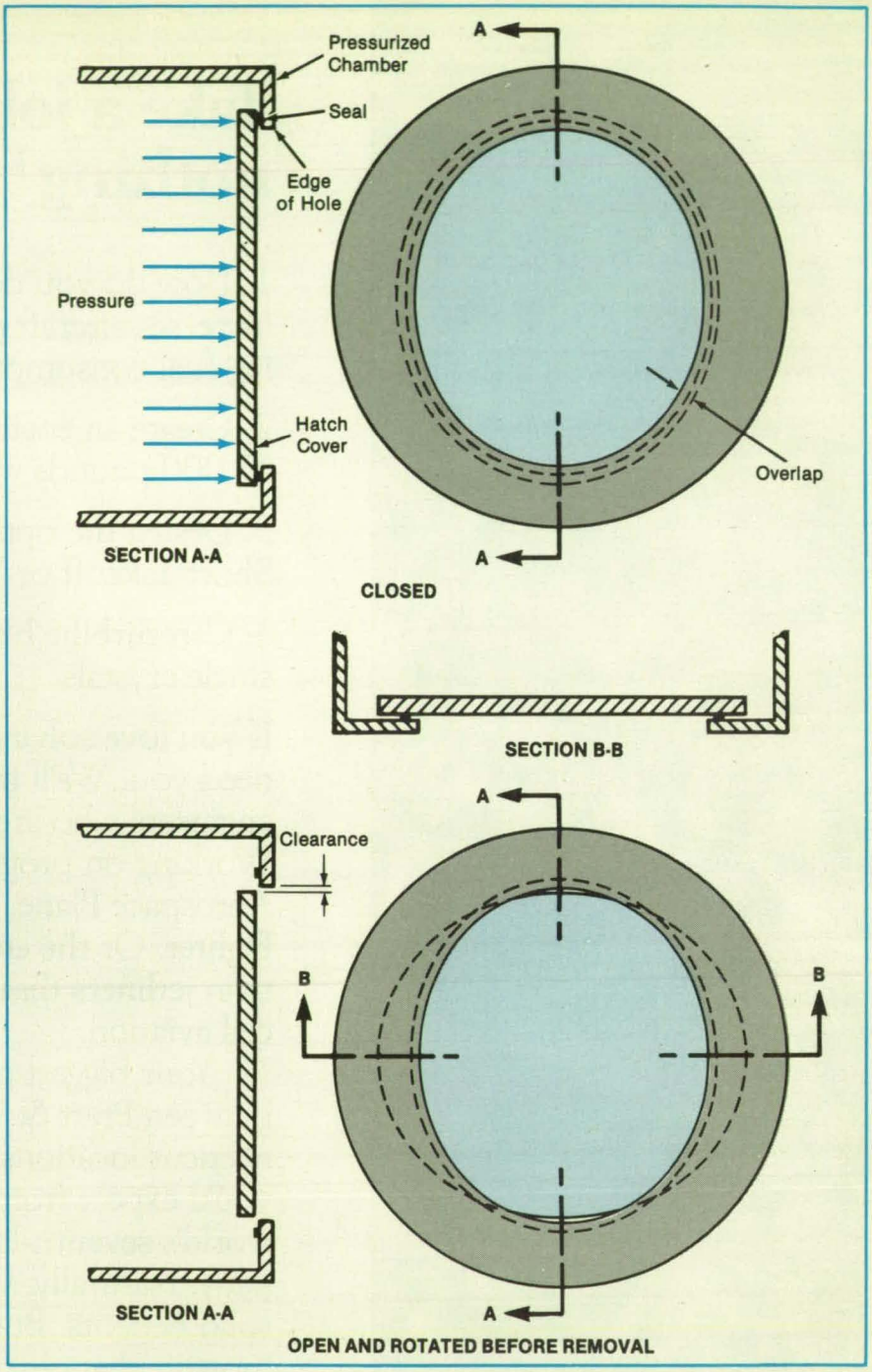


Figure 1. The **Major and Minor Axes of the Hatch Cover** and the hatch hole are aligned when the hatch is closed. Internal pressure seals the plate against the rim of the hole. Upon opening, the plate is rotated 90°, creating clearance at the ends of the hole in preparation for removal.

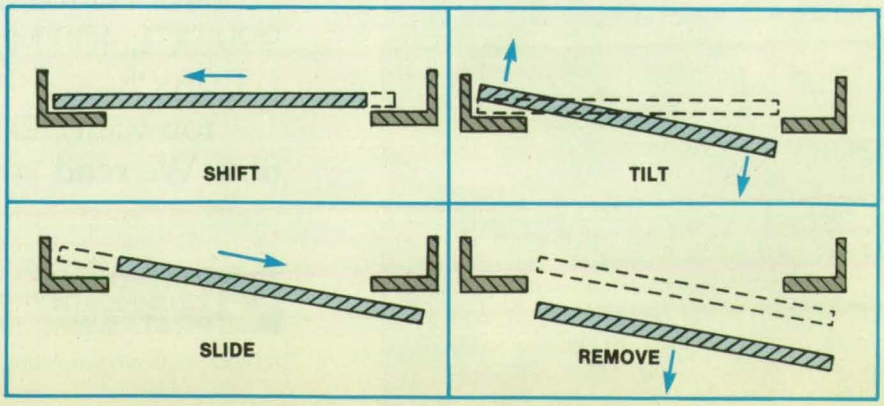
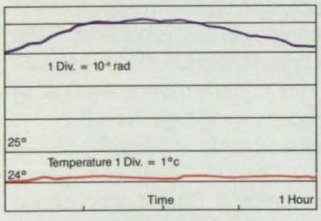


Figure 2. **With the Hatch Cover Plate Oriented Properly**—that is, with its major and minor axes aligned with the minor and major areas, respectively, of the hatch hole—the cover is ready to be removed. The cover is slid sideways, tilted, slid downward, and finally moved away from the hole.

The way some companies build their positioners, could give you the creeps.

Have you ever set up an experiment and had the test results drift over time? We call this mysterious phenomenon "creep." It could be caused by something as seemingly insignificant as minute changes in temperature at the test area.



As temperatures change, differences in the coefficients of expansion of the various materials can cause the positioners to wander off from their initial positions.

At Klinger Scientific, we know why other manufacturers build their positioners of aluminum. It can be easier and less expensive. But we just can't bring ourselves to do it.

All our stages are made of thermally matched materials, stainless steel and hardened tool steel. Rockwell Grade 60, to be exact.

ONLY HARDENED TOOL STEEL CAN STAND UP TO OUR WAY OF WORKING.

We use just one type of material, the best, because it's the best way yet devised to keep the creeps out of our stages and your tests and measurements.

Tool steel has another important advantage. Because it's so incredibly hard, we can grind the guide bearing V-ways absolutely flat and straight.

So our carriages move smoothly on their ball bearing slides with essentially zero trajectory error.

Klinger stages are sensitive to better than one micron. With repeatability to one micron.

NOW YOU CAN AFFORD KLINGER PRECISION.

Klinger manufactures over 200 linear stages, with travel ranges up to 1.5 meters, and over 100 precision rotational stages. Every one is compatible with every standard optical table. And we provide adaptor plates if you need to convert from metric to English mounting surfaces.

Best of all, we've made our products more price competitive without compromising, in any way, the highest standards our customers expect from Klinger Scientific.

So you no longer have to settle for less than the finest. You can build your systems with Klinger parts and never worry about errors creeping into your work again.

To find out more about the complete Klinger line of micropositioning systems, call or write Klinger Scientific Corporation, 999 Stewart Avenue, Garden City, NY 11530. (516) 745-6800. We'll tell you more about our new pricing structure and send you a free copy of our micropositioning handbook.

KLINGER SCIENTIFIC

Building better positioning systems, piece by perfect piece.

U.S.A. Headquarters: 999 Stewart Avenue, Garden City, NY 11530 (516) 745-6800.
Regional Offices: Northern California (415) 969-0247; Southern California (714) 999-5088. Worldwide distribution network: Contact Micro-Controle, Z.I. de St. Guenault, B.P. 144, 91005 Evry Cedex, France. Tel.33(1)64.97.98.98. FAX 33(1)60.79.45.61.

Circle Reader Action No. 368

See us at Spring Design Show Booth #1244

"Smart" Electromechanical Shock Absorber

Mechanical response is adjustable via programmable forcing functions.

Lyndon B. Johnson Space Center, Houston, Texas

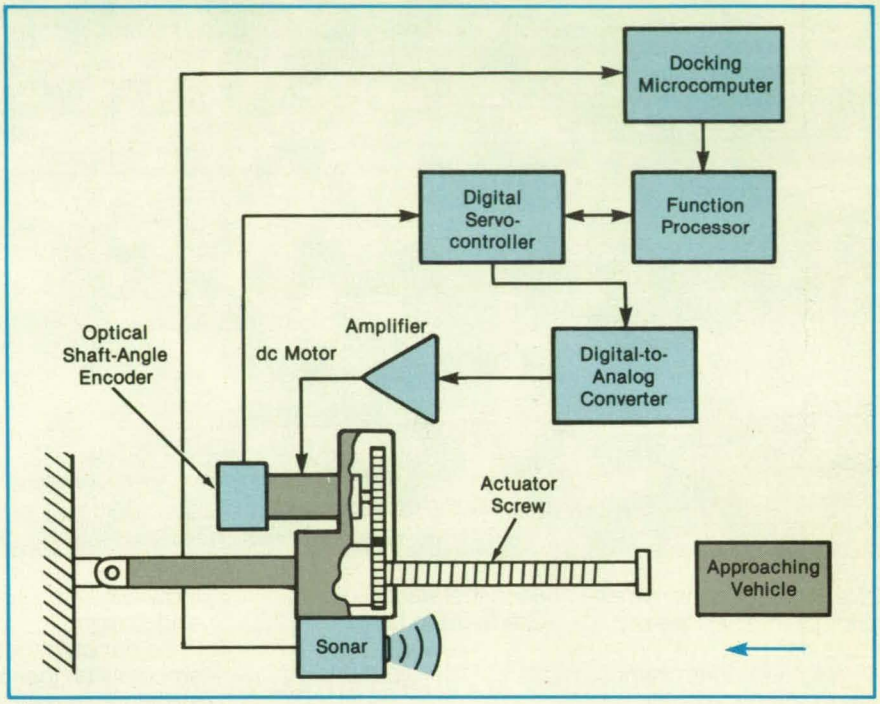
An experimental shock-absorbing apparatus includes an electromechanical actuator and digital feedback control circuitry rather than springs and hydraulic damping as in conventional shock absorbers (see figure). Unlike conventional shock absorbers, the electromechanical device is not subject to leakage and requires little or no maintenance. The attenuator parameters can be adjusted in response to sensory feedback and predictive algorithms to obtain the desired damping characteristic.

The actuator, which is non-back-drivable, includes a screw restrained against rotation and driven by a nut restrained against translation. The nut is driven by a dc electric motor. The motor is driven by a pulse-width-modulated amplifier, which receives an analog drive voltage from a digital-to-analog converter. The direction of torque and/or rotation of the motor is controlled via the polarity of the amplifier output pulses.

A digital servocontroller calculates the axial position of the screw from the rotation of the drive motor as measured by an optical shaft-angle encoder. The servocontroller operates in a position-control mode. It compares the measured position with a commanded position, digitally filters the difference between the two positions, and sends the filtered output as a control signal to the digital-to-analog converter.

The commanded-position signal is generated digitally by a function processor. For example, if the function processor is programmed to produce a constant-deceleration (equivalently, constant-force) damping characteristic, then the commanded position at each digital sampling period is given by

$$x(t) = x_0 + v_0 t + \tfrac{1}{2} at^2$$



The **"Smart" Electromechanical Shock Absorber** is an active device that can be programmed to decelerate a slowly approaching vehicle or other large object according to a prescribed damping characteristic.

where $x(t)$ = the commanded position at time t, v_0 is the initial commanded speed, and a is the commanded acceleration.

A principal anticipated use of this type of apparatus is in damping the impact of a slowly-approaching large vehicle like a docking spacecraft, docking ship, or coupling railroad car. In the experimental version, the distance and speed of approach of the vehicle are detected by sonar. A docking microcomputer converts these distance and speed signals into input signals for the function processor to set the actuator at the proper initial position for the impact of the approaching vehicle and to bring the actuator up to the speed of the approaching vehicle at this position. Once the impact occurs, the function processor executes the constant-deceleration or other desired damping algorithm.

This work was done by LeBarian Stokes and Dean C. Glenn of **Johnson Space Center** *and Monty B. Carroll of Lockheed Engineering and Management Co. For further information, Circle 164 on the TSP Request Card.*
MSC-21368

Low-Cost Vertical Accelerometer for Aircraft

Self-aligning feature eliminates the need for costly attitude-rate sensors.

Ames Research Center, Moffett Field, California

A proposed self-aligning device would measure the vertical acceleration of an aircraft but would cost only a small fraction of the price of a full inertial navigation system. In essence, the device would consist of an accelerometer mounted vertically on the inner gimbal of an artificial horizon.

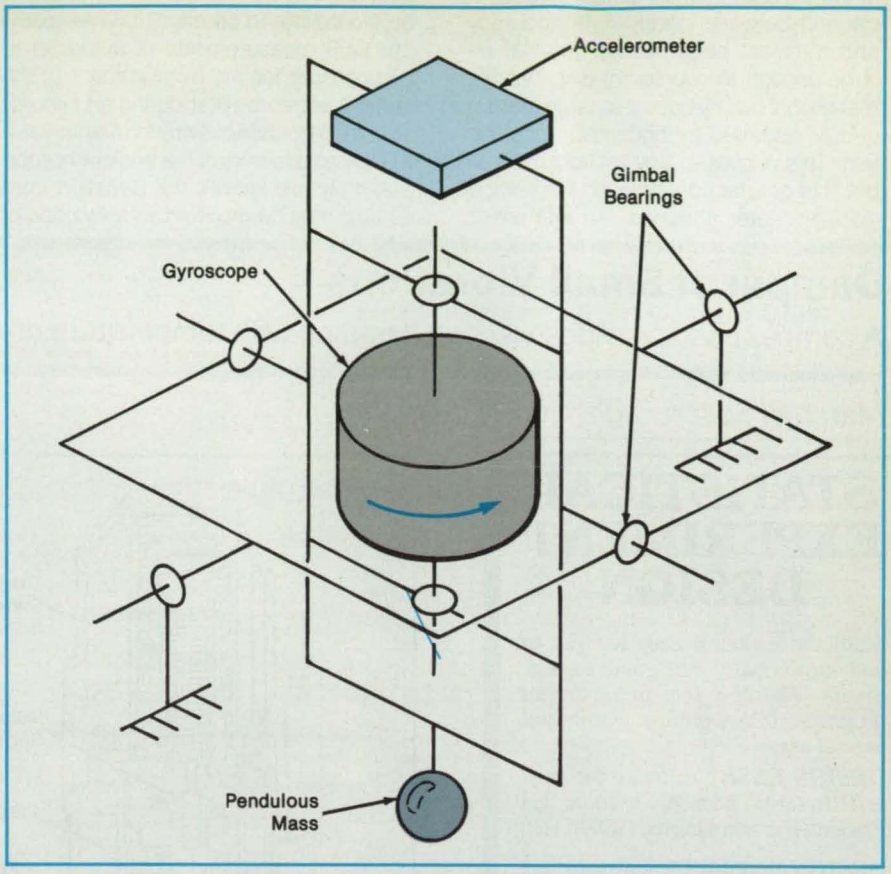
Such a vertical accelerometer could prove to be an effective aid to Global Positioning System (GPS) navigation receivers in general-aviation aircraft and helicopters. GPS receivers tend to be least accurate in the vertical direction, whereas the accuracy requirements for aircraft approach and landing are most stringent in the vertical direction. The low-cost vertical accelerometer could be used to improve on the vertical accuracy and the reliability of the GPS receiver alone. The vertical accelerometer could also be used to improve the altitude accuracy for aircraft that would otherwise be equipped with only a baro-altimeter for altitude measurement.

Commercial and military aircraft will soon use navigation systems that combine a GPS receiver with a full inertial navigation system (INS). The heart of an INS is the inertial measurement unit (IMU), an expensive, high-precision electromechanical device that tracks the attitude and trajectory of the aircraft. An IMU requires high-speed mechanical gyroscopes in nearly-perfect mechanical balance or, alternatively,

sophisticated ring-laser or fiber-optic attitude-rate sensors. The IMU has stringent performance requirements because it provides all three components of the acceleration of the aircraft. However, the two horizontal components are substantially more difficult to determine accurately than is the vertical component because the errors affecting them are much sensitive to misalignment of the IMU in the gravitational field. The proposed vertical accelerometer is intended for low-cost applications in which the vertical component alone will suffice.

An artificial horizon is a low-cost vertical-reference device in common use on general-aviation aircraft for indicating to the pilot the attitude of the aircraft. It consists of a two-degree-of-freedom gyroscope with a small mass imbalance on the spin axis (see figure). The mass imbalance acts as a pendulum to keep the gyroscope aligned with the local vertical during steady flight, while the gyroscope inhibits the pendulum from swinging during horizontal aircraft acceleration. The accelerometer, which would be mounted to the inner gimbal of the gyroscope, would be designed as an integral part of the mass distribution of the gyroscope assembly. Any type of accelerometer may be used, consistent with the cost, packaging, and performance requirements of the particular application.

The magnitude of the mass imbalance



A Pendulous Mass and a Gyroscope in an artificial horizon tend to align an accelerometer in the vertical direction.

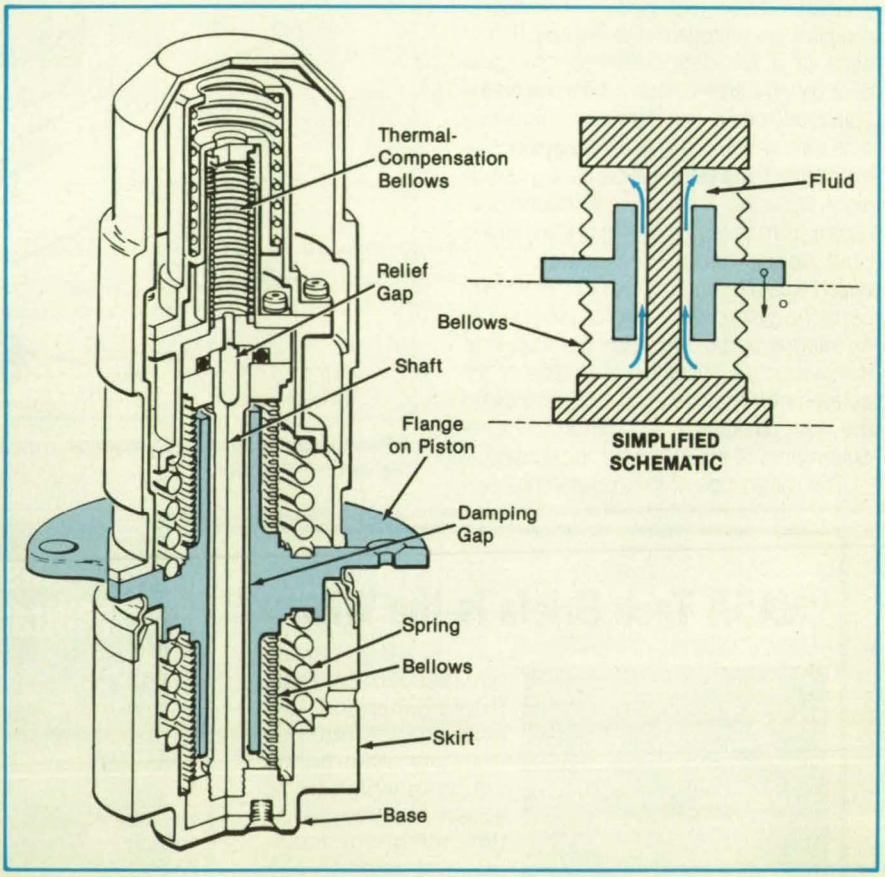
of the gyroscope inner gimbal involves a tradeoff between steady-state accuracy and transient performance. It must be large enough to counteract disturbances reasonably quickly but not so large that it is unduly disturbed by horizontal acceleration. This applies to any artificial horizon but is of greater concern with the vertical accelerometer attached. An interesting approach, which may or may not prove to be worthwhile in practice, involves using the GPS measurements (if available) to compensate for the misalignment of the vertical accelerometer during and shortly after a horizontal acceleration maneuver. If the key parameters of the artificial horizon assembly are known, the deviation from vertical may be modeled as a function of the vehicle acceleration time history, as determined by the GPS system, and then compensated for in software.

This work was done by Russell A. Paielli of **Ames Research Center**. *For further information, Circle 7 on the TSP Request Card.*
ARC-11870

Damper of Small Vibrations

A compact unit provides viscous damping with temperature compensation.

Marshall Space Flight Center, Alabama



The **Coaxial Rigid Shaft** holds the upper and lower bellows at constant length while the piston vibrates up and down. Although the volumes of the upper and lower bellows change continually, the total volume of the bellows assembly stays the same. The simplified cross-sectional diagram at the right illustrates the principle of the operation.

A vibration damper has no rubbing parts. It thus eliminates even very small static frictional forces and can therefore respond to and damp extremely low levels of vibration. The damper dissipates vibration by the motion of a piston in a fixed volume of silicone oil.

The base of the damper is mounted on one of two bodies that vibrate relative to each other. A flange on the damper is clamped to the other body (see figure). The flange is an extension of the piston, the hollow shaft of which is located between an upper and a lower bellows. A coaxial rigid shaft passes through the hole on the axis of the piston, from the bottom of the lower bellows to the top of the upper

bellows. The rigid shaft maintains the bellows assembly at a fixed length and, therefore, at a constant volume.

The vibration causes the piston to oscillate axially, alternately expanding and compressing the upper and lower bellows. The vibrational energy is dissipated in the viscous flow of oil from one bellows to the other along the damping gap between the piston and the shaft. Upper and lower springs give the assembly radial and axial stiffness.

If the temperature of the fluid rises or falls, and the fluid volume consequently increases or decreases, the fluid flows through a relief channel and relief gap, into or out of a thermal-compensation bellows. A preload spring on the compensation bellows applies a positive pressure to it. The fluid is thus kept at a nearly constant pressure, regardless of fluctuations of temperature.

This work was done by L. P. Davis of Honeywell Inc. for **Marshall Space Flight Center**. *For further information, Circle 151 on the TSP Request Card.*

Title to this invention has been waived under the provisions of the National Aeronautics and Space Act [42 U.S.C 2457(f)], to the Honeywell, Inc. Inquiries concerning licenes for its commercial development should be addressed to

Honeywell, Inc.
P. O. Box 21111
Phoenix, AZ 85036-1.

Refer to MFS-28244, volume and number of this NASA Tech Briefs *issue, and the page number.*

Inflatable-Seal Assembly for Cryogenic Fluids

A plastic ring provides a tight seal while minimizing heat transfer.

John F. Kennedy Space Center, Florida

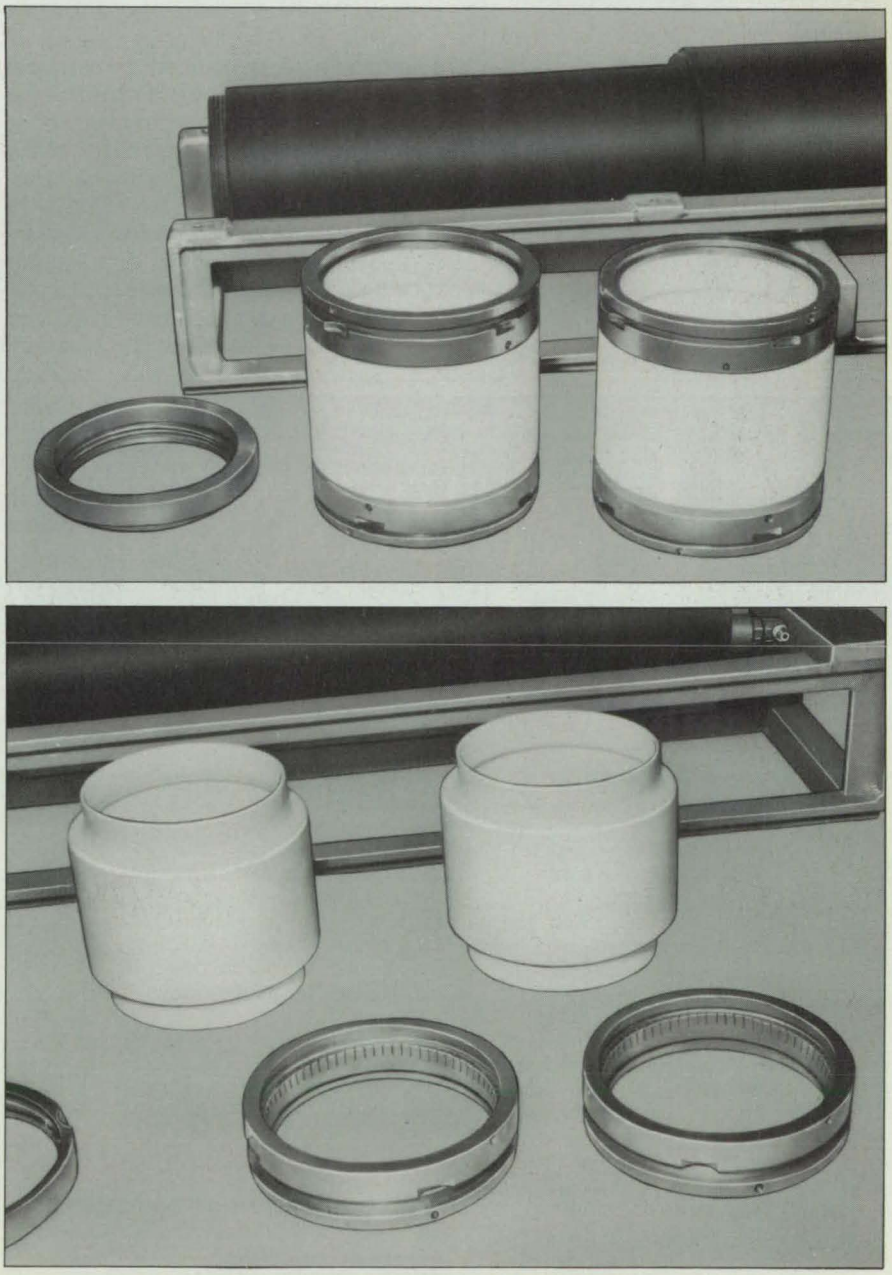
A connector for cryogenic fluid lines can be quickly joined or separated, seals tightly, and reduces the transfer of heat to the fluid. The connector features redundant sealing rings that are inflated after joining so that they wedge tightly against the connector base, preventing leakage.

The connector consists of a bayonet and receptacle. Two seal assemblies are on the bayonet, which is inserted in the receptacle to connect to a fluid line and removed from it to disconnect the line. The seal assemblies consist of an inflatable fluorinated ethylene/propylene (FEP) cylinder between pairs of tightening rings made of corrosion-resistant 304 stainless steel equipped with Acme threads (see figure).

The inflatable seals and tightening rings are slid onto the bayonet. The user screws the steel tightening rings against the inclined plane of the inflatable-seal base, making a tight seal between the bayonet and the inflatable seal. The bayonet is then placed into the receptacle, and the FEP seals are inflated with helium or nitrogen, depending on the cryogenic fluid to be flowed through the bayonet. The tightening rings secure the FEP seals, and the pressurizing gas bows the walls of the FEP seal outward so that it presses against the inner wall of the receptacle, forming the sealing surface.

This work was done by Kurt Buehler and James E. Fesmire of **Kennedy Space Center**. *No further documentation is available.*

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, Kennedy Space Center [see page 14]. Refer to KSC-11368.



A **Cylinder of FEP** is inflatable. A pair of threaded stainless-steel rings — one at each end of the cylinder — secure the cylinder in the quick-disconnect assembly.

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.

Placement of Exciters and Sensors To Measure Vibrations

Nearly optimal positions are found by a simplified method.

A report discusses the use of the simulated-annealing algorithm to place exciters and sensors of vibrations at nearly optimal positions in a complicated structure. Because there are generally fewer exciters and sensors than there are degrees of freedom in the structure, an optimal-placement algorithm is needed to maximize the value of the resulting incomplete set of measurements for the verification of the amplitudes and frequencies of previously-computed vibrational modes.

It is assumed that the sensors are strain gauges or accelerometers and that the best measurements of a vibrational mode of interest are obtained when the exciters and sensors are placed so that the sensors are at the degrees of freedom that have the largest kinetic energies in that mode. The combinatorial optimization problem posed by this criterion for placement cannot be solved exactly with a reasonable amount of computation in any but the simplest of cases. The simulated-annealing algorithm provides suboptimal but usually adequate solutions for complicated systems that defy rigorous analysis.

The simulated-annealing algorithm is so named because in some respects it bears a mathematical resemblance to the theory of annealing of solids. Starting with an initial assignment of exciters and sensors to various locations, changes in the current assignment (solution) are generated according to a simple set of rules for partly random selection. These changes are examined, and only those that improve the objective function (in this case, that increase the observed kinetic energy of the system) are accepted. Usually, such an approach results in convergence on a local optimum and may fail to discover the global optimum. In anticipation of finding a more global optimum, the simulated-annealing method calls for the probabilistic acceptance of solutions that temporarily degrade the objective function.

When the change in energy, ΔE, of an iteration is negative, the new assignment is accepted, but only if the probability $\exp[\Delta E/\theta]$ (where θ is a pseudotemperature parameter with the dimension of energy) exceeds a random number between 0 and 1. Consequently, the system attains a Boltzmann distribution.

The probability of accepting such degrading solutions is made highest (using the highest θ) at the early iterations but is reduced slowly by decreasing θ as the iterations progress; thereby far fewer nonimproving moves are accepted near the optimum. As such, a coarse global search evolves into a fine local search near the global optimum, and the probabilistic "jumps" provide escapes from nonglobal optima.

The performance of the simulated-annealing algorithm was tested in numerical simulations of the placement of exciters and sensors both on a square plate held by the edges but otherwise allowed to vibrate and on a 960-degree-of-freedom three-dimensional truss. The results seemed promising, and future experimental tests are planned.

This work was done by Moktar A. Salama, Theodore L. Rose, and John A. Garba of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Optimal Placement of Excitations and Sensors for Verification of Large Dynamical Systems," Circle 117 on the TSP Request Card.*
NPO-17293

Machinery

Hardware Techniques, and Processes

101 Reducing Thrusts in Solid-Fuel Rockets
101 Dynamic, High-Temperature, Flexible Seal
102 Integrated Heat Switch/Oxide Sorption Compressor
103 Phase-Change Heat-Storage Module
103 Magnetic Coupling Delivers Increased Torque

Books and Reports

105 Theory of Ball-Bearing Vibrations
105 Trash-Disposal Module for Space Station
106 Heat Flux in a Dual-Throat Rocket Engine

Reducing Thrusts in Solid-Fuel Rockets

Opposing pairs of vents are explosively cut in rocket-motor cases.

Langley Research Center, Hampton, Virginia

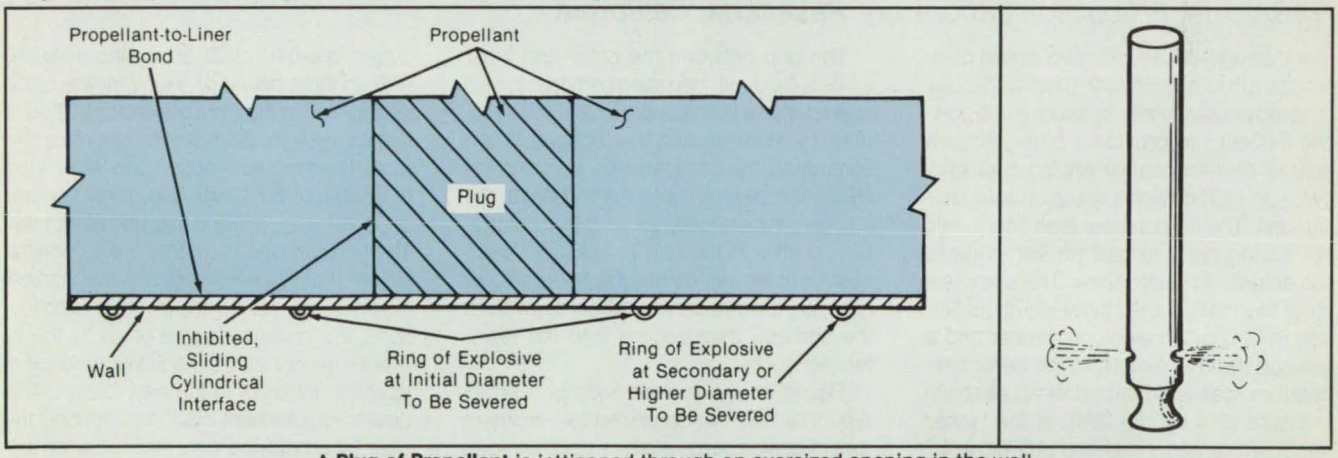
A thrust-terminating system has been conceived to reduce the thrust of a solid-propellant rocket motor in a controlled manner such that the thrust loads are not increased or decreased beyond predictable levels. The concept involves explosively cutting opposing venting pairs in the case of the rocket motor above the nozzles to initiate the venting of the chamber and the reduction of thrust.

No additional thrust would be induced, longitudinally or laterally. The vents would be sized and numbered to control the amount and rate of the reduction in thrust. Vent diameters could be progressively increased by predictable erosion of the case or by further explosive cutting, to continue the depressurization of the thrust chamber.

The system shown in the figure would enable the venting of the pressure from the chamber through the internal propellant slab. Once the skin is explosively cut, a propellant plug would be jettisoned through the oversized opening to allow uninhibited venting. The plug would be formed by placing a blank cylinder against the wall of the case during initial casting to create a void in the propellant. Once the propellant is cured, the blank cylinder would be withdrawn. The interior walls of the cavity would be inhibited to prevent the spread of flames on the surface of the cylinder. A separately cast cylinder of propellant with an inhibited cylindrical surface would then be inserted into the cavity and bonded to the wall of the case.

The plate cut out of the case could be tethered to the case at a distance from the point of severance, to prevent the plate from becoming a projectile that would damage the surrounding structure. The vents would be located to minimize the potential impingement of flames on the surrounding structure. This system could utilize existing "destruct-command" systems.

This work was done by Laurence J. Bement of **Langley Research Center**. *No further documentation is available.*
LAR-13744



A **Plug of Propellant** is jettisoned through an oversized opening in the wall.

Dynamic, High-Temperature, Flexible Seal

Hot gases are confined safely even when engine walls distort under loads.

Lewis Research Center, Cleveland, Ohio

Essential to the successful operation of high-performance, variable-geometry hypersonic engines is the development of advanced high-temperature, flexible seals for the gaps between movable engine panels and their adjacent stationary engine sidewalls. Gaps caused by pressure and thermal loads on the relatively-compliant engine sidewalls can be as much as 0.25 in. (6.4 mm), requiring very-compliant "serpentine" seals to conform to the distortions of the sidewalls. Such a seal is expected to prevent engine-flow-path gas as hot as 1,200 to 5,000 °F (650 to 2,760 °C) and pressurized to 100 psi (0.7 MPa) from leaking past the engine panels to back engine cavities, where it could cause loss of an engine or an entire aircraft.

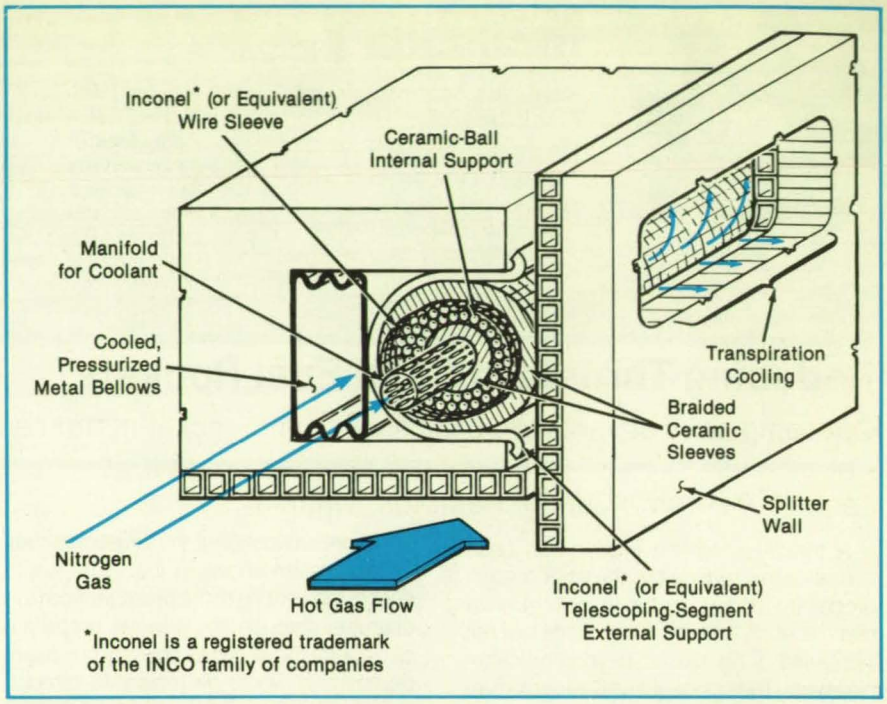
The new seal consists of multiple plies of braided ceramic sleeves filled with small ceramic balls (see figure). The innermost braided sleeve is supported by a high-temperature-wire-mesh sleeve that provides both springback and preload capabilities. The ceramic balls reduce the effect of the relatively high porosity of the braided ceramic sleeves by acting as a labyrinth flow

path for the gases and thereby greatly increasing the pressure gradient that the seal can sustain. This arrangement provides a highly-flexible seal structure that can operate continuously up to 2,000 °F (1,100 °C) without coolant. The seal can also operate up to the maximum engine-gas temperatures if transpiration cooling is used.

Designed as the first-stage seal of a multistage seal system, this concept combines initial-sealing and thermal-barrier capabilities in a simple, flexible package. This dynamic, high-temperature, flexible seal can be employed in hypersonic engines, two-dimensional convergent/divergent and vectorized-thrust exhaust nozzles, reentry vehicle airframes, rocket-motor casings, high-temperature furnaces, and any application requiring nonasbestos high-temperature gaskets.

This work was done by Bruce M. Steinetz of **Lewis Research Center** *and Paul J. Sirocky of Sverdrup. No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Lewis Research Center [see page 14]. Refer to LEW-14672.



The **Dynamic, High-Temperature, Flexible Seal** can operate at temperatures up to 1,100 °C without coolant or at higher temperatures when cooled by transpiration.

Integrated Heat Switch/Oxide Sorption Compressor

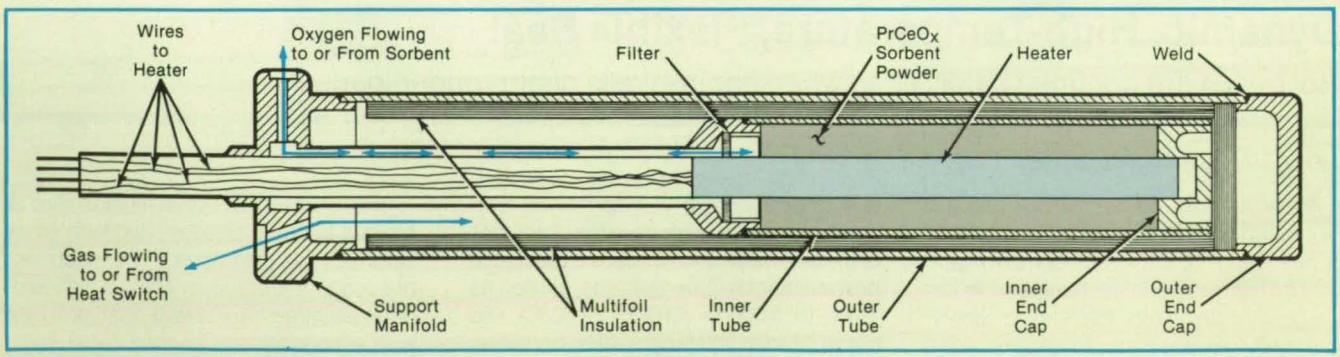
Features include vibration-free operation and long life.

NASA's Jet Propulsion Laboratory, Pasadena, California

A thermally-driven, nonmechanical compressor uses a container filled with compressed praseodymium cerium oxide powder ($PrCeO_x$) to provide a high-pressure flow of oxygen gas for driving a closed-cycle Joule-Thomson-expansion refrigeration unit. The compressor (see figure) has no moving parts except for very-reliable self-actuated check valves. The compressor is thermally cycled between about 350 and 650 °C by an electrical heater and a gas-gap thermal switch. At the lower temperature, gas is adsorbed at an absolute pressure of 4 psi (28 kPa); at the higher temperature, gas is expelled at 600 psi (4.2 MPa).

The gap between the outer and inner tubes is filled with insulation comprising multiple layers of gold-coated nickel foil separated by woven quartz fiber ribbons. When evacuated, the gap insulates, enabling the electrical heater to raise the sorbent to the higher temperature. When the heater is turned off and the gap is filled with such heat-transfer gas as helium, hydrogen, or nitrogen, the gap conducts heat away from the sorbent, thus cooling it to the lower temperature.

Based on the performance of a prototype that was not optimized for minimum loss of heat, a complete two-stage refrigeration system with two compressors produced one-third watt of cooling at 80 K, with an input power of 100 W for the oxide stage. Computer models indicate that a similar system designed to minimize the loss of heat could produce one-fourth watt of cooling at 80 K, with a total input power of 33 W for the oxide stage, and 80 W total. These power requirements are somewhat higher than those of existing mechanical cryocoolers. However, in some applications, this disadvantage is offset by the increase in operating life and the absence of vibration inherent in the new design. This power requirement could be reduced further by employing heat recuperation between stages.



The **Integrated Heat Switch/Oxide Sorption Compressor** has no moving parts except check valves (not shown), which control the flow of oxygen gas between the compressor and a closed-cycle Joule-Thomson refrigeration system. The oxygen is expelled from the sorbent at high pressure by evacuating the heat-switch gap and turning on the heater.

Oxide sorption cryocoolers should be practical for applications requiring maintenance-free, low-vibration cooling in the temperature range of 60 to 100 K. Such units could be used to cool infrared detectors and cryogenic experiments. An oxide sorption compressor could also be used as an upper stage for a 14-to-20 K hydrogen/hydride sorption stage. Such a two-stage cooler would require less than 500 W of input power for 1 W of cooling at 20 K: this represents efficiency higher than that of any other 20 K cooler developed thus far.

This work was done by Steven Bard of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 106 on the TSP Request Card.*
NPO-17162

Phase-Change Heat-Storage Module

Momentary heating or cooling overloads could be accommodated.

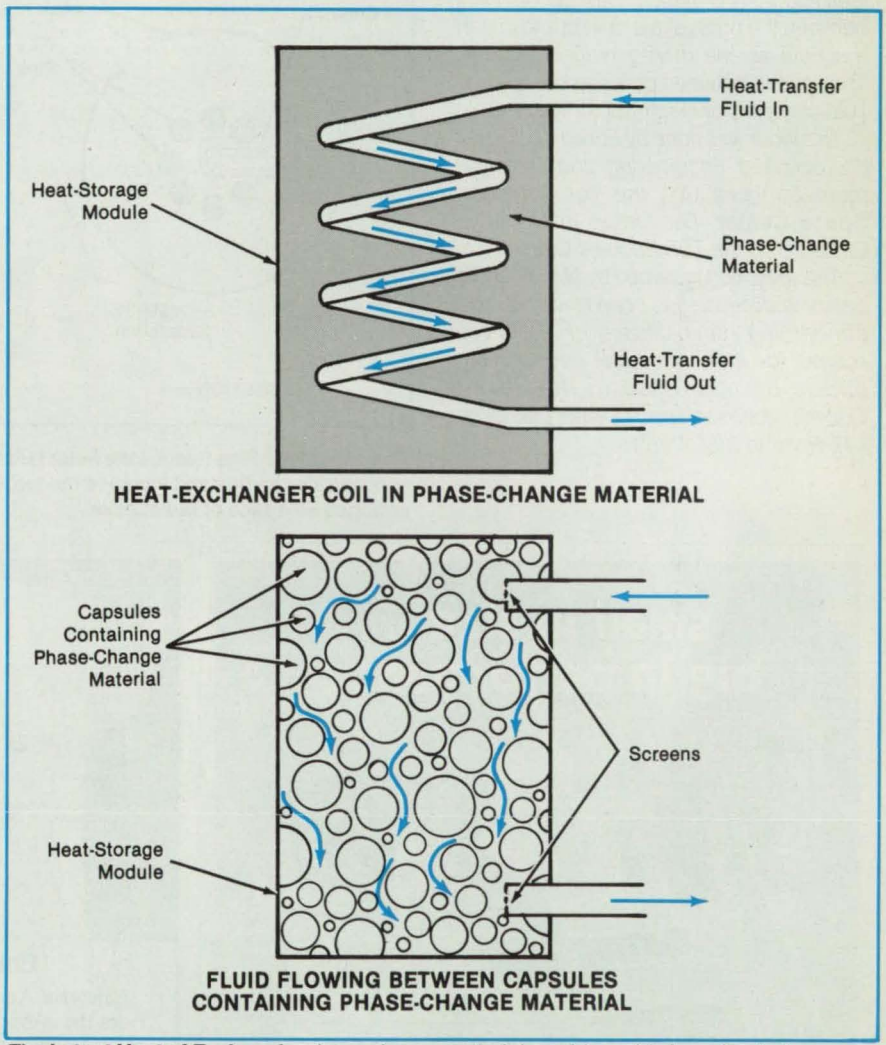
Marshall Space Flight Center, Alabama

A proposed heat-storage module would accommodate a momentary heating or cooling overload in a pumped-liquid heat-transfer system. The large heat-storage capacity of the module would be provided by the heat of fusion of a material that freezes at or near the temperature at which it is desired to maintain the object that is to be heated or cooled.

Conventionally, a heating or cooling load that varies widely is accommodated by choosing the size of equipment to carry the peak load. Therefore, conventional heating and cooling equipment tends to be oversized for most of the operating cycle, with consequent higher cost and lower efficiency than could be obtained by designing for operation at an average load. The incorporation of the proposed module involves relatively small penalties in weight, cost, and size and more than compensates by enabling the design of the rest of the system to handle only the average load.

The module (see figure) could include a heat-exchanger coil through which the heat-transfer fluid would flow and which would conduct heat between the heat-transfer fluid and the phase-change material. Alternatively, the phase-change material could be encapsulated, and the heat-transfer fluid could flow throughout the volume of the module in the spaces between the capsules, providing very efficient heat transfer into the phase change material.

The heat-transfer fluid could be a single-phase liquid, or it could contain a phase-change material in microscopic capsules for enhanced heat-storage capacity. In the latter case, more heat could be transferred with less of a difference in temperature between the source and the sink of heat and with less pumping than in the case of a single-phase fluid.



The **Latent Heat of Fusion** of a phase-change material would provide large heat-storage capacity in a small volume.

This work was done by James C. Mulligan of Triangle Research and Development Corp. for **Marshall Space Flight Center**. *For further information, Circle 160 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 14]. Refer to MFS-26071.

Magnetic Coupling Delivers Increased Torque

Flux pins decrease the reluctance to boost the torque when the gap is large.

Lyndon B. Johnson Space Center, Houston, Texas

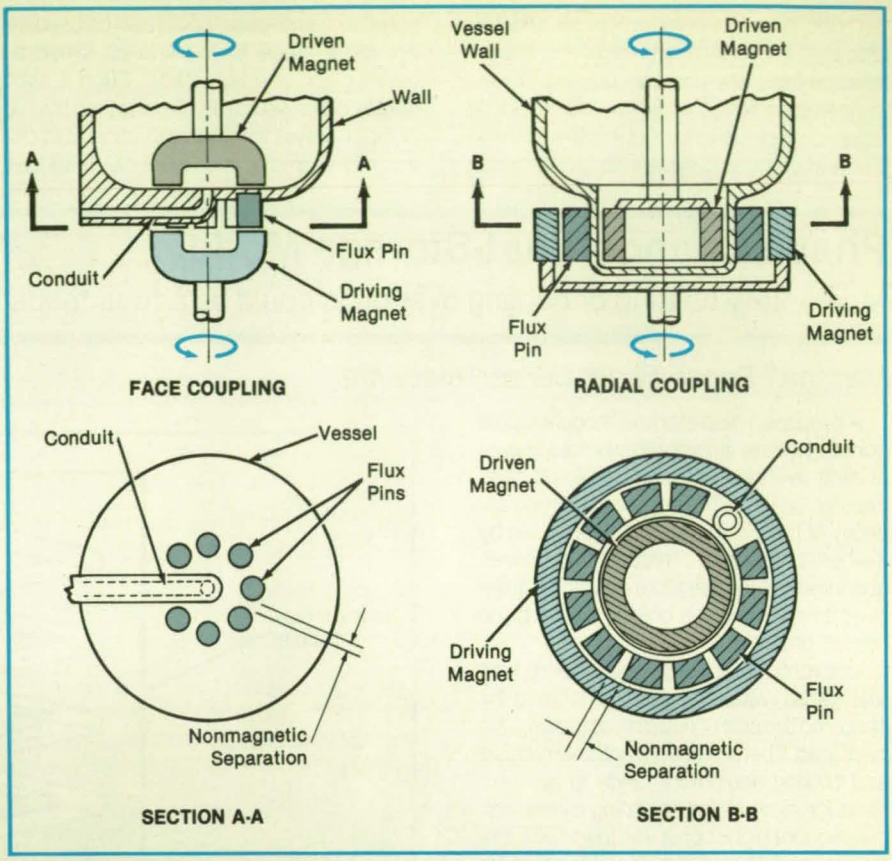
The addition of flux pins to the gap between magnetically coupled shafts in a bioreactor experiment increases the transferred torque by almost 50 percent. Ordinarily, the gap between driving and driven magnets in a magnetic coupling is made

as small as practicable to reduce the leakage of magnetic flux. In the bioreactor, however, the gap must accommodate a wall that isolates the driving shaft (outside the vessel) from the driven shaft (inside the vessel), and a fluid conduit must lie on the axis of rotation of the magnetic coupling.

The flux pins reduce the large magnetic reluctance caused by this arrangement and thereby restore some of the torque lost by the use of such a large gap. The pins are stationary, are made of magnetically soft material, and are separated from each other by air or other nonmagnetic material (see figure). They sequentially conduct flux between the poles of the driving and driven magnets as the driving magnet rotates. The spaces between pins can be used for fluid channels or electrical wiring.

This work was done by Edward L. Carter of Lockheed Engineering and Management Services Co., Inc. for **Johnson Space Center**. *For further information, Circle 26 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, Johnson Space Center [see page 14]. Refer to MSC-21171.



Fixed Magnetic Pins Reduce the Reluctance of the gap in a magnetic coupling. They thereby concentrate the flux and increase the torque that can be transmitted. The coupling can be arranged as a face or radial drive.

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.

Theory of Ball-Bearing Vibrations

Amplitudes of harmonics are related to differences among diameters.

A report describes a theory of vibrations in shafts supported by worn ball bearings. The purpose of the theory is to use strain-gauge measurements of vibrations to detect wear. In practice, two types of errors of form exert the most significant influence on the vibrations of a shaft: the waviness of the inner raceway, which causes vibrations at harmonics of the rotational frequency of the shaft, and differences in diameter among the balls (ball-train asymmetry), which cause vibrations at harmonics of the rotational frequency of the ball cage. Assuming that the ball-train asymmetry is due to wear, the theory enables the interpretation of the ball-cage harmonics in terms of the depths of wear on individual balls.

The theory is developed from a simple model of the radial motion of the shaft along the direction of the applied lateral load. The bearing is assumed to have clearance. The shaft and the outer race are taken to be rigid, and either the outer race or the shaft is assumed to be stationary. The only error of form is the ball-train asymmetry. The shaft rotates slowly enough that the instantaneous radial position of the inner race with respect to the outer race is determined by the diameter of the balls against which it presses at the given instant.

When a ball passes through the load line, the instantaneous radial position is determined by the diameter of that ball alone. Although the exact position is not known between such passages, it can be approximated by a smooth curve drawn among the points corresponding to individual balls, showing the position of the shaft as a function of the angle of rotation of the ball cage.

The angle changes at the rate of rotation of the ball cage, so that the variation in position of the shaft (and, therefore, of ball diameter) can be expressed as a Fourier time series

$$y(t) = \sum_{n=1}^{\infty} a_n \cos(n\omega_c t)$$

where y = the variation in position, t = time, a_n = the amplitude of the nth harmonic, and ω_c = the angular speed of the ball cage.

The force $F(t)$ exerted by the shaft on the outer race can be calculated from the Fourier components, assuming that the shaft is rigid and its effective mass is M

$$F(t) \approx \omega_c^2 M \sum_{n=1}^{\infty} n^2 a_n \cos(n\omega_c t)$$

This force causes the bearing support to vibrate at the ball-cage harmonic frequencies with amplitudes that depend on the dynamic properties of the bearing support. The amplitudes of the ball-cage harmonics measured in the vibration spectrum of the bearing support are therefore proportional to the Fourier coefficients of the curve fitted to the circumferential ball-diameter variation. This has been verified empirically by linear correlations between the ball-cage harmonic amplitudes and measured ball wear for particular machine designs. The ball-cage harmonic amplitudes in the vibration spectrum of the bearing support may thus be used to measure absolute bearing ball wear for a machine type that has such an established correlation. For an absolute wear measurement, at least one ball must be at its original diameter. Without this condition, changes in the relative amplitudes of the ball-cage harmonics indicate changes in the ball-train asymmetry, signifying increases in wear.

This work was done by Michael J. Hine of Rockwell International Corp. for **Marshall Space Flight Center** *. To obtain a copy of the report, "Theory of Ball Bearing Cage Harmonic Generation," Circle 123 on the TSP Request Card.*
MFS-29378

Trash-Disposal Module for Space Station

An expandable container conserves weight and volume.

A report presents the basic engineering concepts of a trash-disposal module for the Space Station. The module would conserve valuable cargo volume and reduce both the launching and returning weights of the Space Shuttle or other spacecraft that would carry materials to and from the Space Station. The module would be relatively cheap and simple to operate.

When empty, the module would have a mass of 915 lbm (415 kg). It would be roughly cylindrical, 7 ft 6 in. (2.3 m) in diameter, with two rigid end plates and a bellowslike expandable section between

them. It would be shipped to the Space Station in its compressed condition, attached to the Space Station via an air lock on one of the end plates, and expanded to the full length of about 5 ft (1.5 m) by the pressure of the air in the Space Station.

The module would be loaded through the air lock by workers in the "shirt-sleeve" environment of the Space Station. It could hold 171 ft^3 (4.8 m^3) of garbage with a mass of 4,488 lbm (2,036 kg); this is estimated to be the amount accumulated during 90 days of operation.

When the module is full, the air lock would be closed, and the module would be released, pushed away from the Space Station by springs at a speed of 1 ft/s (0.3 m/s). When the module reaches an optimum distance, a radio command from the Space Station would be sent to an assembly of equipment on the outer end plate. There, the signal would cause pressurized nitrogen from a canister to inflate a toroidal balloon much larger than the module.

The increased atmospheric drag on the balloon would cause the orbit of the module to decay rapidly. On the average, it should take the module less than 28 days to reenter the atmosphere. The module and its contents would be vaporized by the heat of reentry. The high reentry temperatures are expected to destroy any hazardous chemicals that may be present. Studies must yet be done to determine whether this method of disposal, or the disposal of certain substances in this manner, would damage the upper atmosphere.

This work was done by David B. Wissinger of McDonnell Douglas Corp. for **Johnson Space Center**. *To obtain a copy of the report, "Space Station Trash Disposal Module," Circle 14 on the TSP Request Card. MSC-21324*

Heat Flux in a Dual-Throat Rocket Engine

Measurements of both single- and dual-chamber combustion are reported.

A report describes tests of a dual-throat rocket engine burning hydrogen in oxygen. In the tests, heat-flux profiles were measured in the inner nozzle and outer chamber.

The dual-throat engine is being considered for advanced space transportation. Consisting of two combustion chambers in series that can be operated separately or together, the engine makes it possible to change the mode of operation in flight to obtain performance in the most advantageous regime. For example, it can produce high thrust at sea level or low thrust with higher performance at high altitudes or in space.

The heat fluxes were measured in terms of the rises of temperature of water flowing in calorimetric cooling channels in the walls of the chambers. One of the findings is that the flux of heat near the end of the inner nozzle is significantly higher when both chambers are firing than when only the inner chamber is firing. The higher flux is caused by the separation of flow and the recirculation caused by the back pressure of the outer chamber. As the ratio of pressure in the outer chamber to that in the inner chamber is increased, the flux of heat near the end of the inner nozzle increases, and the region of highest flux density extends farther upstream.

The flux of heat in the plume-attachment region of the outer chamber is reduced by a bleed flow of hydrogen. When only the inner chamber is firing, a bleed flow of less than 2 percent of the flow in the inner chamber is sufficient to maintain this flux below the value encountered when both chambers are firing. Therefore, the attachment of the plume from the inner chamber on the wall of the outer nozzle is not an issue in the thermal aspect of design.

This work was done by R. L. Ewen and C. J. O'Brien of Aerojet TechSystems Co. for **Marshall Space Flight Center**. *To obtain a copy of the report, "Dual Throat Nozzle Heat Flux," Circle 111 on the TSP Request Card. MFS-28261*

Fabrication Technology

Hardware Techniques, and Processes

107 Thermally Stable Truss
108 Spinner for Etching of Semiconductor Wafers
108 Ceramic Honeycomb Panels
109 Fabrication of Fiber-Optic Waveguide Coupler
110 Annealing Increases Stability of Iridium Thermocouples

Thermally Stable Truss

A lightweight structure expands and contracts minimally with changes in temperature.

Marshall Space Flight Center, Alabama

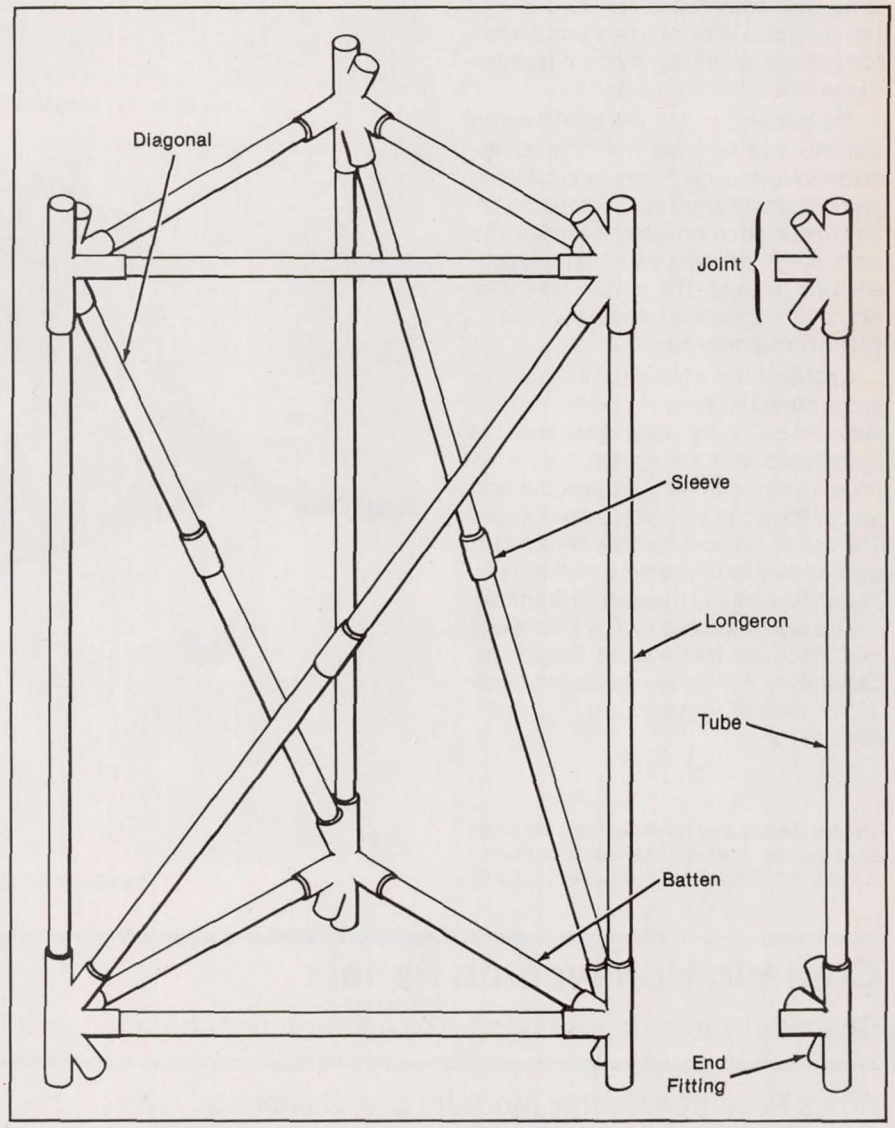
A lightweight truss is made of materials that yield low thermal expansion and contraction. Specifically, its average coefficient of thermal expansion is −0.0428 part per million per degree Fahrenheit (0.0770 ppm/°C) between −100 and +150 °F (−73 and +66 °C). The rotational distortion of the truss is less than ¼° as temperature is varied through the same range. In addition, its high thermal conductivity minimizes temperature gradients, thereby minimizing thermal distortions under a variety of heating and cooling conditions. The elements of the truss can be readily assembled.

The truss has triangular end faces and rectangular side faces braced with diagonal elements (see figure). It consists of tubes joined by end fittings. The tubes are made of aluminum alloy reinforced by continuous graphite fibers. The end fittings are made of aluminum reinforced with ceramic particles. The graphite fibers contract, while the aluminum expands as the temperature increases in the range of interest. The fibers are cross-plied in the aluminum matrix. The net coefficient of thermal expansion of the tubes is designed to be slightly negative to offset the effect of the coefficient of thermal expansion of the end fittings, which is about half that of aluminum.

The tubes are fabricated by laying up the composite material on a mandrel and heating the assembly in a pressure reactor to consolidate it. The end fittings are fabricated by forging to near net external dimensions, then machining the insides to dimensions required for mating with the tubes. The parts are joined together by adhesives.

This work was done by A. M. Nowitzky and E. C. Supan of DWA Composite Specialties, Inc., for **Marshall Space Flight Center**. *For further information, Circle 22 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 14]. Refer to MFS-27216



Tubular Members of Truss are joined by multiarm end fittings. Tubes are 1½ in. (3.81 cm) in diameter. A batten, longeron, and diagonal form a 3- by 4- by 5-ft (0.91- by 1.22-by 1.52-m) triangle.

Spinner for Etching of Semiconductor Wafers

An ordinary electric-fan motor is adapted to a new use.

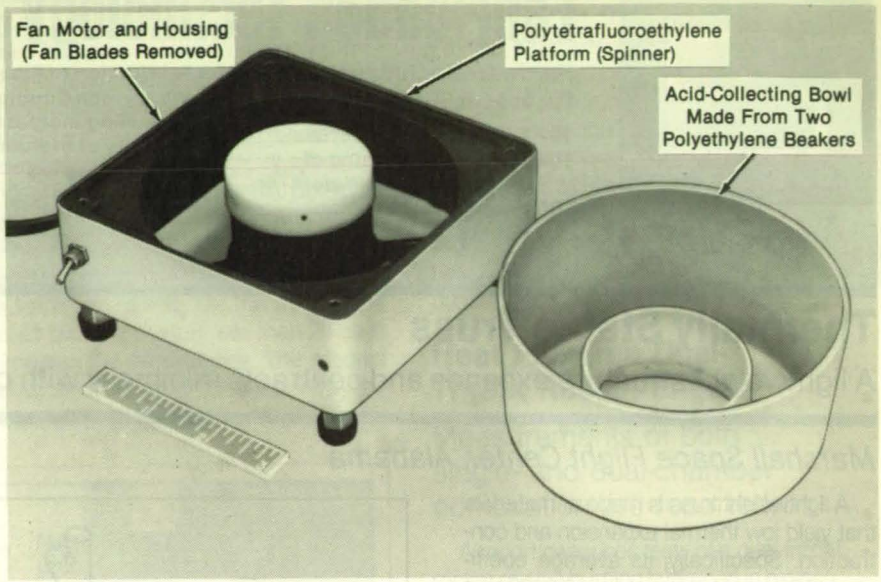
NASA's Jet Propulsion Laboratory, Pasadena, California

A simple, inexpensive apparatus (see figure) coats semiconductor wafers uniformly with hydrofluoric acid for etching. The apparatus is made in part from a small commercial electric-fan motor. It features a bowl that collects the acid.

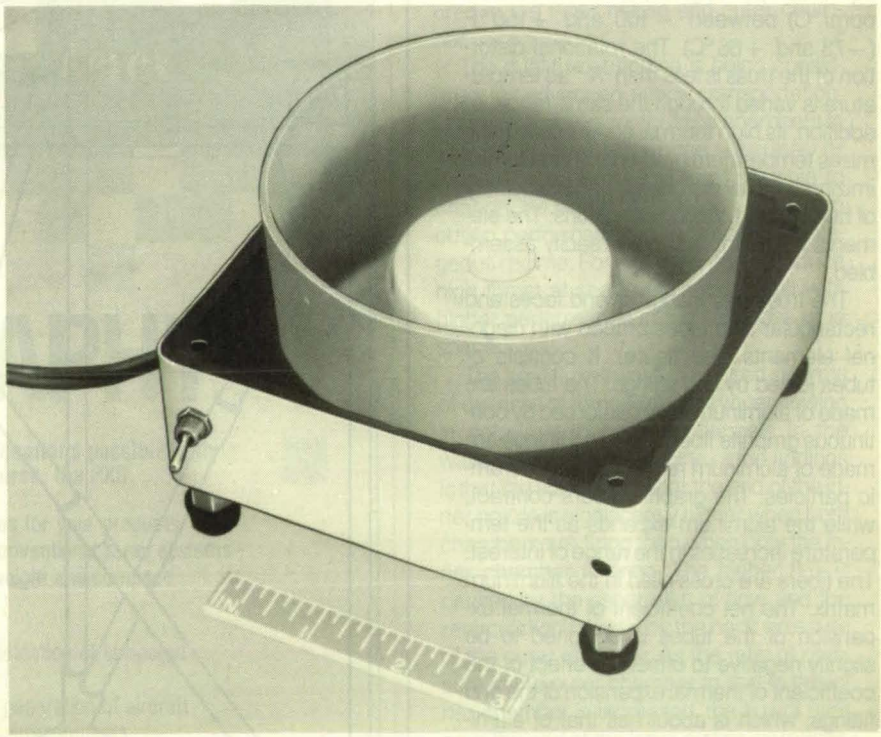
The blades, 3 to 4 in. (7.6 to 10.2 cm) in diameter, are removed from the fan assembly. A cylindrical Teflon (or equivalent) supporting platform, 2 in. (5.1 cm) in diameter, is mounted on the hub of the motor. The acid-collecting bowl is made from two polyethylene beakers. The smaller one, 2 in. (5.1 cm) in diameter, is fused inside the 4 in. (10.2 cm) diameter beaker.

A silicon wafer is placed on the platform and centered on the axis; then the motor is switched on. As the wafer spins, drops of hydrofluoric acid are applied from a syringe. Centrifugal force spreads the acid across the wafer in a fairly uniform sheet. The wall of the bowl catches the drops of acid as they fly off the edge of the wafer. The unit operates at a speed of 3,600 r/min.

This work was done by Frank Lombardi of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 105 on the TSP Request Card.*
NPO-16912



SPINNER ASSEMBLY WITH VESSEL REMOVED



VESSEL INSTALLED OVER SPINNER

The **Fan Motor and Housing** form the basis of a device that etches semiconductor wafers. A bowl collects the used etchant.

Ceramic Honeycomb Panels

Chemical vapor deposition makes a structure of ceramic on a fabric substrate.

Ames Research Center, Moffett Field, California

Ceramic honeycomb panels serve as lightweight, heat-resistant structural members. Depending on the choice of ceramic materials, the panels are expected to withstand temperatures as high as 1,800 °C.

The honeycomb structure is made by vapor-depositing ceramic on a fabric substrate woven in a honeycomb pattern, then eliminating the substrate by oxidizing it. The fabric can be made of a loosely woven polymer such as polyacrylonitrile. It is impregnated with an organic binder such as a phenolic resin for stiffness.

In one version, the fabric honeycomb is placed in a reactor and pyrolized at a temperature of 700 to 1,100 °C. Then at a temperature of 900 to 1,100 °C, trichloromethylsilane vapor is introduced and decomposes, depositing a layer of silicon carbide evenly on the fabric (see figure). The reaction is allowed to continue until the weight of the honeycomb has increased by 100 to 300 percent — a greater amount of deposited ceramic would make removal of the substrate difficult. The ceramic material is not limited to silicon carbide; other reactants may be used to yield silicon boride, silicon nitride, or boron nitride, for example.

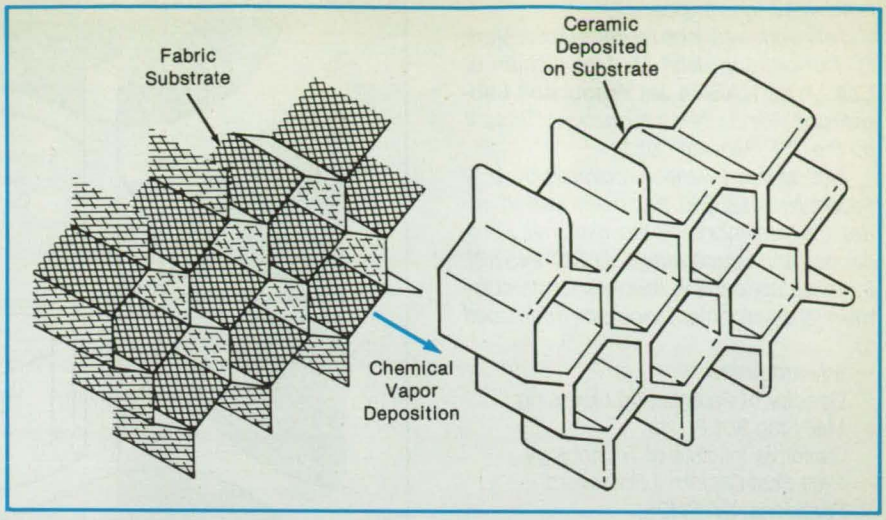
Next, the coated substrate is subjected

to a temperature of 500 to 1,000 °C for 1 to 5 h in an atmosphere of 2 to 5 percent oxygen by volume. The fabric and binder oxidize and pass through the pores of the ceramic as gas, leaving a microstructure of voids.

The voids can be filled with ceramic by further chemical vapor deposition in the reactor. The ceramic filler can be the same as or different from the base ceramic. In addition, the hexagonal holes of the honeycomb can be filled with the same or a different ceramic. Filling the holes reduces convective and radiative transfer of heat and increases the interlaminar shear strength of the honeycomb panel.

This work was done by Domenick E. Cagliostro and Salvatore R. Riccitiello of **Ames Research Center**. *For further information, Circle 95 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center [see page 14]. Refer to ARC-11652.



Polymer Fabric Woven Into a Honeycomb is the substrate for chemically deposited ceramic. The result is a rigid, insulating honeycomb structure.

Fabrication of Fiber-Optic Waveguide Coupler

Monitoring during fabrication enables control of the coupling between ports.

NASA's Jet Propulsion Laboratory, Pasadena, California

A technique for making four-port, single-mode fiber-optic waveguide couplers requires no critically-precise fabrication operations or open-loop processes. Waveguide couplers are analogous to beam-splitter prisms (see Figure 1). They are essential in many applications that require the coherent separation or combination of two waves; for example, for interferometric purposes.

This and earlier coupler designs are based on the placement of two similar weakly-guiding fiber-optic waveguides adjacent to each other. A wave launched in one guide dies out simultaneously with the growth of a similar wave in the other guide. This coupling occurs because the optical waves extend beyond the guiding cores in weakly guiding fibers. The interaction length required for the transfer of half the power at a wavelength of 830 nm is approximately 15 mm for waveguide cores of 5 μm in diameter, center-to-center spacing of 13 μm, and a difference of 0.003 between the indices of refraction of the core and the cladding.

To begin the fabrication of the coupler, most of the cladding layer of a short portion near the midlength of each of two optical fibers is etched away. The diameter of the fibers is monitored during etching by observing the Fraunhofer diffraction pattern produced by illuminating the fibers with a laser beam. To hold the fibers in a plane, the etched portions of the two fibers are stretched taut over two fibers of 125 μm in diameter lying on a microscope slide (see Figure 2). The outer ends of the fibers are held in position by paraffin. The plane of the slide is then held vertically, and small weights, which can be made from short pieces of fiber, are hung on the upper fiber to bring it into contact with the lower fiber along a short length.

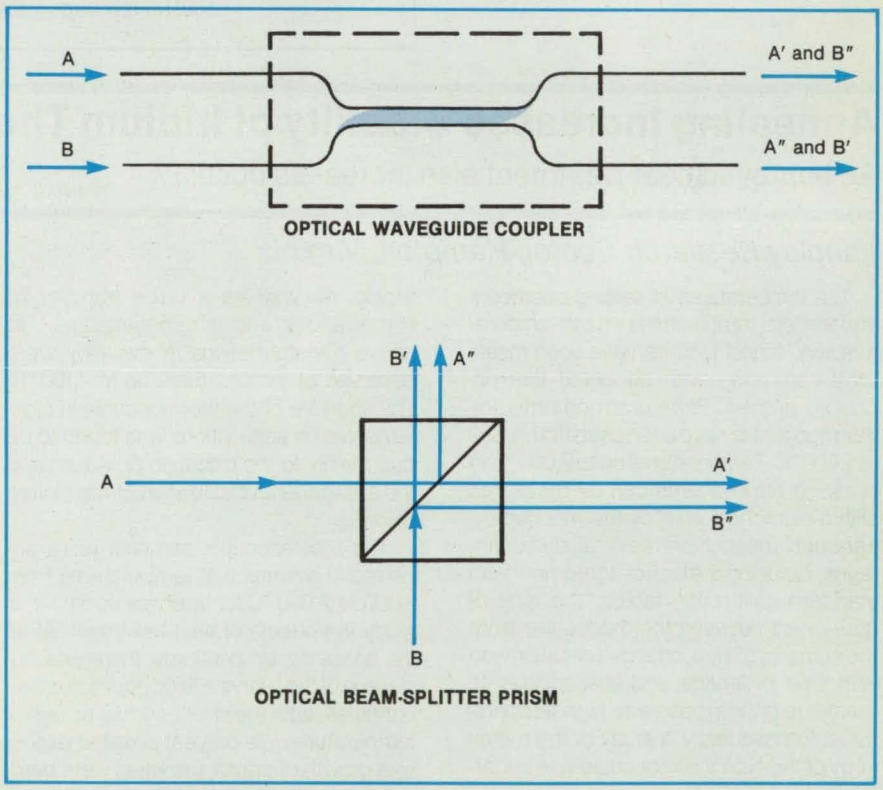


Figure 1. An **Optical Waveguide Coupler** is analogous to an optical beam-splitter prism.

An arc-welding process is used to fuse the remaining cladding of the two fibers. As the welding proceeds, the degree of coupling is monitored by injecting laser light into one of the fibers and monitoring the light emerging from the far ends of both fibers. Because the objective is to obtain a low-temperature fusion of the cladding without distorting the cores of the fibers, a low welding current of about 10 mA is used. When the output signals reach the desired

ratio, welding is stopped.

This work was done by Willis Goss, Mark D. Nelson, and John M. McLauchlan of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 4 on the TSP Request Card.*

Title to this invention, covered by U.S. Patent No. 4523810, has been waived under the provisions of the National Aeronautics and Space Act [42 U.S.C. 2457(f)]. Inquiries concerning licenses for its commercial development should be addressed to

Edward Ansell
Director of Patents and Licensing
Mail Stop 301-6
California Institute of Technology
1201 East California Boulevard
Pasadena, CA 91125

Refer to NPO-15630, volume and number of this NASA Tech Briefs *issue, and the page number.*

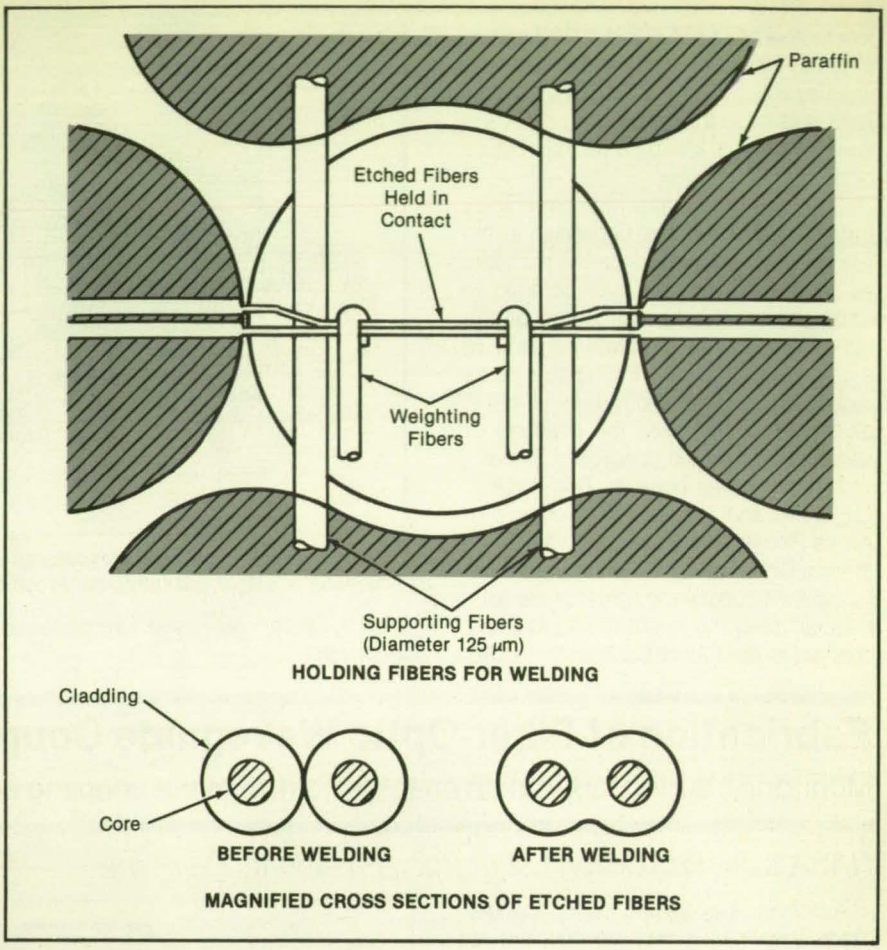


Figure 2. **Components of the Optical Waveguide Coupler** are held by paraffin on a microscope slide while the remaining cladding of the two optical fibers is fused together by arc welding.

Annealing Increases Stability of Iridium Thermocouples

An improved heat treatment also increases ductility.

Langley Research Center, Hampton, Virginia

The temperatures in settling chambers and the total temperatures in high-temperature wind-tunnel facilities have been measured commonly with uncooled thermocouple probes. Platinum/rhodium-alloy thermocouples have been used from 1,300 to 1,800 °C. Temperatures up to 2,000 °C in oxidizing atmospheres can be measured with iridium/rhodium-alloy thermocouples, although these have several disadvantages, including the lack of agreement with standard calibration tables, the lack of agreement between thermocouples from the same lot of wire, changes of calibration with time in service, and susceptibility to breakage after exposure to high temperatures. Consequently, a study of the metallurgy of this type thermocouple was undertaken.

The metallurgical studies were carried out on samples of iridium versus iridium/40-percent rhodium thermocouples in the condition as received from the manufacturer. The metallurgical studies included x-ray, macroscopic, resistance, and metallographic studies. The studies revealed a large amount of internal stress caused by cold-working during manufacturing, as well as a large number of segregations and inhomogeneities. No phase transformations in the alloy were observed at temperatures up to 1,100 °C. The short life of the thermocouple in high-temperature applications was found to be due mainly to the oxidation of iridium and the subsequent volatilization of the iridium oxide.

The thermocouple samples were annealed in a furnace at temperatures from 1,000 to 2,000 °C for intervals up to 1 h to study the effects of heat treatment. At all the annealing temperatures, there was nucleation of the recrystallized grains at different times, with the shorter times at higher temperatures. To prevent possible excessive growth of grains, the wires were heat-treated for 2 h at 1,400 °C after the initial annealing at 1,800 °C and then cooled to room temperature in the furnace. The wire annealed by this procedure was found to be ductile.

The effect of annealing on the stability of thermal electromotive force (emf) was also investigated. The procedure included the annealing of the individual thermocouples in a pyrolytic graphite furnace controlled by an optical pyrometer. Then each thermocouple was inserted in the well of a copper freezing-point standard. A thermal-analysis curve was made on a strip-chart recorder, and simultaneous readings were taken at regular intervals with a nanovoltmeter. This annealing procedure, followed by cooling to room temperature in the furnace, stabilized the thermal emf of the thermocouple to within ±0.02 percent for applications below 1,800 °C.

This work was done by Edward F. Germain, Kamran Daryabeigi, David W. Alderfer, and Robert E. Wright of **Langley Research Center** *and Shaffiq Ahmed of Youngstown State University. Further information may be found in NASA TM-89086 [N87-17018], "A Preliminary Study of Factors Affecting the Calibration Stability of the Iridium versus Iridium-40 Percent Rhodium Thermocouple."*

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.

LAR-13951

MATLAB™

THE HIGH-PERFORMANCE COMPUTATION SYSTEM FOR SCIENCE AND ENGINEERING

- MATRIX COMPUTATION
- SIGNAL PROCESSING
- LINPACK AND EISPACK ALGORITHMS
- 2-D and 3-D GRAPHICS

MATLAB is an interactive system for scientific and engineering numeric computation. Problems and solutions are expressed just as they are written mathematically -- ***without traditional programming***. As a result, you can solve numerical problems in a fraction of the time required to write a program in Fortran, Basic, or C.

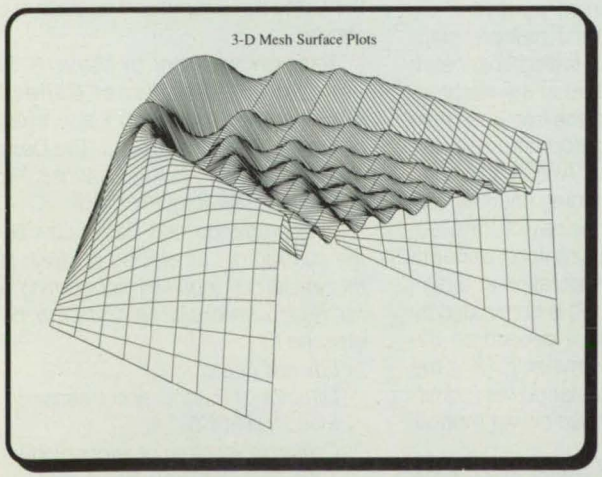
MATLAB has rapidly become an industry standard for engineering and scientific research. Its unique interactive interface, algorithmic foundation, easy extensibility, and speed make MATLAB the software system of choice for ***high productivity and high creativity*** research.

Over 200 Built-in Functions

- eigenvalues
- least squares
- inverse
- pseudoinverse
- cubic splines
- quadrature
- convolution
- interpolation
- curve fitting
- singular value decomposition, ***and more***
- 1-D and 2-D FFTs
- matrix arithmetic
- complex arithmetic
- multivariate statistics
- polynomial arithmetic
- nonlinear optimization
- differential equations
- linear equation solving
- windowing functions

2-D and 3-D Color Graphics

With MATLAB, you can create high-resolution, publication-quality 2-D, 3-D, linear, log, semilog, polar, and contour plots on your plotters, dot-matrix printers, and laser printers.



Computers

- ✓PC and AT Compatibles
- ✓80386 Computers
- ✓Macintosh
- ✓Sun Workstations
- ✓Apollo Workstations
- ✓VAX/VMS and Unix
- ✓Other Computers

Open and Extensible

MATLAB is a fully extensible environment. Create functions and programs rapidly -- without the time-consuming compiling, linking, and complex syntax of traditional languages. Our open-system philosophy gives you access to algorithms and source code so you can edit functions or add your own.

Optional ***Toolboxes*** extend MATLAB by providing application-specific capabilities, such as parametric modelling and control system design.

Fast, Accurate, and Reliable

MATLAB's import/export facilities provide access to ***your*** data. MATLAB can handle lots of data -- and do it ***fast***, fully utilizing all available floating point hardware for maximum performance. You won't have to question the results either -- the algorithms have been programmed by leading experts in mathematical software.

Benchmarks (20 MHz 386-based PC)

20x20 matrix multiply	0.05s
20x20 inverse	0.11s
20x20 eigenvalues	0.6s
1024 point FFT	0.16s

MATLAB is the teaching and research system chosen by Computer Science, Engineering, and Mathematics departments at most top universities. These creative researchers use MATLAB to design algorithms that are at the cutting edge of technology. As a result, you are assured of an exciting future of new developments, implemented with the speed, power, and flexibility that have made MATLAB a standard.

Please provide additional information!

Name _____
Company _____
Dept. _____
Addr. _____
City _____
State, Zip _____
Tel. _____
Computer _____

The MATH WORKS Inc.
21 Eliot Street
South Natick, MA 01760
(508) 653-1415
Telex 910-240-5521

NASA 4-89

Circle Reader Action No. 503

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.

More on the Decoder-Error Probability of Reed-Solomon Codes

An explicit expression for the probability of error is derived.

A paper extends the theory of the decoder-error probability for linear maximum-distance separable (MDS) codes. This general class of error-correcting codes includes the Reed-Solomon codes, which are important in communications with distant spacecraft, in military communications, and in the compact-disk recording industry. Advancing beyond previous theoretical developments that placed upper bounds on decoder-error probabilities, the author derives an exact formula for the probability $P_E(u)$ that the decoder will make an error when u code symbols are in error.

In this paper, by using the principle of inclusion and exclusion, the formula for the number of code words of Hamming weight u in a linear MDS code is derived. This idea is extended to derive a more-complicated general formula for the number of decodable code words of Hamming weight u. Some combinatorial theorems are then invoked to obtain a simplified weight-distribution formula. The formula is then used to calculate the numbers of decodable words in a (4,2) MDS code over GF(5) with $t = 1$ and in a (6,3) MDS code over GF(4) with $t = 1$ (where t = the number of errors that the code can correct).

By assuming that the decoder is a bounded-distance decoder and that all error patterns of Hamming weight u are equally probable, the exact decoder-error probability $P_E(u)$ is derived using the weight-distribution formula of the number of decodable words. It was shown in an earlier paper that $P_E(u)$ is the ratio of the number of decodable words of Hamming weight u to the number of words of Hamming weight u in the whole vector space.

At this point, the author introduces Q, the probability that a completely-random error pattern will cause a decoder error. It is shown that as u becomes large, $P_E(u)$ approaches Q — more specifically, that the upper bound on $|P_E(u)/Q - 1|$ decreases nearly exponentially with u as u increases. The paper concludes with the important examples of $P_E(u)$'s of the (255,223) NASA code and the (31,15) JTIDS code.

This work was done by Kar-Ming Cheung of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "More on the Decoder Error Probability for Reed-Solomon Codes," Circle 56 on the TSP Request Card.*
NPO-17467

Design of Trellis Codes for Fading Channels

A new distance metric provides an additional degree of freedom in design.

A report develops the theoretical basis for the design of trellis codes that perform optimally when used in multiple trellis-coded modulation on Rician fading communication channels. These codes perform better than do codes designed to be optimal on nonfading channels with only additive white Gaussian noise (AWGN). The design of the improved codes is based on a new distance measure suitable for fading channels. (Here "distance" denotes a measure of separation in an abstract space in the theory of codes rather than in ordinary three-dimensional space.)

The authors look more carefully than before into the properties of the trellis-coded modulation that enter into the various expressions for average bit-error probability, then use these properties as design criteria for conventional and multiple trellis codes operating over a fading channel. It has been well established in the literature that the maximization of the free Euclidean distance (d_{free}) is the appropriate optimum-design criterion for an AWGN channel. However, for a Rician fading channel with interleaving and deinterleaving, the authors show that the asymptotic performance of trellis-coded modulation at a high signal-to-noise ratio (SNR) is dominated by several other factors that depend on the value of the Rician parameter K. [K is the ratio of direct plus specular power (coherent components) to diffuse power (noncoherent component).]

In particular, at small values of K (where the channel tends toward Rayleigh fading), the primary design criteria for high SNR become (1) a newly defined length of the shortest error-event path and (2) the product of branch distances along that path, with d_{free} a secondary consideration. Thus, at low values of K, the longer the shortest error-event path and the larger the product of the branch distances along that path, the better the code performs, even though d_{free} does not reach its optimum value for an AWGN channel. As K increases, the relative significance of these primary and secondary considerations shifts until K reaches infinity (AWGN), in which case optimum performance is once again achieved by a trellis code designed to maximize d_{free}

To demonstrate the foregoing analytically, the authors first take previously derived upper bounds on the average error-probability performance in the presence of fading and investigate their asymptotic behavior as the SNR grows large. The comparison of these results for the different cases (coherent versus differentially coherent detection and the presence versus the absence of information on the state of the channel) reveal some striking similarities with regard to the way in which certain properties of the trellis-code design affect the rate of descent of the average probability of error with the average SNR. The authors then show that when these properties are used as a motivation for the design of a good code, multiple trellis-coded modulation, wherein more than one channel symbol is assigned to each trellis branch, is a natural choice. Indeed, multiple trellis-coded modulation can achieve a performance on the fading channel superior to that of conventional (single channel symbol per trellis branch) trellis-coded modulation of the same throughput and number of trellis states.

This work was done by Marvin K. Simon and Dariush Divsalar of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "The Design of Trellis Codes for Fading Channels," Circle 127 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

Edward Ansell
Director of Patents and Licensing
Mail Stop 301-6
California Institute of Technology
1201 East California Boulevard
Pasadena, CA 91125

Refer to NPO-17356, volume and number of this NASA Tech Briefs *issue, and the page number.*

CLEO®/ QELS '89

CONFERENCE ON LASERS AND ELECTRO-OPTICS

April 24-28, 1989
Baltimore Convention Center
Baltimore, Maryland

The ninth annual Conference on Lasers and Electro-Optics (CLEO®) and the first Quantum Electronics and Laser Science Conference (QELS) present the world's largest technical conference on lasers. The combined meeting — with more than 900 technical papers anticipated — represents a broad forum for dissemination of information on advances in all aspects of lasers and electro-optic technology, from basic research to applied research to systems engineering and industrial applications. A unified technical exhibition will be open April 25-27.

CLEO

The CLEO program will provide a central forum for an update and review of laser and electro-optic disciplines, from device development to systems engineering and applications. The fifteen general areas of the technical program and their respective chairpersons are:

- **Gas and Free-Electron Lasers,** Joseph F. Figueira, Los Alamos National Laboratory
- **Solid-State and Liquid Lasers,** John M. Eggleston, Solidlite
- **Semiconductor Diode Lasers,** William Streifer, Spectra Diode Laboratories
- **Nonlinear Optics, Phase Conjugation, and Spectroscopy,** Richard C. Lind, Hughes Research Laboratories
- **Optical Materials and Components,** C. Martin Stickley, BDM Corporation
- **Lasers for Fusion and Strong-Field Physics,** W. Howard Lowdermilk, Lawrence Livermore National Laboratory
- **Ultrafast Optics and Electronics,** Anthony M. Johnson, AT&T Bell Laboratories
- **Atmospheric, Space and Ocean Optics,** Paul J. Titterton, GTE Government Systems Division
- **Optical Switching, Bistability, and Storage Devices,** William T. Rhodes, Georgia Tech
- **Imaging and Infrared Technology,** Grady Roberts, Texas Instruments
- **Electro-Optical Instruments and Devices,** Gary E. Sommargren, Zygo Corp.
- **Industrial Applications,** Tony Hsu, Newport Corp.
- **Medical and Biological Applications,** Ronald V. Alves, Coherent Medical Group
- **Lasers in Electronic Processing,** Peter Brewer, Hughes Research Laboratories
- **Lightwave Communications,** Paul W. Shumate, Bellcore

QELS

The QELS conference is the largest North American conference concerning basic research in lasers, nonlinear optics and fundamental laser spectroscopy. The five broad areas of coverage and their respective chairpersons are:

- **Laser Spectroscopy,** William Phillips, U.S. National Institute of Standards and Technology
- **Nonlinear Optical Processes,** Gary C. Bjorklund, IBM Almaden Research Center
- **Optical Interaction with Condensed Matter and Ultrafast Phenomena,** Erich P. Ippen, MIT
- **Physics of Laser Sources,** Stephen E. Harris, Stanford University
- **Lasers in Chemistry and Biology,** James Gole, Georgia Tech

Joint CLEO/QELS Plenary Session Monday, April 24

A joint plenary session Monday afternoon highlights the combined meeting. Speakers are:

- **Quantum Jumps, Ion Crystals, and Solid Plasmas,** David J. Wineland, U.S. National Institute of Standards and Technology
- **Optical Spectroscopy of Electronic Excitations in Semiconductor Microstructures,** Aaron Pinczuk, AT&T Bell Laboratories
- **Optical Neural Networks,** Dana Z. Anderson, University of Colorado, Boulder
- **Synthetic Holography,** Stephen A. Benton, MIT Media Laboratory

Commercial Exhibit Soars

Attendees will find the latest in laser and electro-optical technology on display April 25-27 in the Convention Center. The latest products and services available from more than 350 leading manufacturers from around the world will be prominently exhibited. Don't miss this opportunity to keep abreast of commercial products in the laser industry!

For conference information
CLEO '89 or QELS '89, c/o Optical Society of America
1816 Jefferson Place NW, Washington, DC 20036
Circle Reader Action No. 584

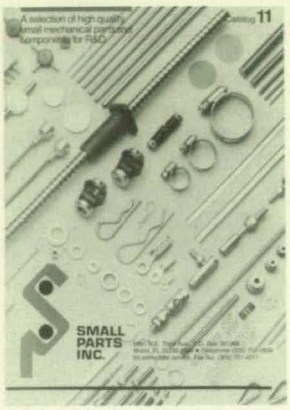
For information on exhibiting
Tel: (202) 223-9034 or (202) 223-9037
FAX: (202) 223-1096 TELEX: 5106003965

New Literature

Low cost now rivals technology as the basis for competition in aerospace manufacturing, according to a report from Booz Allen & Hamilton Inc. entitled **"Operation Strategies for the Changing Aerospace Industry."** Recent declines in the number of new defense program starts, "winner takes all" defense procurements, and large, homogenous airline equipment orders all have been catalysts for escalating the importance of low cost, the report states. Booz Allen believes aerospace companies must make major structural changes in their businesses to succeed in this new environment. Specifically, they need to develop a more detailed understanding of costs, create tailored manufacturing responses for a variety of customer needs, and rethink long-term strategies such as plant focus, vertical integration, and automation investments.
Circle Reader Action Number 724.

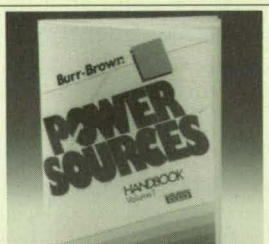
A four-color catalog from Happ Controls Inc., Elk Grove Village, IL, highlights the company's line of **electronic controls for OEM applications.** Included are joystick controls, pushbutton controls, trackball controls, power controls, driving controls, and coin/currency controls. Available free of charge, the catalog is replete with diagrams showing product size, composition, and construction.
Circle Reader Action Number 722.

An **introductory guide to parallel processing and transputer technology** is available free of charge from MicroWay, a Kingston, Massachusetts-based manufacturer of parallel processing boards for PCs. The 50-page report identifies various types of parallel architectures and includes a parallel programming primer with examples. It also describes transputer operating environments and languages designed to provide microcomputers with parallel processing capabilities.
Circle Reader Action Number 708.



A free catalog from Small Parts Inc., Miami, FL, features thousands of hard-to-find **mechanical parts and material components** in small quantities and sizes. Products include bearings, cables, connectors, joints, plugs, rivets, screws, washers, wire, and much more. The 208-page publication also describes hand and power tools for miniaturized applications.
Circle Reader Action Number 718.

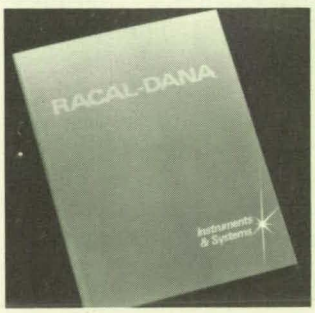
Information Handling Services (IHS) of Englewood, CO, has compiled on microfilm more than 8,000 pages of technical reports, studies, and handbooks issued by the Plastic Technical Evaluation Center (PLASTEC), a Department of Defense-sponsored research center that generates and exchanges technical data related to **plastics, adhesives, and organic matrix composites.** PLASTEC publications cover new technology — from applied research through fabrication — with emphasis on properties and performance. IHS' "PLASTEC Service" is available on 16mm microfilm cartridges and comes with a printed index that is updated every 180 days.
Circle Reader Action Number 716.



The **Power Sources Handbook** from Burr-Brown, Tucson, AZ, describes more than 450 single-, dual-, and triple-output power supplies in a broad range of modular and DIP packages. In addition to numerous product data sheets, the 96-page publication contains a detailed selection guide, application notes, and a glossary of power conversion terminology.
Circle Reader Action Number 702.

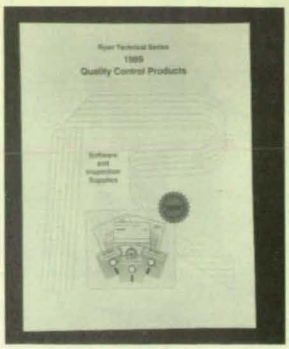
The new **Temperature Measurement Handbook** published by the Nanmac Corp., Lake Worth, FL, contains specifications for 10,000 temperature measurement and control products. The 270-page handbook features a full line of thermocouple, RTD, and thermistor probes, as well as thermocouple wire, insulators, protection tubes, and other accessories. More than 50 pages of technical notes and test results for temperature measurement of plastics processing, heat treating, glass manufacturing, and aerospace applications are included.
Circle Reader Action Number 728

"Fiber Optics Test: Tools of the Trade" is the title of a newly released article that summarizes the present state of the fiber optic test industry. Published by Intelco Corp., Acton, MA, the article illustrates the advantages and disadvantages of current commercial equipment, and also anticipates technology advances on the near horizon.
Circle Reader Action Number 720.



A free catalog from Racal-Dana Instruments Inc., Irvine, CA, covers **programmable switching systems** from DC to 26.5 GHz; universal counter/timers with 1 nanosecond resolution and frequency counters to 20 GHz; digital test subsystems; and RF instrumentation. The 114-page catalog includes product descriptions, specifications, photographs, and ordering information.
Circle Reader Action Number 706.

The **CAPS (Computer-Aided Product Selection) system** is described in a free brochure from the Cahners Technical Information Service Div., Newton, MA. A PC-based engineering tool, CAPS contains specifications, application notes, and text and graphics images of manufacturers' data sheets for more than 400,000 integrated circuits and semiconductors produced by 250 companies worldwide. The information is organized, indexed, and stored on a set of CD-ROM disks.
Circle Reader Action Number 710.

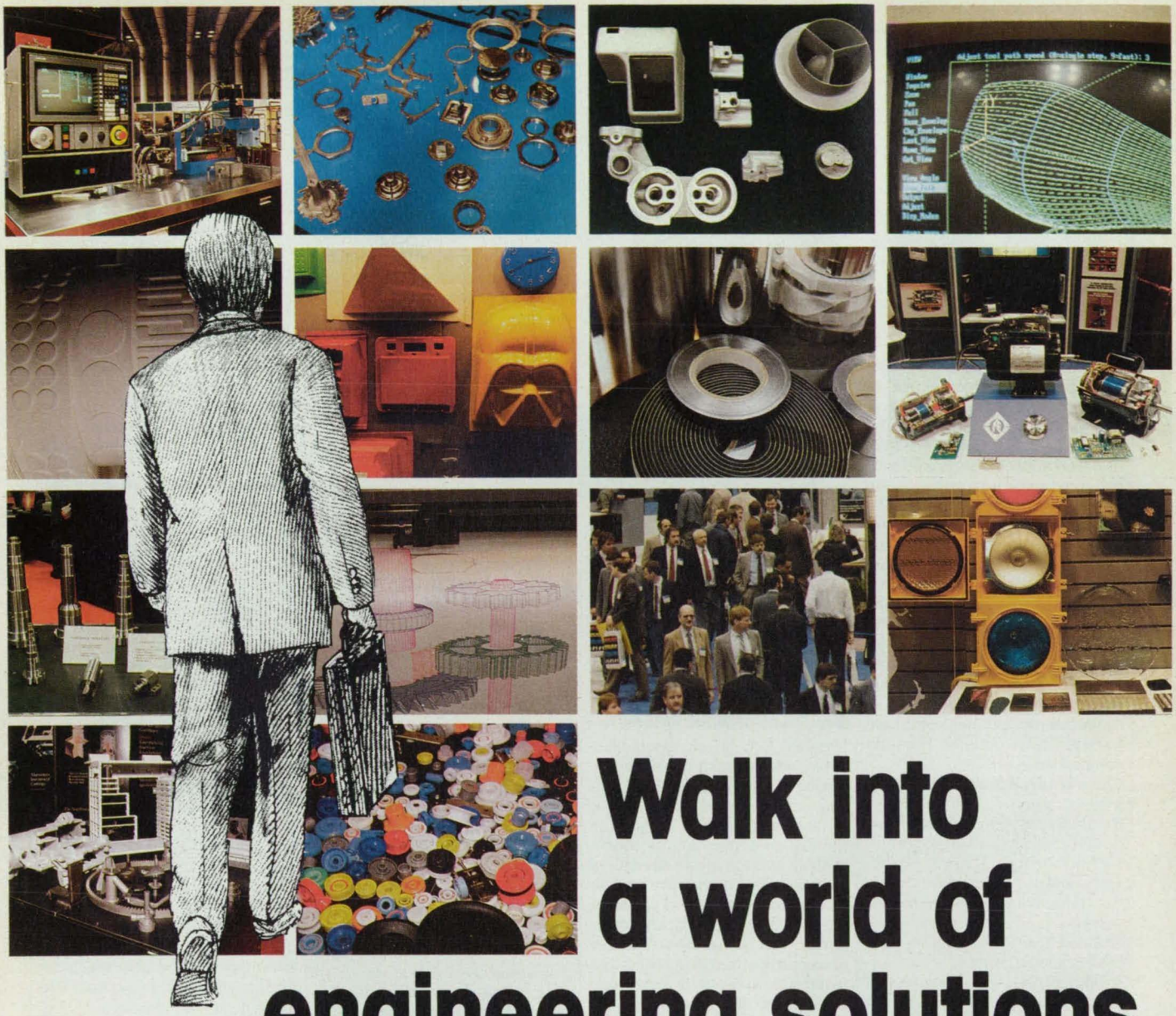


Ryan Enterprise, Wrightwood, CA, is offering a 24-page **catalog of quality control software and supplies.** Software includes a quality control manual, calibration procedures, military specifications, and a calibration control database. The supplies section features inspection stamps, stock calibration labels, and stock inspection tags, as well as information on custom-made items.
Circle Reader Action Number 714.

Metawell has published a new **design guide** that displays the Providence-based company's full line of corrugated metal sheets. Offered free of charge, the handbook provides load bearing characteristics and technical specifications for a variety of aluminum and galvanized steel sheets, each designed with a corrugated metal core. Diagrams allow the user to determine boundary conditions such as bearing length, span, deflection, and load.
Circle Reader Action Number 704.

An eight-page, color brochure spotlights the new line of **target mounting systems** from Scientific-Atlanta Inc., Atlanta, GA. Designed to minimize backscatter, the Series 55500 target mounting systems provide a reliable way to mount and position RCS targets weighing up to 3,000 pounds. The brochure covers specifications and applications for the new pylons and rotators, and includes a glossary of terms.
Circle Reader Action Number 712.

Bruel & Kjaer Instruments Inc., Marlborough, MA, has published its 1989 catalog of regional seminars and workshops on **sound and vibration analysis.** Seminar topics include: Acoustical Noise Control; Digital Signal Analysis for Applications in Vibration and Sound; Measuring Light; Modern Techiques for Machine Vibration Analysis; Principles of Acoustics and the Measurement of Sound; Spectral Analysis in Sound and Vibration; and Understanding Model Analysis.
Circle Reader Action Number 726.



Walk into a world of engineering solutions

Discover new ideas to spark your imagination...at the **Spring National Design Engineering Show & Conference.™**

Meet technical reps from over 700 companies—**IBM, McDonald-Douglas, Unisys, DuPont, Amoco**—and hundreds of others. Find solutions for *all* your requirements. Participate in hands-on demonstrations. At Spring Design ...an environment alive with fresh ideas! A showcase of all the latest components and systems.

Plus, increase your knowledge of the latest trends at topical ASME-sponsored conference sessions, workshops and professional development courses.

See CAD/CAM/CAE • mechanical components • plastics and metals • fluid power systems • fastener and joining systems • electrical and electronic components and shapes and forms. And you'll find new ideas *fast* with the help of the **Spring Design Product Locator Service.**

Special bonus!
Spring Design will be co-located with AMS and National Plant. See three major industry events in one location!

SAVE $25! Bring this ad to the Show for FREE Show admission.
For further information, call 1-800-255-7798, (in CT 203-964-0000) today!

Spring Design... your number one OEM resource.

Spring National Design Engineering Show & Conference™
April 24-27, 1989
McCormick Place North, Chicago, Illinois

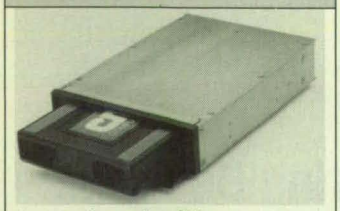
Circle Reader Action No. 677

XZ

New on the Market

Stat-Ease Inc., Minneapolis, MN, is now issuing site licenses for its experimental **design software**, DESIGN-EASE® and DESIGN-EXPERT®. These programs help engineers and scientists to efficiently set up and analyze experiments with powerful statistical tools. DESIGN-EASE allows reseachers to choose, conduct, and analyze fractional factorial, Plackett-Burman, and other experimental designs. Recommended for advanced research, DESIGN-EXPERT offers response surface and mixture design capabilities. The program features high-resolution graphics and can handle up to five responses simultaneously in its optimization routines. Stat-Ease software runs on IBM PCs and compatibles.
Circle Reader Action Number 800.

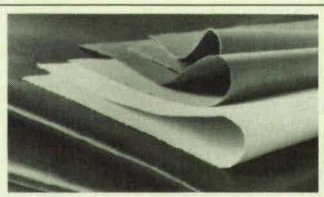
A nonsolvent, all-natural **degreaser** developed by Environmental Technology Inc., Sanford, FL, lifts grease and oil from metals and other hard surfaces while allowing for safe and easy disposal of spent solution. Dubbed the RB Degreaser, the biodegradable formula is noncorrosive to metal and degreases rapidly in soak tanks, power washers, and spray application. Unlike conventional solvents used to clean parts, RB Degreaser contans no toxic ingredients.
Circle Reader Action Number 782.



A new line of **solid-state storage systems** has been unveiled by the Citadel Computer Corp., Amherst, NH. Targeted for harsh industrial and military environments, the DATAVAULT systems can survive extreme shock and vibration in temperatures from −40° to +85°C. The removable-cartridge systems feature data storage capacities to 4 megabytes. Host interfaces are available supporting the IBM PC/XT/AT, STD Bus, MULTIBUS iSBX, VME Bus, and CIMBUS.
Circle Action Reader Number 790

SPEAK! Voice Recognition Technologies, Laguna Hills, CA, has introduced a **workstation** that accurately translates foreign-language research material or scientific data into English. The voice-input data is instantly converted into any modern word processing format, thereby eliminating dictation or transcription errors. Complex software commands, numbers, words, phrases, scientific expressions, formulae, and chemical compounds are translated with 100% accuracy, according to the manufacturer. The SPEAK! Research Workstation includes a Toshiba T3200 portable computer, the voice recognition board and software, a database, scientific word processor, and a headset microphone.
Circle Reader Action Number 780.

Metalset A-4, an aluminum-filled **epoxy resin cement** developed by Smooth-On Inc., Gillette, NJ, adheres to both porous and nonporous surfaces and is highly resistant to thermal and mechanical shock. With an average tensile strength of 3600 psi and a compressive strength of 7500 psi, Metalset A-4 can withstand drilling, tapping, and other forms of machining. The solvent-free epoxy can be used to make jigs and fixtures, stop leaks in pipes and valves, and repair flaws in metal casting. It can also be applied as a smoothing compound, a shim material, or as a solder.
Circle Reader Action Number 798.



Mid-Mountain Materials Inc., Redmond, WA, has created a new line of heat-resistant, **silicone-coated fabrics** for industrial applications where protection or insulation is needed. Nonflammable and UV-resistant, silicone provides heat protection to 260°C and serves as an excellent weather barrier. The coatings are applied to such fabrics as fiberglass, Kevlar®, Nomex®, Nextel®, carbon, quartz, and ceramic fiber to produce gaskets, seals, blankets, shields, thermal drapes, and other products.
Circle Reader Action Number 784.

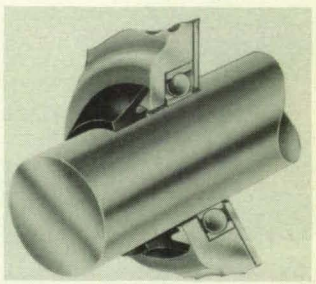
Motorola Inc., Schaumburg, IL, has introduced a compact **CCD camera** for surveillance, industrial, medical, and image processing applications. Suited for unattended operation in extremely tight spaces, the camera weighs 14 ounces, measures 2.0″x3.7″x2.5″, and uses less than 14 watts of power. The unit's solid-state design helps prevent image retention and burn-in during both stationary and action scenes.
Circle Reader Action Number 796.

STRIP-TEEZE® **TFE tape** from the Swagelok Company, Solon, OH, seals tapered pipe threads and protects them from galling. The product is compatible with fuels, acids, alcohols, hydraulic fluids, refrigerants, and other systems fluids. Applications include pump connections, compressed air lines, instrument lines, and lubrication systems.
Circle Reader Action Number 792.

VRIFS™ image synthesis and graphics generation software from Iterated Systems Inc., Norcross, GA, enables 1,000 complex, high resolution color images to be designed and stored in a single megabyte of disk space. Each image is identified by a signature consisting of a small file of numeric data. The signature provides an encoded image that can be transmitted 1,000 times faster than standard bit-mapped images. The core algorithm generates natural scenes, man-made objects, fractal entities, standard graphics, fonts, maps, and diverse textures.
Circle Reader Action Number 778.

EZ-COPY PLUS™ **diskette duplication software** from EZX Publishing, Webster, TX, enables IBM PC users to quickly and inexpensively copy 5¼″ and 3½″ diskettes. The program, which retails for $199, copies 1.2M and 1.44M floppies with a single drive; reads and stores compressed disk images on hard drive for future retrieval or modem transfer; and allows bypassing of most copy protection schemes for legitimate software backup.
Circle Reader Action Number 758.

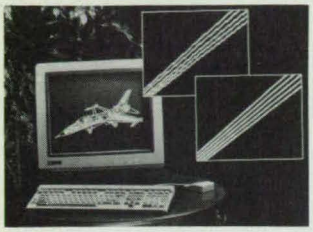
Tech Spray Inc., Amarillo, TX, markets the Zero Charge® Guardian, an **anti-static coating** for plastics, fabrics, corrugated materials, and Formica. A homogeneous polymer, Zero Charge Guardian coats evenly to eliminate voids where electrostatic discharge (ESD) can strike. The abrasion-resistant coating is available as a liquid or concentrate and can be applied in seconds.
Circle Reader Action Number 794.



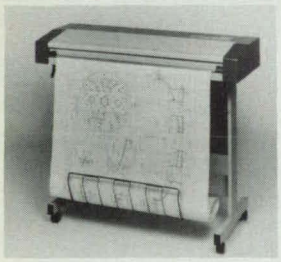
An all-rubber, self-adjusting **radial lip seal** called Rota-Seal has been introduced by Sealmor Industries, Columbus, OH. Designed to retain lubricants within bearings while excluding contaminants, Rota-Seal exhibits low wear and is highly resilient and fluid-resistant. Typical applications include bearings, axles, wheels, pumps, electric motors, mixers, and transmissions. The new seal is offered in 48 standard sizes from 5 to 500 millimeters.
Circle Reader Action Number 786.

Jandel Scientific, Corte Madera, CA, has updated its Sigma-Scan® **digitizing and morphometric measurement software** for IBM PC, XT, AT, PS-2, and compatible computers. Like the earlier programs, Sigma-Scan Version 3.9 is used with a digitizing table to measure and analyze areas, distances, angles, and slopes, as well as to perform point, stream, and incremental x-y digitizing and object tallying. New features include an expanded 16,000 column by 65,000 row data worksheet, enhanced data transforms, and improved calibration options.
Circle Reader Action Number 788

New on the Market



A new monochrome **graphics terminal** introduced by Codonics Inc., Middleburg Heights, OH, can display a graphics image with an effective resolution of 16,000 × 12,000 pixels. Using multiple pixels of varying sizes, the Codonics 4096 TrueLine™ terminal creates circular and diagonal lines with no jagged edges. Endpoints can be placed anywhere on the screen to within 1/4096 of the screen size in both axes. Other graphics terminals simply truncate down to a 1024 × 780 grid, which degrades accuracy. The new raster graphics terminal offers DEC VT320/220/100 emulation and features a communications interface with three bidirectional RS-232C serial ports, current loop, RS-422, and a Centronics-compatible parallel printer port.
Circle Reader Action Number 768.



The Model RY-T001 **thermal plotter** from RDK Inc., Austin, TX, is designed for high-volume production of single-color, large-format (D/E size) drawings for the manufacturing, architectural, and construction industries. Similar to electrostatic plotters in resolution, the Model RY-T001 can plot a drawing in under three minutes. Features include a built-in vector/raster converter, RS-232C/Centronics parallel interfaces, HP-GL compatibility, and eight line widths.
Circle Reader Action Number 764

ARCO Solar Inc., Camarillo, CA, has introduced a series of **Solar Charger Kits** that convert sunlight into DC electricity to charge batteries and run appliances. Four kits are available — from the Solar Charger 1, a "trickle charger" that maintains batteries when not in use, up to the Solar Charger 4, which can run a coach full of small appliances. The kits work in both hot and cold weather and on cloudy days.
Circle Reader Action Number 760.

The PR® -900 video-photometer from Photo Research® , Chatsworth, CA, performs spatial, photometric, and colorimetric inspection of a wide array of displays, including commercial monitors, cockpit CRTs, and automotive panel LED, LCD, and electroluminescent displays. The PC-based system dramatically reduces the time required for these inspections by virtue of its ability to learn a measurement and then automatically repeat it. Data from the unit's CCD-array video camera is captured at the rate of 30 frames per second. The image is digitized via computer and displayed on a monitor for analysis.
Circle Reader Action Number 762.

National Testing Laboratories, Cleveland, OH, has developed **a kit that enables home owners to quickly test their drinking water** for lead, pesticides, PCBs, solvents, bacteria, and other contaminants. The water sample is drawn into a bottle containing the necessary preservatives and then shipped to the lab for analysis. Within five days of receipt, the lab sends the customer a report containing a detailed explanation of the findings and recommendations for corrective action.
Circle Reader Action Number 766.

High-temperature superconductive thin-films — the building blocks of future superconductive electronic applications — are now available in round, square, and patterned forms from Superconductive Components Inc., Columbus, OH. The films are approximately 1 micron thick, with typical critical temperature above 87 degrees Kelvin and critical current of 100,000 amps/cm² on single-crystal strontium titanate substrates. They can be ordered with complete characterization, including x-ray diffraction.
Circle Reader Action Number 770.

A new precision-chopped, **conductive metal-coated graphite fiber** has been introduced by the American Cyanamid Company, Wayne, NJ. Available with either nickel or copper coating, the ultra-fine fiber can be used in conductive adhesives, aerospace sealants and gaskets, electronics, architectural shielding, and automotive applications.
Circle Reader Action Number 756.

Subject Index

A

ACCELEROMETERS
Low-cost vertical accelerometer for aircraft
page 94 ARC-11870

AEROELASTICITY
Computing flutter boundaries
page 87 LEW-14380

AIRCRAFT INSTRUMENTS
Low-cost vertical accelerometer for aircraft
page 94 ARC-11870

AIRFOILS
Computing flutter boundaries
page 87 LEW-14380

ALGORITHMS
Placement of exciters and sensors to measure vibrations
page 100 NPO-17293

ALUMINUM OXIDES
Alumina-enhanced thermal barrier
page 78 ARC-12135

AMIDES
Additives lower pickup of moisture by polyimides
page 80 LAR-13679

ANALOG DATA
Detector for FM voice or digital signals
page 66 NPO-16788

ANEMOMETERS
Signal preprocessor for laser-fringe anemometers
page 32 LEW-14663

ANNEALING
Annealing increases stability of iridium thermocouples
page 110 LAR-13951

AUDITORY DEFECTS
Directional hearing aid
page 34 GSC-13027

B

BALL BEARINGS
Theory of ball-bearing vibrations
page 105 MFS-29378

BINARY CODES
Design of trellis codes for fading channels
page 112 NPO-17356

More on the decoder-error probability of Reed-Solomon codes
page 112 NPO-17467

BUCKLING
Calculating buckling and vibrations of lattice structures
page 84 LAR-13876

C

CADMIUM COMPOUNDS
CdO pretreatment for graphite lubricant films
page 82 LEW-14635

CARBON FIBER REINFORCED PLASTICS
Degradation of carbon/phenolic composites by NaOH
page 82 MFS-27099

CARBON MONOXIDE
Modified technique for chemisorption measurements
page 73 LAR-13725

CENTRAL PROCESSING UNITS
Eight-bit-slice GaAs general processor circuit
page 65 GSC-13012

CERAMICS
Alumina-enhanced thermal barrier
page 78 ARC-12135

Ceramic honeycomb panels
page 108 ARC-11652

CHANNELS (DATA TRANSMISSION)
Design of trellis codes for fading channels
page 112 NPO-17356

CHARGE COUPLED DEVICES
Metal film increases CCD quantum efficiency
page 24 NPO-16815

CHEMISORPTION
Modified technique for chemisorption measurements
page 73 LAR-13725

CIRCUIT PROTECTION
Output-isolation and protection circuit
page 26 ARC-11834

COMBUSTION CHAMBERS
Heat flux in a dual-throat rocket engine
page 106 MFS-28261

COMPRESSORS
Integrated heat switch/oxide sorption compressor
page 102 NPO-17162

COMPUTER COMPONENTS
Keyboard emulation for computerized instrumentation
page 37 LEW-14180

COMPUTERIZED SIMULATION
Optimization of simulated trajectories
page 85 LAR-13938

Optimizing simulated trajectories of rigid bodies
page 86 LAR-13939

CONNECTORS
Inflatable-seal assembly for cryogenic fluids
page 99 KSC-11368

CONTINUOUS WAVE LASERS
Stable 1.25-W CW methanol laser
page 22 NPO-17346

CONTROL SYSTEMS DESIGN
Simplified linear multivariable control of robots
page 36 NPO-16857

CONTROLLERS
Interface for fault-tolerant control system
page 40 ARC-11791

COUPLERS
Fabrication of fiber-optic waveguide coupler
page 109 NPO-15630

COUPLINGS
Magnetic coupling delivers increased torque
page 103 MSC-21171

CRYOGENIC COOLING
Surface tension confines cryogenic liquid
page 88 GSC-13112

CRYOGENIC FLUIDS
Inflatable-seal assembly for cryogenic fluids
page 99 KSC-11368

CRYOGENICS COOLING
Integrated heat switch/oxide sorption compressor
page 102 NPO-17162

D

DAMPERS (VALVES)
Damper of small vibrations
page 96 MFS-28244

DATA PROCESSING EQUIPMENT
Keyboard emulation for computerized instrumentation
page 37 LEW-14180

DATA TRANSMISSION
Fast asynchronous data communication via fiber optics
page 38 NPO-16972

DECODING
More on the decoder-error probability of Reed-Solomon codes
page 112 NPO-17467

DESULFURIZING
Metal oxide/zeolite combination absorbs H_2S
page 81 NPO-17099

DIGITAL DATA
Detector for FM voice or digital signals
page 66 NPO-16788

DIGITAL SYSTEMS
Eight-bit-slice GaAs general processor circuit
page 65 GSC-13012

DIRECTIONAL SOLIDIFICATION (CRYSTALS)
Measurement of composition in transparent model alloy
page 72 MFS-26079

DISCONNECT DEVICES
Theory of a pyrotechnically driven device
page 76 NPO-17117

E

ELECTRIC FIELDS
Review of fiber-optic electric-field sensors
page 76 NPO-17242

ELECTROMECHANICAL DEVICES
"Smart" electromechanical shock absorber
page 94 MSC-21368

ELECTRON PARAMAGNETIC RESONANCE
Measurement of molecular mobilities of polymers
page 74 NPO-17216

ELECTRON SCATTERING
Electron/ion-scattering apparatus
page 70 NPO-16789

ELECTRONIC EQUIPMENT
Output-isolation and protection circuit
page 26 ARC-11834

ERROR CORRECTING CODES
More on the decoder-error probability of Reed-Solomon codes
page 112 NPO-17467

ETCHING
Spinner for etching of semiconductor wafers
page 108 NPO-16912

EXPLOSIVE DEVICES
Theory of a pyrotechnically driven device
page 76 NPO-17117

F

FAR INFRARED RADIATION
Stable 1.25-W CW methanol laser
page 22 NPO-17346

FEEDBACK CONTROL
"Smart" electromechanical shock absorber
page 94 MSC-21368

FIBER OPTICS
Fabrication of fiber-optic waveguide coupler
page 109 NPO-15630

Fast asynchronous data communication via fiber optics
page 38 NPO-16972

Review of fiber-optic electric-field sensors
page 76 NPO-17242

Spectrum-modulating fiber-optic sensors
page 24 LEW-14662

FIGURE OF MERIT
Increasing and combining outputs of semiconductor lasers
page 30 NPO-17473

FLIGHT CONTROL
Interface for fault-tolerant control system
page 40 ARC-11791

FLIGHT SIMULATION
Optimization of simulated trajectories
page 85 LAR-13938

Optimizing simulated trajectories of rigid bodies
page 86 LAR-13939

FLOW CHARACTERISTICS
Making displaced holograms at two wavelengths
page 68 MFS-28242

FLUE GASES
Metal oxide/zeolite combination absorbs H_2S
page 81 NPO-17099

FLUORINATION
Better PFAE's from direct fluorination
page 80 LEW-14613

FLUTTER
Computing flutter boundaries
page 87 LEW-14380

FREQUENCY MODULATION
Detector for FM voice or digital signals
page 66 NPO-16788

FUSION (MELTING)
Phase-change heat-storage module
page 103 MFS-26071

G

GALLIUM ARSENIDES
Eight-bit-slice GaAs general processor circuit
page 65 GSC-13012

GAS-METAL INTERACTIONS
Effects of aging on embrittlement by hydrogen
page 83 ARC-11762

Modified technique for chemisorption measurements
page 73 LAR-13725

GRAPHITE
CdO pretreatment for graphite lubricant films
page 82 LEW-14635

GYRO HORIZONS
Low-cost vertical accelerometer for aircraft
page 94 ARC-11870

H

HATCHES
Hatch cover slides through hatch
page 92 MSC-21356

HEARING
Directional hearing aid
page 34 GSC-13027

HEAT FLUX
Heat flux in a dual-throat rocket engine
page 106 MFS-28261

HEAT STORAGE
Phase-change heat-storage module
page 103 MFS-26071

HELICOPTER CONTROL
Interface for fault-tolerant control system
page 40 ARC-11791

HIGH ELECTRON MOBILITY TRANSISTORS
Optically-controlled microwave devices and circuits
page 31 LEW-14710

HIGH TEMPERATURE ENVIRONMENTS
Dynamic, high-temperature, flexible seal
page 101 LEW-14672

HIGH TEMPERATURE FLUIDS
Better PFAE's from direct fluorination
page 80 LEW-14613

HOLOGRAPHY
Making displaced holograms at two wavelengths
page 68 MFS-28242

HONEYCOMB STRUCTURES
Ceramic honeycomb panels
page 108 ARC-11652

HYDROGEN EMBRITTLEMENT
Effects of aging on embrittlement by hydrogen
page 83 ARC-11762

HYDROGEN SULFIDE
Metal oxide/zeolite combination absorbs H_2S
page 81 NPO-17099

HYGROSCOPICITY
Additives lower pickup of moisture by polyimides
page 80 LAR-13679

HYPERSONIC AIRCRAFT
Dynamic, high-temperature, flexible seal
page 101 LEW-14672

I

IGNITERS
Igniter simulator
page 31 MFS-29402

IMAGERY
Making displaced holograms at two wavelengths
page 68 MFS-28242

INFRARED LASERS
Stable 1.25-W CW methanol laser
page 22 NPO-17346

INFRARED SPECTROSCOPY
Measurement of composition in transparent model alloy
page 72 MFS-26079

ION BEAMS
Electron/ion-scattering apparatus
page 70 NPO-16789

IRIDIUM
Annealing increases stability of iridium thermocouples
page 110 LAR-13951

J

JOULE-THOMSON EFFECT
Integrated heat switch/oxide sorption compressor
page 102 NPO-17162

L

LASER ANEMOMETERS
Signal preprocessor for laser-fringe anemometers
page 32 LEW-14663

LASERS
Increasing and combining outputs of semiconductor lasers
page 30 NPO-17473

LUBRICANTS
CdO pretreatment for graphite lubricant films
page 82 LEW-14635

M

MAGNETS
Magnetic coupling delivers increased torque
page 103 MSC-21171

MAN MACHINE SYSTEMS
Simplified linear multivariable control of robots
page 36 NPO-16857

MECHANICAL DRIVES
Magnetic coupling delivers increased torque
page 103 MSC-21171

MICROWAVE EQUIPMENT
Optically-controlled microwave devices and circuits
page 31 LEW-14710

MICROWAVE HOLOGRAPHY
Measuring shapes of reflectors by microwave holography
page 74 NPO-17382

MOBILITY
Measurement of molecular mobilities of polymers
page 74 NPO-17216

MODULATION
Spectrum-modulating fiber-optic sensors
page 24 LEW-14662

MODULES
Trash-disposal module for Space Station
page 105 MSC-21324

MONOTECTIC ALLOYS
Measurement of composition in transparent model alloy
page 72 MFS-26079

N

NEODYMIUM LASERS
Cladding for transversely-pumped laser rod
page 68 NPO-17355

NICKEL
Effects of aging on embrittlement by hydrogen
page 83 ARC-11762

NUMERICAL CONTROL
Keyboard emulation for computerized instrumentation
page 37 LEW-14180

O

OSCILLATION DAMPERS
Damper of small vibrations
page 96 MFS-28244

OVERVOLTAGE
Output-isolation and protection circuit
page 26 ARC-11834

P

PARABOLIC REFLECTORS
Measuring shapes of reflectors by microwave holography
page 74 NPO-17382

PERFLUORO COMPOUNDS
Better PFAE's from direct fluorination
page 80 LEW-14613

PHASE CHANGE MATERIALS
Phase-change heat-storage module
page 103 MFS-26071

PHENOLIC RESINS
Degradation of carbon/phenolic composites by NaOH
page 82 MFS-27099

PHOTOCONDUCTIVITY
Optically-controlled microwave devices and circuits
page 31 LEW-14710

PHOTOMETERS
Metal film increases CCD quantum efficiency
page 24 NPO-16815

PIEZOELECTRIC TRANSDUCERS
Review of fiber-optic electric-field sensors
page 76 NPO-17242

PISTONS
Sensing the position of a piston in a cylinder
page 90 NPO-16956

POLYIMIDES
Additives lower pickup of moisture by polyimides
page 80 LAR-13679

POLYMERS
Measurement of molecular mobilities of polymers
page 74 NPO-17216

POSITION SENSING
Sensing the position of a piston in a cylinder
page 90 NPO-16956

PRESSURE SWITCHES
Sensing the position of a piston in a cylinder
page 90 NPO-16956

PRESSURE VESSELS
Hatch cover slides through hatch
page 92 MSC-21356

PULSE COMMUNICATION
Fast asynchronous data communication via fiber optics
page 38 NPO-16972

R

RADIO ANTENNAS
Measuring shapes of reflectors by microwave holography
page 74 NPO-17382

REDUCED GRAVITY
Surface tension confines cryogenic liquid
page 88 GSC-13112

REFRACTORY MATERIALS
Alumina-enhanced thermal barrier
page 78 ARC-12135

REMOTE SENSORS
Spectrum-modulating fiber-optic sensors
page 24 LEW-14662

ROBOTS
Simplified linear multivariable control of robots
page 36 NPO-16857

ROCKET ENGINES
Heat flux in a dual-throat rocket engine
page 106 MFS-28261

ROTATING SHAFTS
Theory of ball-bearing vibrations
page 105 MFS-29378

S

SCATTERING
Electron/ion-scattering apparatus
page 70 NPO-16789

SEALS (STOPPERS)
Dynamic, high-temperature, flexible seal
page 101 LEW-14672

Hatch cover slides through hatch
page 92 MSC-21356

Inflatable-seal assembly for cryogenic fluids
page 99 KSC-11368

SEMICONDUCTOR DEVICES
Metal film increases CCD quantum efficiency
page 24 NPO-16815

SEMICONDUCTOR LASERS
Increasing and combining outputs of semiconductor lasers
page 30 NPO-17473

SEMICONDUCTORS (MATERIALS)
Spinner for etching of semiconductor wafers
page 108 NPO-16912

SHOCK ABSORBERS
"Smart" electromechanical shock absorber
page 94 MSC-21368

SIGNAL FADING
Design of trellis codes for fading channels
page 112 NPO-17356

SIGNAL PROCESSING
Signal preprocessor for laser-fringe anemometers
page 32 LEW-14663

SIMULATORS
Igniter simulator
page 31 MFS-29402

SODIUM HYDROXIDES
Degradation of carbon/phenolic composites by NaOH
page 82 MFS-27099

SOLID PROPELLANT ROCKET ENGINES
Reducing thrusts in solid-fuel rockets
page 101 LAR-13744

SOLID STATE LASERS
Cladding for transversely-pumped laser rod
page 68 NPO-17355

SPACE SHUTTLE MAIN ENGINE
Igniter simulator
page 31 MFS-29402

SPACE STATIONS
Trash-disposal module for Space Station
page 105 MSC-21324

SQUIBS
Theory of a pyrotechnically driven device
page 76 NPO-17117

STEREOPHONICS
Directional hearing aid
page 34 GSC-13027

STRAIN GAGES
Theory of ball-bearing vibrations
page 105 MFS-29378

STRUCTURAL MEMBERS
Thermally stable truss
page 107 MFS-27216

STRUCTURAL STABILITY
Calculating buckling and vibrations of lattice structures
page 84 LAR-13876

STRUCTURAL VIBRATION
Placement of exciters and sensors to measure vibrations
page 100 NPO-17293

SUPERCOOLING
Surface tension confines cryogenic liquid
page 88 GSC-13112

T

THERMAL STABILITY
Thermally stable truss
page 107 MFS-27216

THERMOCOUPLES
Annealing increases stability of iridium thermocouples
page 110 LAR-13951

THRUST CONTROL
Reducing thrusts in solid-fuel rockets
page 101 LAR-13744

TRAJECTORY OPTIMIZATION
Optimization of simulated trajectories
page 85 LAR-13938

Optimizing simulated trajectories of rigid bodies
page 86 LAR-13939

TRUSSES
Thermally stable truss
page 107 MFS-27216

V

VAPOR DEPOSITION
Ceramic honeycomb panels
page 108 ARC-11652

VENTING
Reducing thrusts in solid-fuel rockets
page 101 LAR-13744

VIBRATION
Calculating buckling and vibrations of lattice structures
page 84 LAR-13876

VIBRATION ISOLATORS
Damper of small vibrations
page 96 MFS-28244

VIBRATION MEASUREMENT
Placement of exciters and sensors to measure vibrations
page 100 NPO-17293

W

WAFERS
Spinner for etching of semiconductor wafers
page 108 NPO-16912

WASTE DISPOSAL
Trash-disposal module for Space Station
page 105 MSC-21324

WAVEGUIDES
Fabrication of fiber-optic waveguide coupler
page 109 NPO-15630

Y

YAG LASERS
Cladding for transversely-pumped laser rod
page 68 NPO-17355

DON'T FORGET TO CHECK YOUR LABEL

0020 EXP DATE FEB 88 T9999999
JOHN DOE
XYZ COMPANY
123 MAIN BLVD
BLARNEY NJ 07335

Your NASA Tech Briefs address label contains very valuable information:

1. **Subscription Expiration Date**—a great way to remember to renew before you're caught unaware of interrupted service.
2. **Personal Identification Number**—aids in the rapid processing of your renewal.

It's fast and easy to renew when you use the convenient peel-off address label. Just attach to the subscription form in your magazine, sign, date & complete all questions. **We must have your company name and address if your copy of NTB is being sent to your home address.**

Don't take a chance on missing out on any of NTB's latest technology, new product ideas or industry trends you need to acquire the knowledge, solutions, and ideas that have inspired progressive industry leaders—look at your label, and renew early.

NASA Tech Briefs, ISSN 0145-319X, USPS 750-070, copyright © 1989 in U.S., is published by Associated Business Publications Co., Ltd. 41 E. 42nd St., New York, NY 10017-5391. The copyrighted information does not include the individual Tech Briefs which are supplied by NASA. Editorial, sales, production and circulation offices at 41 E. 42nd Street, New York, NY 10017-5391. Subscriptions for non-qualified subscribers in the U.S., Panama Canal Zone, and Puerto Rico, $75.00 for 1 year; $125.00 for 2 years; $200 for 3 years. Single copies $10.00. Remit by check, draft, postal or express orders. Other remittances at sender's risk. Address all communications for subscriptions or circulation to NASA Tech Briefs, 41 E. 42nd Street, New York, NY 10017-5391. Second-class postage paid at New York, NY and additional mailing offices. **POSTMASTER: please send address changes to NASA Tech Briefs, 41 E. 42nd Street, Suite 921, New York, NY 10017-5391.**

Advertiser's Index

Advanced Products Corporation	(RAC* 580)	73
Aerospatiale	(RAC 658-660)	25, 27, 29
Allied Signal Aerospace Company	(RAC 656)	9
Allied Signal Engineered Plastics	(RAC 606)	35
Amco Engineering Co.	(RAC 499)	COV III
American Precision Industries	(RAC 329)	95
AMP	(RAC 667)	49
Apollo Computer	(RAC 591)	8
Aurora Bearings	(RAC 540)	8
Automation Gages	(RAC 433)	104
Best Power Technology, Inc.	(RAC 370)	121
BMC Software	(RAC 481)	64
Brown Book Shop	(RAC 458)	55
Carrollton/Economic Development	(RAC 494)	62
City of DeSoto	(RAC 470)	56
City of Farmers Branch	(RAC 317)	48
CLEO/QELS '89	(RAC 584)	113
Coil Annodizers	(RAC 332)	83
Concurrent Computer Corporation	(RAC 581)	5
Control Laser Corporation	(RAC 563-564)	37
COSMIC	(RAC 450)	86
Dallas Partnership	(RAC 534)	42-43
David Sarnoff Research Center	(RAC 604)	11
Dean Products, Inc.	(RAC 507)	28
DSP Development Corporation	(RAC 652)	31
EGC Corporation	(RAC 461)	51
Eighteen Eight Laboratories	(RAC 675)	100
Electro Scientific Industries, Inc.	(RAC 530)	100
Entrepreneur's Library	(RAC 318)	123
Federal Procurement Services	(RAC 447)	121
Fluoramics	(RAC 354)	119
Garland Economic Develpment	(RAC 484)	61
GE Plastics	(RAC 615)	74-75, 77
Grafpoint	(RAC 686)	122
Grumman Corporation	(RAC 554)	53
Hamamatsu Photonic Systems	(RAC 532)	89
Honeywell Optoelectronics	(RAC 486)	53
Horizon Capacitors	(RAC 610)	124
Houston Instrument	(RAC 550)	45
Humphrey Inc.	(RAC 626)	30
Hydra-Electric Co.	(RAC 427)	121
Inco Alloys International, Inc.	(RAC 569)	79
Information Development, Inc.	(RAC 488)	55
Intel	(RAC 382)	85
Intermetrics, Inc.	(RAC 464)	52
Interphase Corporation	(RAC 496)	58
Ion Werks	(RAC 479)	57
Kaiser Systems, Inc.	(RAC 657)	84
Kevex X-Ray Tube Division	(RAC 430)	106
Kinetic Systems Corporation	(RAC 324)	121
Klinger Scientific Corp.	(RAC 368)	93
Kontron Electronics, Inc.	(RAC 640)	33
Lakeshore Cryotronics, Inc.	(RAC 579)	36
Leybold Vacuum Products, Inc.	(RAC 561)	121
Lindberg	(RAC 671)	120
Martin Marietta		COV II-1
MathSoft, Inc.	(RAC 628)	39
The MathWorks, Inc.	(RAC 503)	111
The Matthews Corporation	(RAC 490)	57
McDonnell Douglas	(RAC 501)	COV IV
Measurement Systems, Inc.	(RAC 472)	12
Meister Engineering, Inc.	(RAC 487)	61
Meridian Laboratory	(RAC 596)	61
Microcompatibles, Inc.	(RAC 389)	120
MiTech Metals Inc.	(RAC 631)	82
Modgraph	(RAC 337)	15
Morgan Building Systems	(RAC 485)	57
Morgan Buildings & Spas	(RAC 492)	63
MTI Instruments	(RAC 365)	119
National Electrostatics Corporation	(RAC 360)	96
National Instruments	(RAC 489)	59
Newport Corporation	(RAC 509)	7
Odectics Kode Division	(RAC 346)	3
Omincomp Graphics Corporation	(RAC 647)	50
Optima Enclosures	(RAC 495)	123
Palantir, Inc.	(RAC 475)	48
Plano Economic Development Board	(RAC 463)	58
Plasticorp	(RAC 691)	71
Polaroid Corporation	(RAC 557)	21
Pratt & Whitney	(RAC 419)	91
Quantitative Technology Corporation	(RAC 570)	13
RF Monolithics Inc.	(RAC 468)	57
Richardson Chamber of Commerce	(RAC 499)	48
Rolyn Optics Co.	(RAC 551)	121
Schmidt Instruments	(RAC 474)	61
Sellers Boon	(RAC 476)	52
Spectra-Physics	(RAC 406	4
Spring National Design Engineering Show & Conference	(RAC 667)	117
Stat-Ease, Inc.	(RAC 393)	96
STN International	(RAC 385)	67
TEAC Corporation of America	(RAC 344)	2
Temple Economic Development Council	(RAC 453)	57
Thermoplastic Composites	(RAC 679)	121
Thomas Instrument & Machine	(RAC 497	55
Thomson Saginaw	(RAC 413, 573)	69, 121
3-D Visions	(RAC 669	84
Tiodize	(RAC 421)	87
Trinity	(RAC 457)	58
TU Electric	(RAC 456)	54
TWA Cargo	(RAC 438)	23
Wardwell Braiding Machine Co.	(RAC 396)	87
Waxahachie Chamber of Commerce	(RAC 482)	62
Weed Instruments	(RAC 466)	55
Yellow Springs Instrument Corporation	(RAC 681)	121
Zebec Data Systems	(RAC 460)	61
Zircar	(RAC 595)	10

*RAC stands for **Reader Action Card.** For further information on these advertisers, please circle the RAC number on the Reader Action Card elsewhere in this issue. This index has been compiled as a service to our readers and advertisers. Every precaution is taken to ensure its accuracy, but the publisher assumes no liability for errors or omissions.

AMCO ENCLOSURES. THEY'RE LOADED EVEN WHEN THEY'RE EMPTY.

George Sergeena, Quality Control:

"My title is misleading, in a way. 'Cause everyone at AMCO is gung-ho on quality control."

"These enclosures become 'home' to equipment that deserves the best. Some of our enclosures have housed systems that work miracles. Like the modular system we designed for NASA way back in Mercury Project days.

We take your specs and work to improve the results. We know the quality of the product is only as good as the workmanship involved.

And me? I'm seldom in my office waiting for a problem to pop up. I'm out on the floor trying to prevent them. OK quality is a word and anybody can say it. But you spend 30 minutes in our plant, and the quality is so real you can almost *feel* it."

"It's as simple as this: you work at AMCO, you get fanatical about quality."

Call us now for your free full color catalog. #800 shows our general modular enclosure line, #500B is our 5-Work day fast-delivery line.

Dial 1-800/833-3156.
In Illinois 1-312/671-6670.*

*As of November 11, 1989—New Area Code will be 708.

AMCO®

AMCO Engineering Co.
3801 N. Rose Street
Schiller Park, IL 60176-2190

AMCO GETS THERE FIRST.

See us at:
Electro – New York, NY 4/11 - 4/13 Booth # 1925
NAB –Las Vegas, NV 4/29 - 5/2 Booth # 3747, 48, 49

Circle Reader Action No. 500

THE X-30 IS KID STUFF.

The power to break the bonds of Earth. To leap up and away. To fly 18,000 miles an hour, 200,000 feet high. For a kid, that's the stuff dreams are made of.

Kid stuff, because it's your kids, and ours, who will gain most from the advances in propulsion technology required for the X-30 National AeroSpace Plane (NASP).

We'll need new, advanced engines, including those through which air moves at supersonic speeds. Fuel? Liquid hydrogen which would serve as both fuel and coolant for the plane's superhot skin surfaces during flight.

The X-30 is kid stuff, because it is our children who will move from Earth to space and back at far less cost than we do today. And the ecology-safe fuel promises benefits for the lives our kids will lead—benefits far removed from space flight.

It is our children who will have—or not have—world leadership in science and technology as a result of America's decisions today. It is a time to push forward. A time to invest in the future.

Let's go full throttle.

MCDONNELL DOUGLAS

A company of leaders.

Circle Reader Action No. 501