NASA Tech Briefs

THE DIGEST OF NEW TECHNOLOGY

Official Publication of the National Aeronautics and Space Administration

March 1995 Vol.19 No.3

Transferring Engineering Technology to Over 200,000 Qualified Readers Throughout Industry and Government

Special Focus: Computer-Aided Design

Resource Report: Ames Research Center

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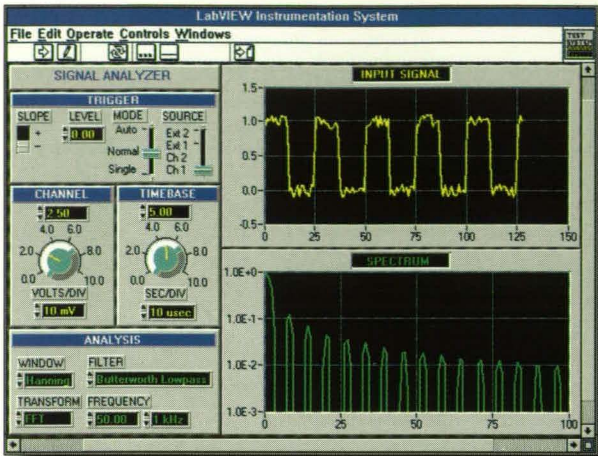

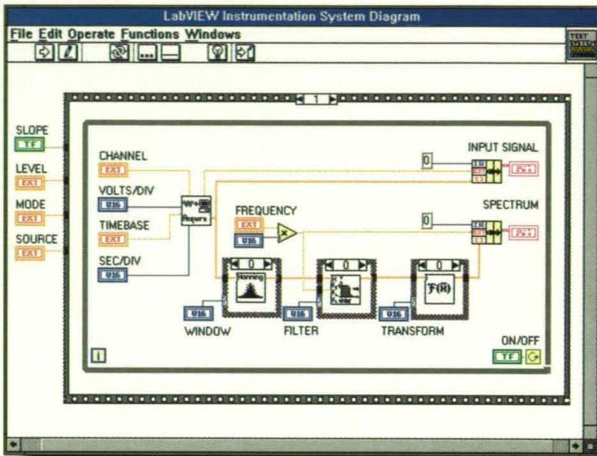

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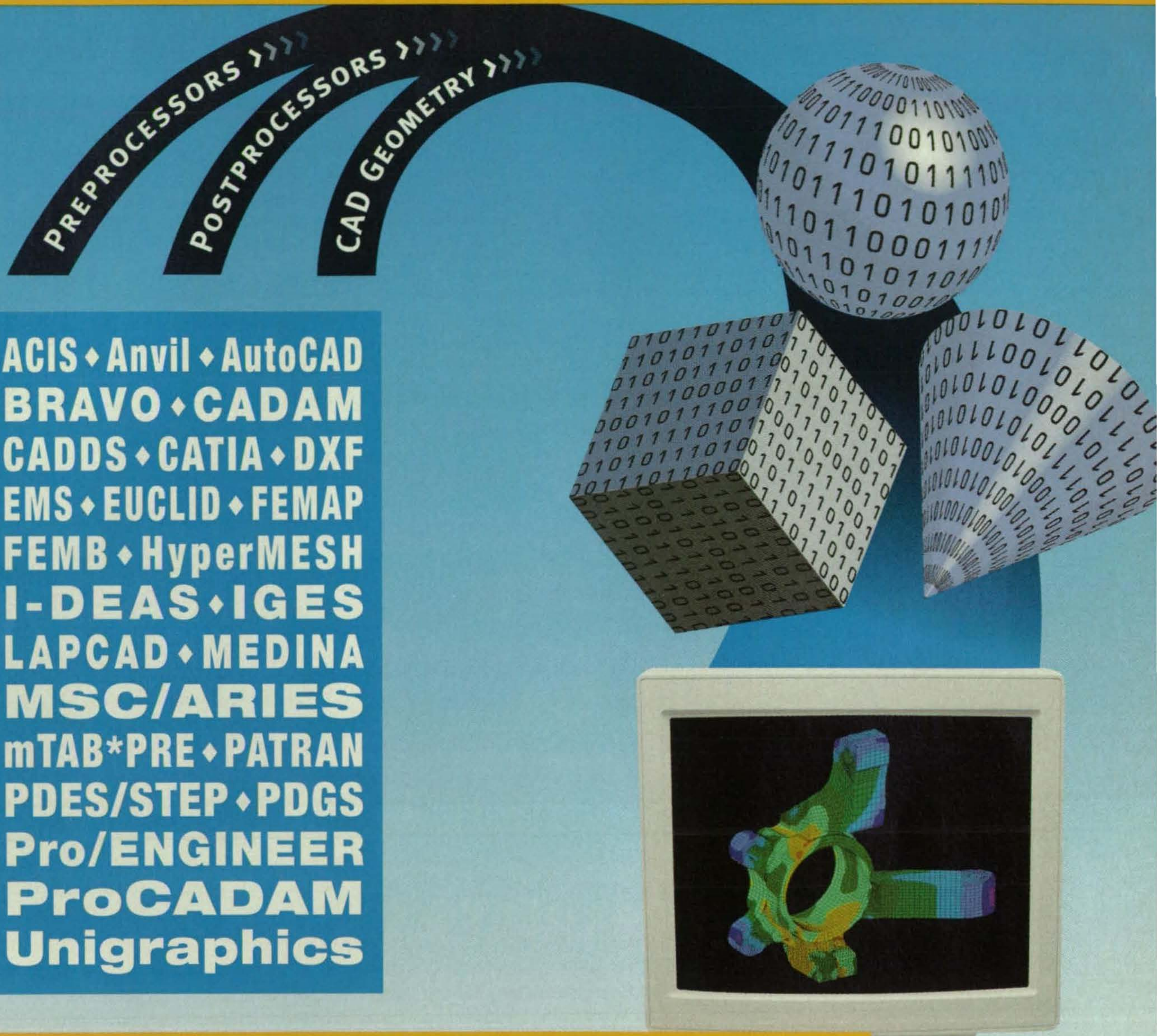

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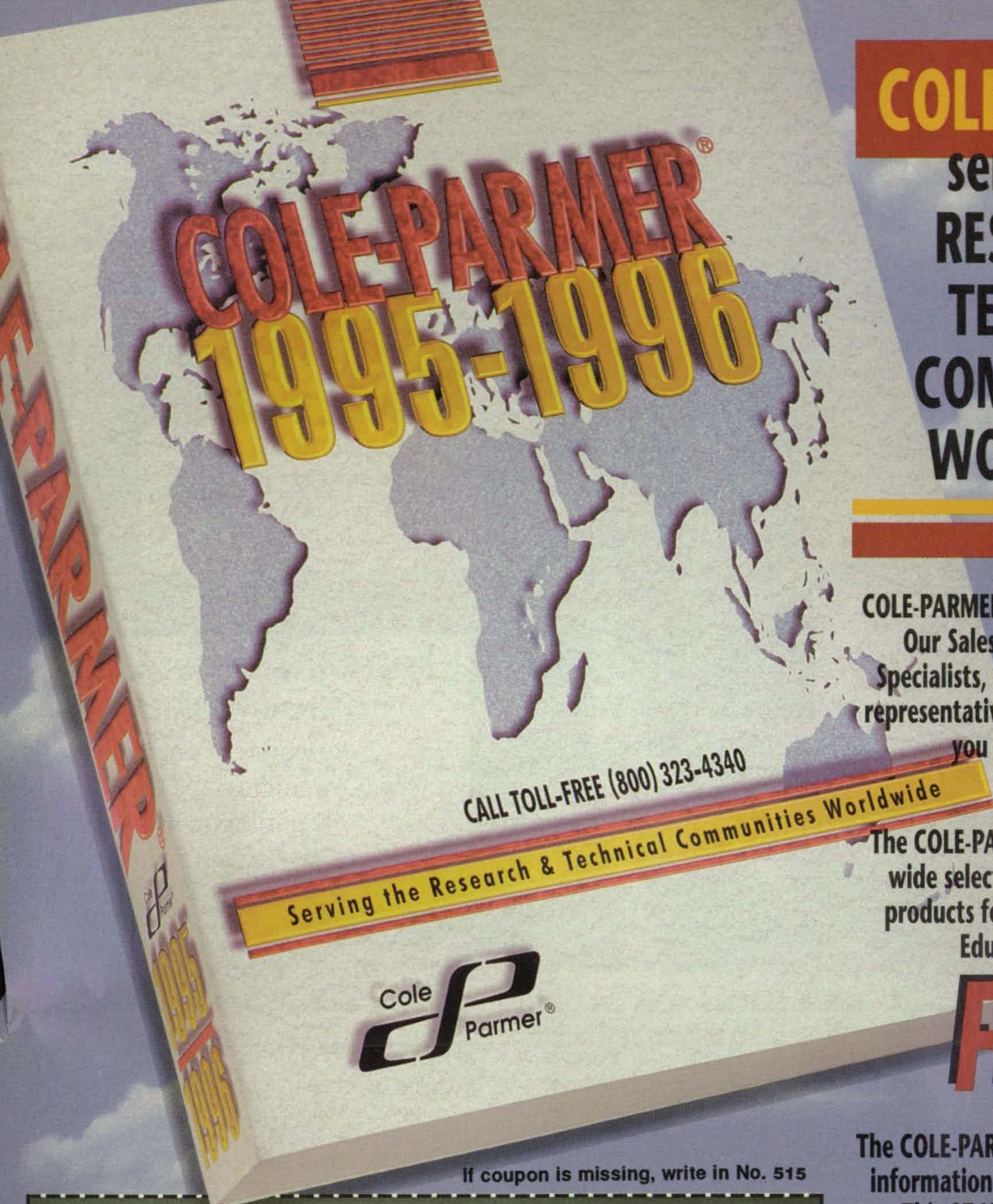
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Contents

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FEATURES

TECHNICAL SECTION

(continued on page 8)

A small machine attached to a table-top belt sander makes it possible to grind a glass disk quickly to a specified diameter to within ±0.05 mm. The combination of attachment and sander is designed for use in place of a production-shop glass grinder, which is more versatile but far more expensive, slower, and more accurate than necessary for most applications. The attachment includes a supporting frame, a motor-driven slide assembly that holds the glass to be ground, and a micrometer-driven slide to adjust the drive assembly's position. See the tech brief on page 92.

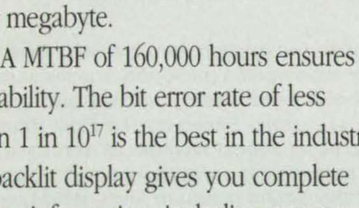
Photo courtesy Goddard Space Flight Center

The Only 35 GB Tape Drive With Fast SCSI Compression

All tape subsystems are not created equal. Only the CY-8505 can give you capacity of up to 35 GB and transfer rates as fast as 90 MB per minute.

That's because the CY-8505 is the only tape subsystem that features switch-selectable, Fast SCSI Compression. So you get the highest performance possible — and the lowest cost per megabyte.

A MTBF of 160,000 hours ensures reliability. The bit error rate of less than 1 in 10^{17} is the best in the industry. A backlit display gives you complete status information, including command under execution, transfer rate, compression ratio, tape remaining, and more.



Our CY-CHS10A features two tape drives and can store up to 385 GB on eleven tapes — without tape handling.

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DEC SCSI	Intergraph	PICK	*— and more*
DEC BI-Bus	Macintosh	Plexus	
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Fast SCSI Compression can increase the native 7 GB capacity by as much as five times; *Accelerated File Access* (for Unix systems) allows you to locate a file in an average of 85 seconds; *Data Encryption* lets you control access to sensitive data through the use of uniquely encoded card keys; and the *Advanced SCSI Processor* allows multiple drives to work together in striping, mirroring, cascade and independent modes. You can even copy and verify tapes off-line.

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Contents *(continued)*

On the cover:

The Computational Sciences and Applied Aerodynamics Divisions at Ames Research Center developed a microphone array sensing system that measures noise produced by aircraft and engine models during wind tunnel testing. Based on the Flow Analysis Software Toolkit developed at Ames' Numerical Aerodynamic Simulation, the acoustic data display software overlays colors on the aircraft model to display sound pressure level. White represents the loudest noise source. For more on resources available at Ames, turn to page 16.

photo courtesy of Ames Research Center

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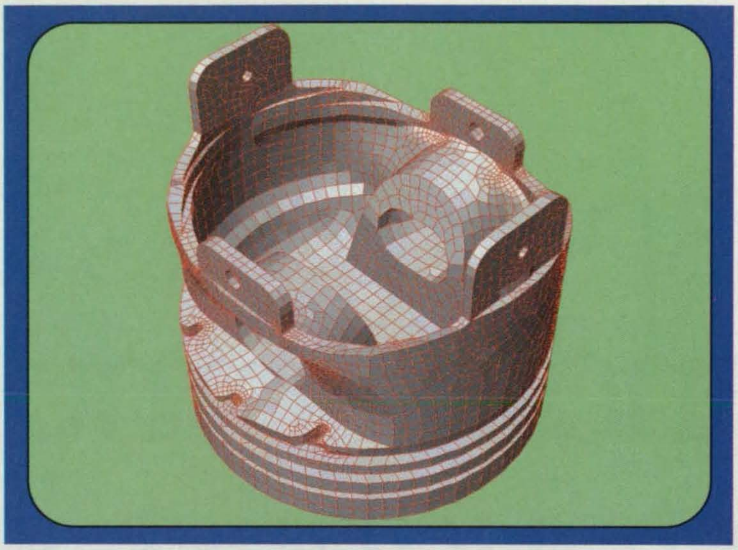

8-Node "Brick" Model by Houdini
Houdini meshed this CAD solid model directly from Pro/ENGINEER® with 8-node "brick" finite elements. Note local mesh refinement.

...Now, add Houdini™ to use 8-node "bricks" instead of Pro/MESH™ tetrahedra.

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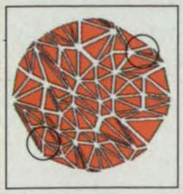
Why Houdini gives more accurate results

Houdini improves the surface mesh of the entire model as needed. Then, Hexagen™ (included with Houdini) creates a solid 8-node "brick" mesh from the complete surface inward. Brick elements generally give better results than other 3-D element shapes.

Hexagen puts the best shaped elements on the surface. This is important because the surface is where you need the best answers; where loads and boundary conditions are applied and where stress levels tend to be highest.

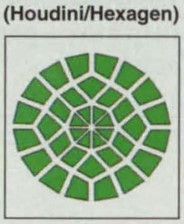
Generation of tetrahedral elements (Pro/MESH and others)



The mesh is generated using low-accuracy tetrahedral elements. This type of generation may put poorly-shaped, low-accuracy elements at the surface.

Generation of Hexahedral elements from the surface in (Houdini/Hexagen)

The mesh is created with high-accuracy 8-node "brick" elements. Houdini and Hexagen put the best-shaped elements at the surface.



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For free information on how Houdini can increase accuracy and a copy of Algor's technical white paper on 8-node "bricks" versus tetrahedra, call or fax today.

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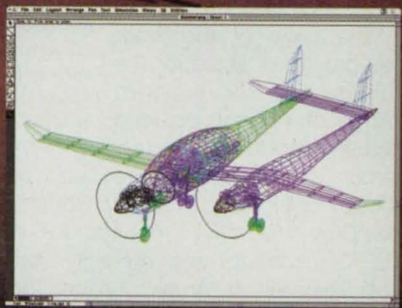
Burt Rutan Makes Vellum Fly

Two years after the Voyager completed its record-shattering around-the-world flight, you could still find its designer, Burt Rutan, working at a drafting table with pencil and paper.

Hardware wasn't the problem. He had computers. His company could buy any design system worth owning. What kept Burt grounded was software. CAD so clumsy, it squashed creativity. Or so weak, it simply couldn't do his job.

Maybe that's why the first time he sat down to design with Vellum®, Burt compared the experience to the exhilaration of flying. Vellum is the first CAD program with an autopilot.



Burt's creativity and willingness to explore uncharted territory is exemplified by this sneak peek at one of his latest designs produced (of course) in Vellum.

CAD Software that Works the Way You Think

From GD&T symbols to NURB splines to DXF and IGES file format translators, Vellum has every professional design and drafting tool your job demands. And each tool is endowed with an expert system called the Drafting Assistant™—built-in intelligence that instantly makes every designer more productive. Even on enormously complex jobs.

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According to Burt, "the only way to fully appreciate Vellum is to sit down and use it; tackle a tough job right off. See if the Drafting Assistant doesn't make you two, or even three times more productive than any other CAD package."

If you're like Burt Rutan, you'll find yourself using Vellum from conceptual design right through finished drawings. Best of all, you'll never give the drafting board, or another CAD program, a second thought.

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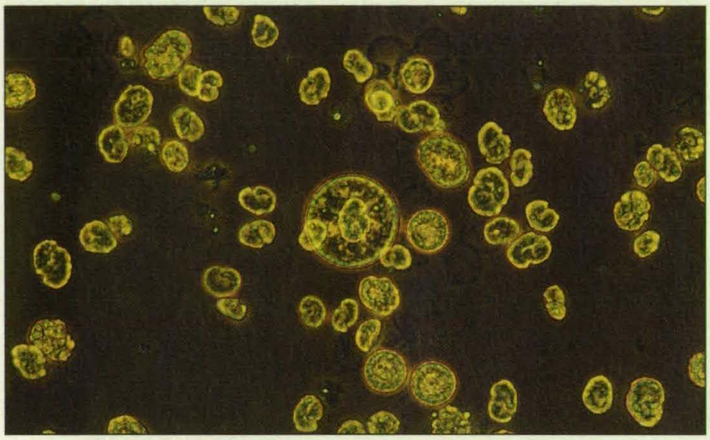
Mission Accomplished

Estimated at 80-100,000 species strong, the microalgae are a biochemically rich and diverse group of organisms long overlooked by science and commercial interests largely because of culturing difficulties. However, recent successes by the first company to harness the tiny flora suggest they may hold great potential for solving health and nutrition problems. Martek Biosciences Corp., Columbia, MD, has employed algae to improve infant formula, simplify medical diagnostic tests, and provide new pharmaceutical drugs.



Closed-system culturing has enabled Martek Biosciences Corp. to exploit algae for a wide range of health and nutrition problems. The species above produces a fatty acid found in human milk but not in infant formula. Linked to brain cell development, the fatty acid has been incorporated into an infant formula additive called Formulaid®.

The unique technologies that make Martek's venture into the algal realm possible got their start in the early 1980s with contracts undertaken by Martin Marietta Laboratories in support of NASA's Controlled Ecological Life Support System (CELSS) program.

"The topic of the work was growth of algae for the purpose of life support. Things of interest included oxygen production rates, carbon dioxide uptake rates, and production of biomass," said Dr. Robert D. MacElroy, technical monitor for the CELSS contracts and currently senior staff scientist of Ames' Space Technology Division.

In 1985, Martin Marietta decided to focus on aerospace and defense contracts, spinning off Martek to assume the non-aerospace applications and pick up the CELSS contracts. However, using algae for life support ran into difficulties. "A principal component in the CELSS concept is that you must produce food. Algae produce biomass, but in order to make it into something edible, it has to go through extensive processing," explained MacElroy. "It became apparent that this processing was too complicated to do in space."

NASA gradually eliminated funding for the algal work but not before the contracts had provided Martek the groundwork to pursue algae cultivation for other applications. "We got good experience in closed cultures, which is what we do at Martek," said Dr. Richard J. Radmer, the primary investigator on the Martin Marietta contracts and currently Martek's president and chief scientific officer.

Growing the algae in closed bioreactors proved the key to unlocking their potential. "Most algae just grow out in the wild, in ponds—nobody knew how to manipulate and control their culturing," said Henry Linsert, Jr., chairman and chief executive officer at Martek. As Linsert explained, in order to grow, algae require inorganic salts, carbon dioxide, and some form of energy. A small percentage of algae grow heterotrophically, using organic matter as an energy source. The remainder are photosynthetic, requiring light to grow. Providing light efficiently was Martek's greatest challenge.

"The denser they grow, the more they shade the light," said Linsert. "So you have to look at channels and at various light sources. You not only have to understand how the organisms grow—and different algae grow differently—but to find the right organisms, how they utilize light, and then the right pH, temperature, etc. There are a hundred and one tradeoffs to constructing a good bioreactor.

"It was that basic understanding of the geometry and engineering systems associated with bioreactors acquired through the NASA contracts that allowed Martek to start rigidly controlling the culture organism by organism, and then to change the conditions to get them to do things they might not do in nature."

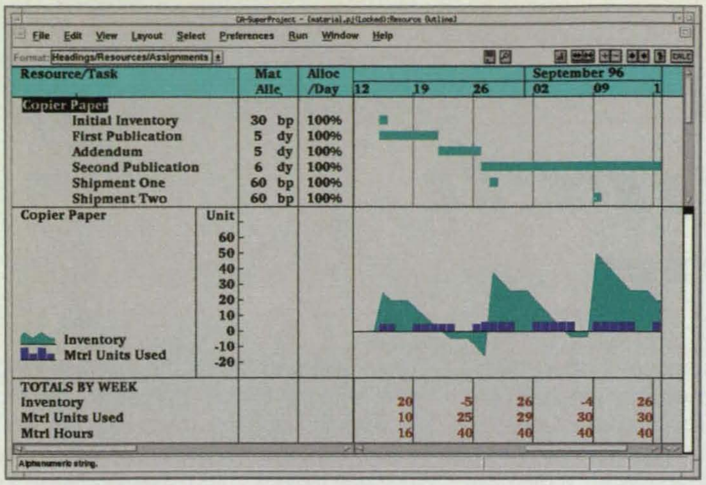
Martek, which has grown from six to 65 employees, has refined methods to culture both types of algae. The 2-5 percent of algal species that are heterotrophic can be grown in very large fermenters. For these, Martek employs 150,000-liter fermenters the size of a six-story building, said Linsert. "The others are grown in photobioreactors we have here at our plant, in sizes ranging from 40 liters to 500 liters," he explained.

Using its large commercial fermenters, Martek discovered an inexpensive means to produce two essential long-chain polyunsaturated fatty acids found in human breast milk but not in infant formulas derived from cow's milk or soybeans. Published studies have linked these two fatty acids, docosahexacenoic acid (DHA) and arachidonic acid (ARA), to brain and retinal cell development in infants. While the predominance of DHA and ARA in human tissue had been known, they had not been added to infant formula because no economically-viable sources had been available. Purifying the fatty acids from fish oil, for example, had proven prohibitively expensive.

Martek now sells a patented blend of oils rich in DHA and ARA called Formulaid® and has licensed its use to manufacturers representing more than 35 percent of the world's $5 billion infant formula market. Research has shown that DHA and ARA blood-lipid levels of babies

continued on page 108

Like plants, algae have enormous potential to provide pharmaceutical drugs. Martek is screening its library of 1800 algal species for active compounds that may be effective against bacterial or fungal infections.



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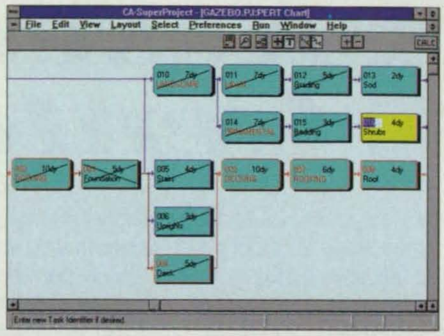

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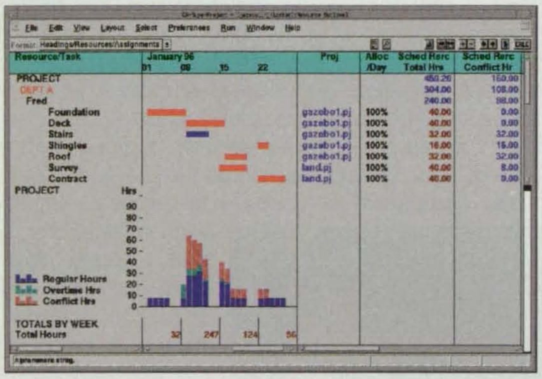

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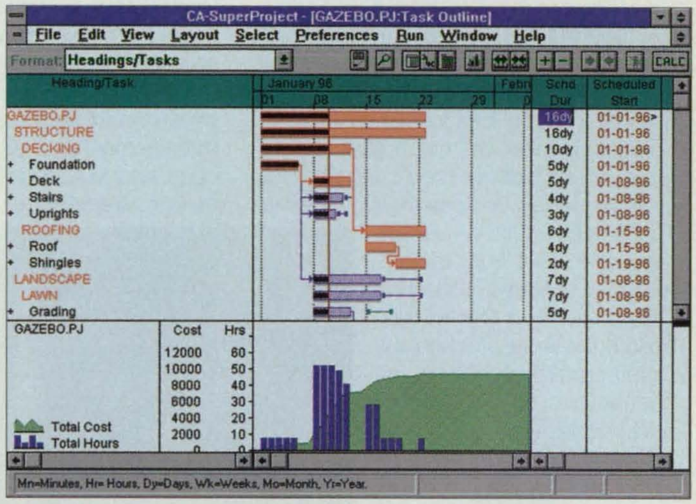

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Ames Research Center

Founded in 1939 expressly to assist US industry, Ames Research Center in Moffett Field, CA, has a long history of interacting with the commercial sector on research and development projects. Branching out over the years from its original aeronautics focus to other commercially viable areas such as computing and life sciences, Ames has instituted the necessary support offices to fulfill its mission.

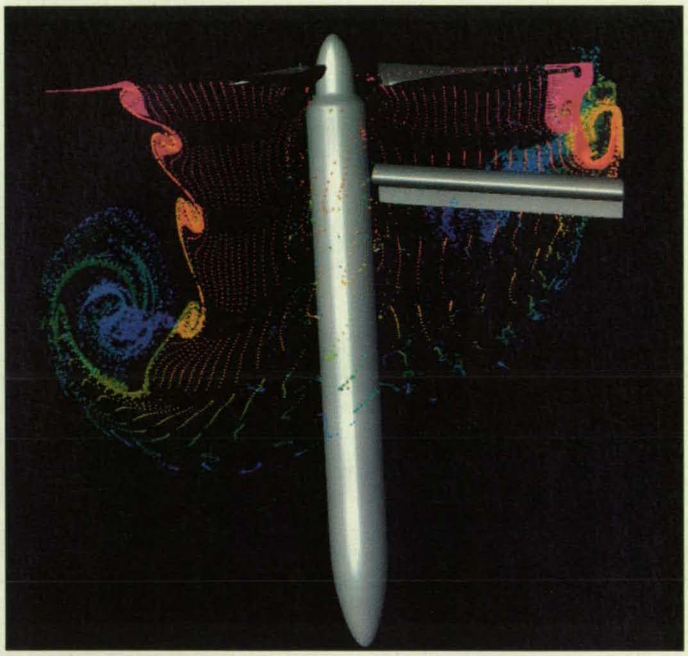
Ames is one of the largest federal research and development laboratories in Silicon Valley. Besides the Commercial Technology Office (CTO), formed in 1994 from the former Technology Utilization Office, the field center also boasts the Ames Technology Commercialization Center, an "incubator" for developing new businesses.

"We have a strong emphasis on partnerships, joint work with industry," said Syed Shariq, the Ames CTO director. "As opposed to looking for someone to take the technology from you after you have developed it, we are moving more toward proactive collaboration between the private sector and NASA."

As Joan Salute, CTO marketing inreach officer, described Ames' approach, "We focus on partners in research. Instead of asking a company 'What are your problems? Let us help you solve it,' we work on problems that are common to both of us."

CTO's outreach has had several successes. In 1994, Ames' Joint Sponsored Research Program, which the CTO oversees, established a partnership between NASA and aviation companies to help rejuvenate American general aviation. The CTO initiated a collaboration with General Motors to use Ames' thermal protection materials in developing cost-effective automotive emission systems that offer faster start-up after ignition while conforming to new environmental protection standards. A work-in-progress for the CTO is a regional (Bay Area) multimedia alliance composed of academic, government, and industry groups.

As a partnership between Ames, IC^2 Institute of Austin, TX, and the University of Texas, the Ames Technology Commercialization Center helps entrepreneurs start new ventures based substantially on NASA technology. The center provides access to a network of business experts in marketing and sales, high-tech management and operations, patent and corporate law, and financing, and technology transfer. It helps companies research NASA technology for suitability to commercial purposes and obtain rights to these technologies.



Researchers in Ames' Aeronautics directorate created this unsteady Navier-Stokes simulation of a 0.658-scale V-22 rotors and wing configuration in hover. The image was generated by releasing particles along a line in the plane of the rotor every 50 time-steps to mimic the hydrogen bubble flow visualization technique.

Photo courtesy Ames Research Center

Further helping Ames' business outreach is the proximity of NASA's Joint Sponsored Research Program, or American Technology Initiative (Amtech), a nonprofit entity located in Menlo Park that promotes collaborations with the private sector. Although not exclusively an Ames resource, the JSR Program regularly interacts with Ames as well as the other NASA field centers around the country. From a project's outset, the program seeks to match the research plan with a commercial application, identify government and industry customers, and negotiate intellectual property rights. Besides spinoffs from NASA, the JSR also looks for "spin-ins" to NASA.

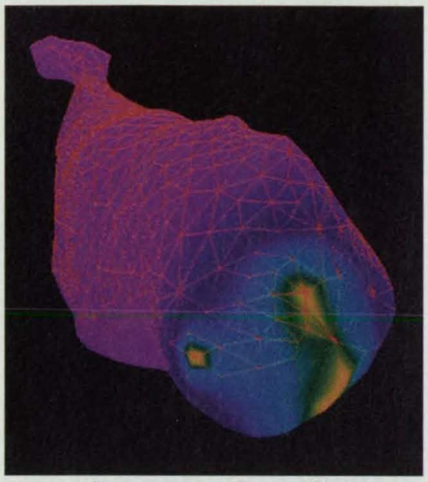
Currently, Ames is in the process of spinning off several Ames-developed technologies to industry. These include spacesuit technologies to treat multiple sclerosis and burning limb syndrome; environmentally friendly deicing fluids (originally created for aircraft) to make winter roads safer; and a resistant biofilm coating to counter such contamination problems as bathtub mildew and tooth plaque. Exemplifying the far-ranging applications of aerospace technology, Ames' thermal protection materials are being used in human bone implants, extravehicular system technologies incorporated into hazardous material-handling vehicles, and biological recycling technologies fashioned for remote areas such as Antarctica and Alaska.

One major effort at Ames that could have a significant impact on the private sector is the development of automation tools for air transport management, which are already in operation at Dallas and Denver airports' air traffic control centers. "Improvements in the air traffic management system are considered by aviation industry experts to be their first priority," said Ames director Dr. Ken Munechika.

Each of the four Ames directorates—Aeronautics, Space Research, Information Sciences, and Center Operations—offers access and assistance to industry. In Aeronautics, Ames' wind-tunnel research facilities have long been a significant resource for the aircraft industry, such as for Boeing's 777, rolled out in April 1994. The airplane also incorporated Ames-developed human engineering concepts into the cockpit. Companies can schedule use of the 80x120-foot wind tunnel, the world's largest, for full-scale aircraft, rotorcraft, and aeronautical models, or the subsonic 40x80-foot tunnel for such purposes as attaining an aeroacoustic environment for large-scale, high-speed aircraft components or testing full-scale rotorcraft. Ames also offers several smaller wind tunnels.

Information and computer sciences have gained prominence, and the center dedicates several resources to advanced studies in these fields. NASA Administrator Dan Goldin has named Ames the Center for Excellence in Information Sciences. The Automation Sciences Research Facility (ASRF) focuses on intelligent systems, many of which already have or promise commercial applications. ASRF's AutoClass software, which performs automatic data analysis by classification, has been used in cancer epidemiology and criminology. Optical neural networks for robot vision processing may one day spin off new aids for the blind. Scheduling methods developed for telescope observation and spacecraft mission planning hold potential application to industrial processes that operate under similar optimization criteria. Ames annually reviews proposals for use of the Numerical Aerodynamic Simulation Systems—which houses two Cray C-90 supercomputers, a Thinking Machine CM-5, and three Convex supercomputers—by both NASA and outside research groups nationwide.

Ames has spawned a life sciences research program, recently establishing the Center for the Health Applications of Aerospace-Related Technologies. The center has set up projects in the battle against filariasis in the Nile Delta, schistosomiasis in China, and malaria in the Amazon. Facilities available for collaborative studies or in some cases direct access include a biocomputation center, a vestibular research facility, and a neutral buoyancy research laboratory that simulates weightlessness.



At Ames' Biocomputation Center, 3D reconstructions are used to determine the geometric organization of neurons in the gravity sensors of a rat's ear. Here, a grid generated from an electron micrograph simulates synapse activation on a nerve ending through use of a new finite volume method of compartmental analysis based on mathematical concepts borrowed from computational flow dynamics.
Photo courtesy Ames Research Center

The Center Operations Directorate offers a fleet of aircraft for airborne research. The C-130B laboratory supports earth science experiments such as meteorology and sensor development for satellites; the DC-8 laboratory can be used for space technology, simulation, gas sampling, and local and remote sensing; and the ER-2 high altitude laboratory can carry aloft a 2700-lb payload to 70,000 ft as a high-altitude simulator or an engineering testbed.

For further information, contact the Ames Technology Commercialization Office, MS 292A-3, Moffett Field, CA 95035-1000; Tel: 415-604-1919; the Ames Technology Commercialization Center, 155A Moffett Park Drive, Suite 104, Sunnyvale, CA 84089; Tel: 408-734-4700; Fax: 408-734-4946; or the American Technology Initiative, Suite 180, Menlo Park, CA 94025; Tel: 415-325-5353.

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 in 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 Commercial Technology Office of the sponsoring NASA center (see page 20).

Microfermentation Test for Identification of Yeast

Results can be obtained in days instead of weeks using this more economical method of identifying yeasts. The method can be used in clinical or environmental laboratory studies. Fast identification can lead to early treatment of potentially fatal yeast infections.
(See page 104.)

Material Removes Heavy Metal Ions From Water

A high-capacity ion-exchange polymer removes toxic metal cations from contaminated water even when calcium is present. The metals can be easily reclaimed by either destructive or nondestructive processes.
(See page 70.)

High Temperature Graphite/Phenolic Composite

This composite material retains relatively high strength and modulus of elasticity at temperatures as high as 1,000 °F (538 °C). The material costs only 5 to 20 percent as much as refractory materials do.
(See page 71.)

Improved Growth of Cadmium Telluride Crystals From Vapors

This method grows crystals from vapors at temperatures lower than those used to grow crystals from melts. The crystals from vapors are often purer and structurally more nearly perfect.
(See page 99.)

Automated Hardware-Identification System

Compressed symbology would be used in place of bar codes to identify inventory in warehouses and on assembly lines. Using computers, one will be able to keep track of items and apply appropriate manufacturing operations in a paperless environment.
(See page 96.)

Circuit Stops Prelasing in a Q-Switched Laser

This circuit turns off the laser power supply when it detects laser light before the end of the Q-switch-trigger pulse. Prelasing is undesirable because it can damage the optical component of the laser and associated equipment.
(See page 44.)

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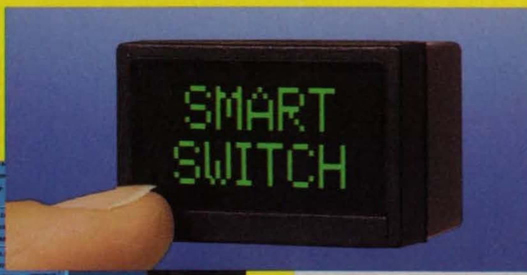

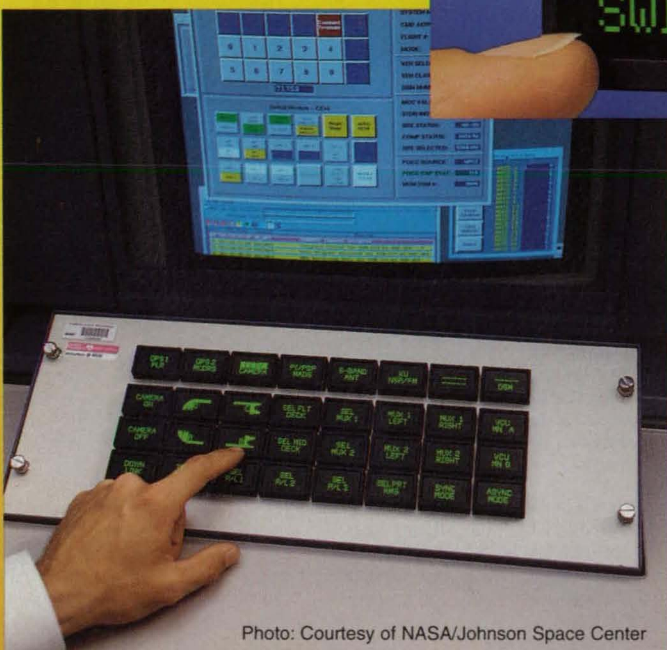

Photo: Courtesy of NASA/Johnson Space Center

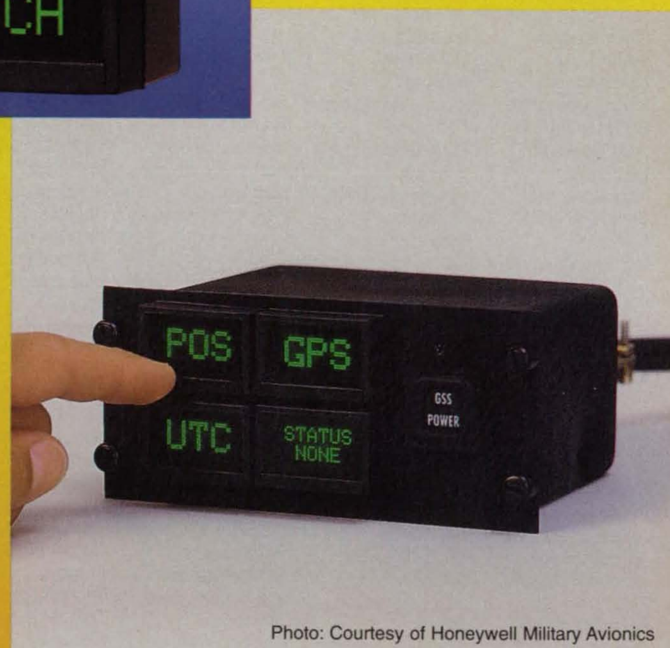

Photo: Courtesy of Honeywell Military Avionics

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NASA Commercial Technology Team

NASA's R&D efforts produce a robust supply of promising technologies with applications in many industries. A key mechanism in identifying commercial applications for this technology is NASA's national network of commercial technology organizations. The network includes ten NASA field centers, six Regional Technology Transfer Centers (RTTCs), the National Technology Transfer Center (NTTC), business support organizations, and a full tie-in with the Federal Laboratory Consortium (FLC). We encourage all businesses with technical needs to contact the appropriate organizations for more information. For those who have access to the Internet, general information can be accessed with Mosaic software on the NASA Commercial Technology Home Page at URL: http://nctn.oact.hq.nasa.gov. Instructions regarding how to acquire the free Mosaic software can be obtained by sending an e-mail request to: innovation@oact.hq.nasa.gov.

NASA's Technology Sources

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

Ames Research Center
Selected technological strengths: Fluid Dynamics; Life Sciences; Earth and Atmospheric Sciences; Information, Communications, and Intelligent Systems; Human Factors.
Syed Shariq
(415) 604-0753
syed_shariq@qm gate.arc.nasa.gov

Dryden Flight Research Center
Selected technological strengths: Aerodynamics; Aeronautics Flight Testing; Aeropropulsion; Flight Systems; Thermal Testing; Integrated Systems Test and Validation.
Lee Duke
(805) 258-3119
duke@louie.dfrf.nasa.gov

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

Jet Propulsion Laboratory
Selected technological strengths: Near/Deep-Space Mission Engineering; Microspacecraft; Space Communications; Information Systems; Remote Sensing; Robotics.
William Spuck
(818) 354-2240
william_h_spuck@jpl.nasa.gov

Johnson Space Center
Selected technological strengths: Artificial Intelligence and Human Computer Interface; Life Sciences; Human Space Flight Operations; Avionics; Sensors; Communications.
Hank Davis
(713) 483-0474
hdavis@profs.jsc.-nasa.gov

Kennedy Space Center
Selected technological strengths: Emissions and Contamination Monitoring; Sensors; Corrosion Protection; Bio-Sciences.
Bill Sheehan
(407) 867-2544
billsheehan@ksc.nasa.gov

Langley Research Center
Selected technological strengths: Aerodynamics; Flight Systems; Materials; Structures; Sensors; Measurements; Information Sciences.
Charlie Blankenship
(804) 864-6005
c.p.blankenship@larc.nasa.gov

Lewis Research Center
Selected technological strengths: Aeropropulsion; Communications; Energy Technology; High Temperature Materials Research.
Walter Kim
(216) 433-3742
wskim@lims01.lerc.nasa.gov

Marshall Space Flight Center
Selected technological strengths: Materials; Manufacturing; Nondestructive Evaluation; Biotechnology; Space Propulsion; Controls and Dynamics; Structures; Microgravity Processing.
Harry Craft
(205) 544-5419
harry.craft@msfc.nasa.gov

Stennis Space Center
Selected technological strengths: Propulsion Systems; Test/Monitoring; Remote Sensing; Nonintrusive Instrumentation.
Lon Miller
(601) 688-1632
lmiller@ssc.nasa.gov

NASA-Sponsored Commercial Technology Organizations

These organizations were established to provide rapid access to NASA and other federal R&D and foster collaboration between public and private sector organizations. They also can direct you to the appropriate point of contact within the Federal Laboratory Consortium.

Lee Rivers
National Technology Transfer Center
(800) 678-6882

Robert Stark
Far-West Technology Transfer Center
University of Southern California
(800) 472-6785 or
(213) 743-6132

Dr. William Gasko
Center for Technology Commercialization
Massachusetts Technology Park
(800) 472-6785 or
(508) 870-0042

J. Ronald Thornton
Southern Technology Applications Center
University of Florida
(800) 472-6785 or
(904) 462-3913

Gary Sera
Mid-Continent Technology Transfer Center
Texas A&M University
(800) 472-6785 or
(409) 845-8762

Lani S. Hummel
Mid-Atlantic Technology Applications Center
University of Pittsburgh
(800) 472-6785 or
(412) 648-7000

Chris Coburn
Great Lakes Technology Transfer Center
Battelle Memorial Institute
(800) 472-6785 or
(216) 734-0094

Easy Access To The FLC: Call (206) 683-1005 for the name of the Federal Laboratory Consortium Regional Coordinator in your area. The Regional Coordinator, working with the FLC Locator, can help you locate a specific laboratory to respond to your needs.

NASA Program Offices

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

Gene Pawlik
Small Business Innovation Research Program (SBIR)
(202) 358-4661
gpawlik@oact.hq.nasa.gov

Robert Norwood
Office of Space Access and Technology (Code X)
(202) 358-2320
rnorwood@oact.hq.nasa.gov

Philip Hodge
Office of Space Flight (Code M)
(202) 358-1417
phodge@osfms1.hq.nasa.gov

Gerald Johnson
Office of Aeronautics (Code R)
(202) 358-4711
g_johnson@aeromail.hq.nasa.gov

Bill Smith
Office of Space Sciences (Code S)
(202) 358-2473
wsmith@sm.ms.ossa.hq.nasa.gov

Bert Hansen
Office of Microgravity Science Applications (Code U)
(202) 358-1958
bhansen@gm.olmsa.hq.nasa.gov

Granville Paules
Office of Mission to Planet Earth (Code Y)
(202) 358-0706
gpaules@mtpe.hq.nasa.gov

NASA's Business Facilitators

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

Dr. Stephen Gomes
American Technology Initiative
Menlo Park, CA
(415) 325-5353

Dr. Jill Fabricant
Johnson Technology Commercialization Center
Houston, TX
(713) 335-1250

John Gee
Ames Technology Commercialization Center
Sunnyvale, CA
(408) 734-4700

Dan Morrison
Mississippi Enterprise for Technology
Stennis Space Center, MS
(800) 746-4699

If you are interested in information, applications, and services relating to satellite and aerial data for Earth resources, contact: Dr. Stan Morain, **Earth Analysis Center,** (505) 277-3622. For software developed with NASA funding, contact **NASA's Computer Software Management and Information Center (COSMIC)** at (706) 542-3265, fax (706) 542-4807. If you have a questions...**NASA's Center for AeroSpace Information** can answer questions about NASA's Commercial Technology Network and its services and documents. Use the Feedback Card in this issue or call (410) 859-5300, ext. 245.

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For More Information Write In No. 505

Special Focus: Computer-Aided Design and Engineering

Computational System for Rapid CFD Analysis in Engineering

A modular, all-electronic system will promote utilization of CFD.

Marshall Space Flight Center, Alabama

A computational system that comprises modular hardware and software subsystems is being developed to accelerate and facilitate the use of techniques of computational fluid dynamics (CFD) in an engineering environment. Although the hardware and software used in CFD are well developed, the utilization of CFD to its full potential has been impeded by the length of time needed to conduct a typical CFD analysis. The total analysis time is long because of the need to preprocess design and flow-geometry data for processing by the CFD software, and to postprocess flow-field data computed by the CFD software into informative displays and summaries. Heretofore, preprocessing and postprocessing hardware and software have been developed separately, without a view toward standardization or integration with each other or with the CFD hardware and software.

The present development addresses the integration of all aspects of the CFD analysis process, including definition of hardware surfaces, generation of computational grids, the CFD flow solution, and postprocessing. The system incorporates interfaces for integration of all the hardware and software tools needed to perform a complete CFD analysis. The system includes tools for efficient definition of flow geometry, generation of computational grids, computation of flows on the grids, and postprocessing of flow data. Multiple options exist within each functional block, and the modularity of the system enables the analyst to select the most appropriate optional tool at each step of the analysis process. To ensure modularity, common data formats are utilized between the major steps in the analysis process. Whenever possible, the common format is based on a national standard to ensure commonality with other CFD systems.

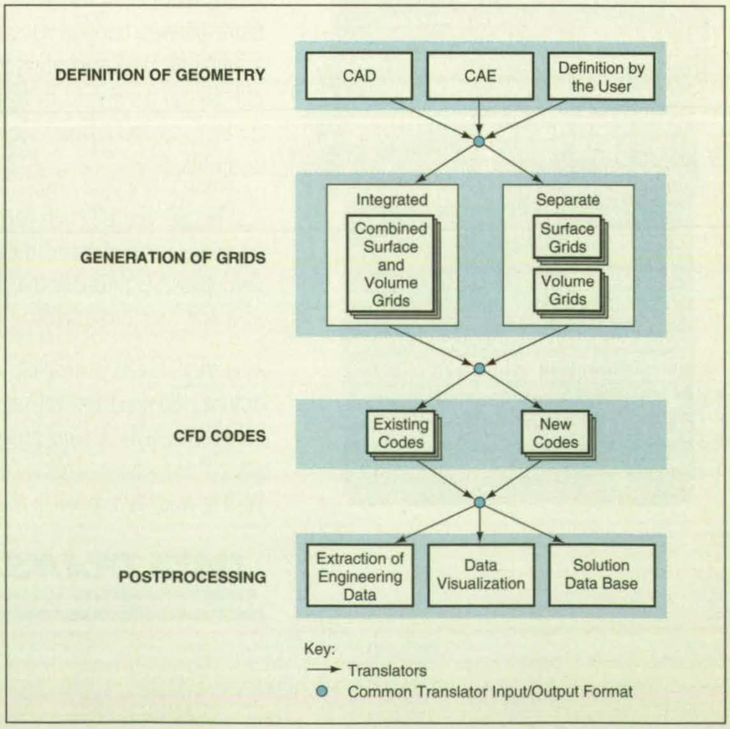
The system accepts geometric input from any of three basic sources: computer-aided design (CAD), computer-aided engineering (CAE), or definition by the user. CAD and CAE systems typically have native- and standard-format output options. Geometric descriptions defined by the user are typically generated through relatively simple computer codes written by the user, and their outputs can generally be written in any desired format. For acceptance by this system, the definition of geometry must be translated into the Initial Graphics Exchange Standard (IGES) format. The definition of geometry can then be transferred readily to any of the grid-generating subsystems within this system.

The grid generators in this system are divided into two categories, maintaining the highest level of modularity possible. The first category includes those grid generators that simultaneously generate surface and volume grids. A grid generator in the second category contains separate modules first to generate grids on surfaces, then generate volume grids based on the surface grids. Typically, surface and volume grids are generated sequentially through algebraic techniques, then smoothed with elliptic techniques, as needed.

The system provides for selection of any of several CFD codes that have been developed by various experts and that implement a variety of theoretical and numerical approaches. These codes have been modified for integration into the system. Any of these codes can read any grid represented in the common format of the system. The outputs of all of these codes are in a common format for postprocessing. The common input and output formats provide a conceptual framework for incorporating new CFD codes.

Postprocessing is needed to reduce the large volume of output information to a form in which it can be readily assimilated and integrated with other products of engineering analysis. As defined within this system, postprocessing encompasses three major functions: extraction of engineering data, visualization of data, and generation of a postprocessing data base.

For extraction of engineering data,



The **Relationships Among the Functional Blocks** of the system reflect those among the four major steps of the CFD analysis process.

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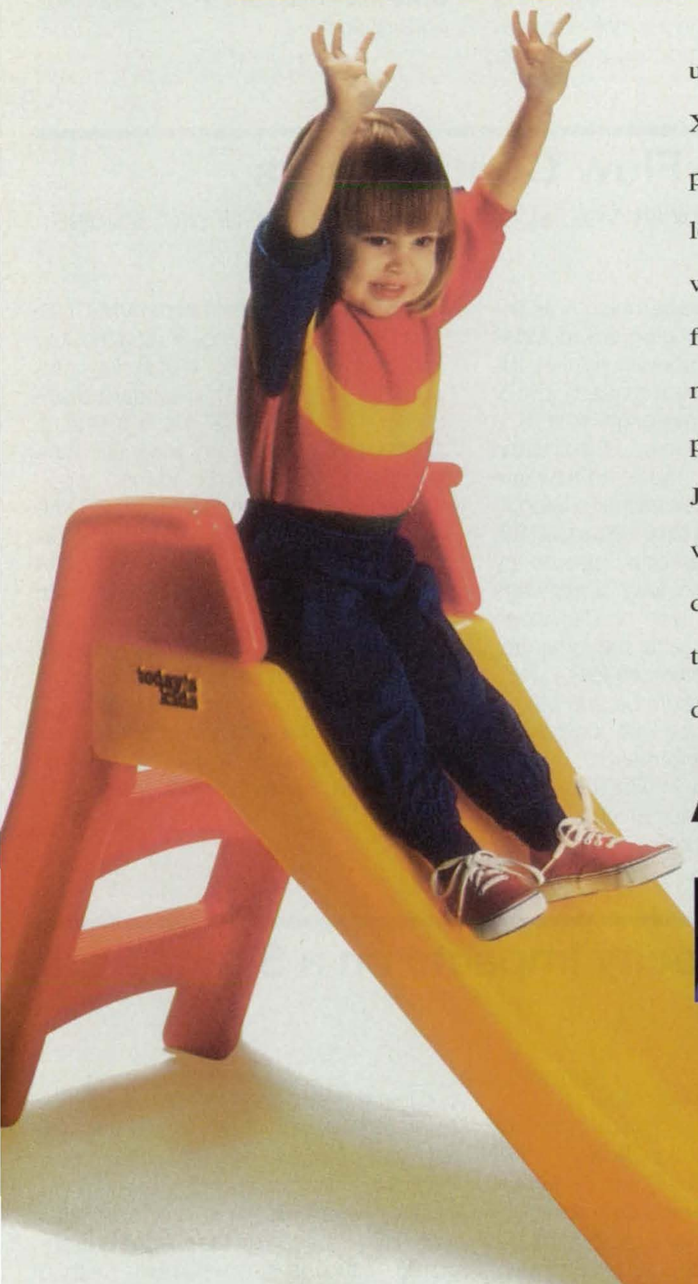

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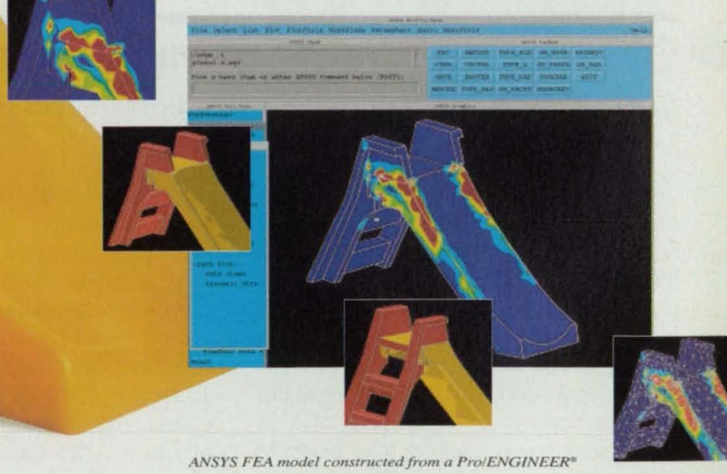

ANSYS FEA model constructed from a Pro/ENGINEER® assembly accurately showed that large, nonlinear deflections tripled the maximum stresses in the slide handrail.

Photograph and FEA model provided courtesy of Today's Kids, Dallas and DRD Corporation, Tulsa.

For More Information Write In No. 507

this system implements a two-step approach to postprocessing intended to maintain a high level of modularity. First, a subroutine is developed and embedded within each CFD code. This subroutine accesses other portions of the code as needed, computes appropriate quantities, and writes them in a common data format.

The Flow Analysis Software Toolkit (FAST) computer program is the first visualization tool to be selected for inclusion in this system. FAST, a product of NASA's Ames Research Center, is a collection of software modules for use in visualizing geometries, grids, and computed flows.

The development of a postprocessing data base is still in an early stage. The large number of data generated in CFD analyses calls for significant effort to develop hardware and software to handle the data. Storage of a complete data base of all final solutions in the common output format would necessitate significant investment in mass-storage devices. Currently, a limited data base of graphical images is being considered. Even so, typical image files can exceed one million bytes each. A possible alternative to storing image files is to maintain a data base of FAST scripts: Given a solution file, one need not store images, but only the script file used to generate the images in FAST. This provides the ability to regenerate previous images quickly, and offers the additional flexibility of being able to modify images within FAST.

This work was done by Steven L. Barson, Edward P. Ascoli, Michelle E. DeCroix, and Munir M. Sindir of Rockwell International Corp. for **Marshall Space Flight Center.** *For further information,* ***write in 247*** *on the TSP Request Card.*
MFS-29966

Program for Analysis of Axial-Flow Compressors

Computations based on simplifying assumptions quickly yield approximate results for design studies.

Lewis Research Center, Cleveland, Ohio

CSPAN (Compressor SPanline ANalysis) is a FORTRAN 77 computer program that assists in the design of axial-flow compressors. This program enables the design engineer to study the relationships among the number of stages, the flow-path radii, the gas velocities, the flow angles, and the resultant variation of compressor efficiency. It also rapidly provides conceptual designs for preliminary design studies of air-breathing engines.

The program is based on the assumption of isentropic simple radial equilibrium. Maximum rotor-tip and stator-hub loadings, maximum turning at the rotor hub, and maximum stator-hub mach number are specified as design constraints. Many advanced compressor designs require reductions in tip radii to provide adequate blade heights at the exits. Therefore, this program includes an input for direct specification of the change of tip radius across each row of blades. The hub-ramp-angle limit is a constraint that is included to avoid excessive wall slope. The mass-flow rate can be specified by the user and used to calculate the inlet-tip axial velocity, which can optionally be specified directly by the user. Two built-in loss correlations are available to the user: one for stage polytropic efficiency, and the other for the blade-element pressure-loss coefficient. The velocity diagrams and stage-by-stage performance are calculated along with overall performance.

CSPAN is written in FORTRAN 77, and requires a compiler which supports NAMELIST input. It was originally written on an IBM mainframe running VM/CMS. This version has also been successfully implemented on a DEC VAX series computer running VMS. The standard distribution medium for CSPAN is a 9-track 1600-bit/in. (630-bit/cm) magnetic tape in DEC VAX FILES-11 format. Upon request, it is also available on a TK50 tape cartridge in DEC VAX BACKUP format or on a 5.25-in. (13.335-cm) 360K MS-DOS format diskette. CSPAN, which was developed in 1992, is an update of the program N34 previously available from COSMIC as part of LEW-10765.

This program was written by Arthur J. Glassman of the University of Toledo for **Lewis Research Center**. *For further information,* ***write in 209*** *on the TSP Request Card.*
LEW-15609

Computing Effects of Hypervelocity Impacts on a Spacecraft

MLITEMP estimates damage and thermal effects.

Marshall Space Flight Center, Alabama

The MLITEMP computer program is a design software tool that utilizes empirical equations to predict the damage and the thermal effects of impacts of hypervelocity particles on spacecraft. (One of the thermal effects predicted by MLITEMP is the amount of condensate formed.) A Whipple style of spacecraft wall (which consists of multiple layers of insulation and a "bumper" layer in addition to a pressure wall) is assumed. Three different techniques for empirically predicting the damage caused by hypervelocity impacts are used in MLITEMP: an "inverse-R" prediction technique, a polynomial-function prediction technique, and a nondimensional-parameter prediction technique.

The "inverse-R" prediction technique uses a prediction equation of very general form that can be applied in the same manner to all problems. Thus, the user is not required to develop a suitable form for the prediction, and additional independent variables can be incorporated easily as needed. This method is designed to use a data base that can be updated continuously as new experimental data become available. The method automatically takes advantage of the most appropriate data in the data base for a given set of independent variables. The measured data points that are used for prediction can be considered to "radiate" information to an interpolation point. The farther the data point is from the interpolation point, the weaker the "radiation."

The polynomial-function prediction technique is based on the concepts associated with the finite-element method (FEM). In the FEM, polynomials of relatively low order are used to interpolate a function of interest over a small portion (a finite element) of the domain wherein the function is active. The coefficients of the polynomial are derived from known values of the function of interest at points called nodes on the boundary of the element. For this application, the nodal values of the

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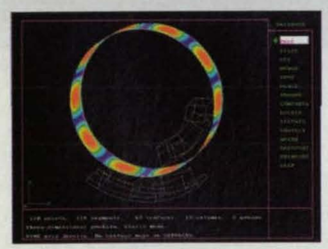

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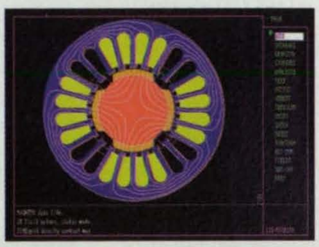

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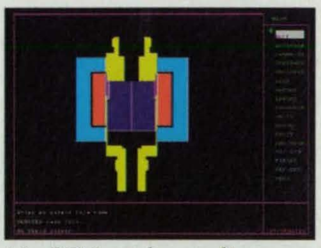

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function of interest are measured experimentally and are thus known quantities. This technique involves selecting a sufficient number of experimental data (node) points and then determining the coefficients of the polynomial from these data.

The nondimensional-parameter prediction technique has been found to be the best method to represent empirical functions in many applications. The coefficients of the functions are determined by use of an optimization routine to adjust the values of the coefficients so as to maximize the coefficient of determination of each of the functions. The nondimensional functions are adjusted to match the experimental results as closely as possible in a least-squares sense. This approach to evaluation of coefficients is suitable for any form of prediction function — linear or nonlinear.

The thermal behavior of the pressure wall, the multiple insulating layers, and the bumper layer are all explicitly modeled by use of an axisymmetric finite-difference analysis technique. Steady-state thermal conditions are also modeled.

The condensate-prediction subprogram is used to determine the height of condensate for a given distribution of temperature on the surface of the spacecraft. Two sets of conservation equations are solved: one for the condensate layer and one for the vapor layer, with appropriate interface conditions. The boundary-layer theory breaks down near the center of the circular region, so that the full Navier– Stokes (conservation-of-momentum) equations must be considered.

MLITEMP is written in BASIC for IBM PC-series and compatible computers running MS-DOS. This package includes sample executable codes, which were compiled under the Microsoft BASIC Professional Development System (BPDS). Although written for compilation under Microsoft BPDS, the programs of MLITEMP that do not use the menu, window, and mouse toolbox of BPDS can be modified and recompiled using Microsoft QuickBasic 4.5. Earlier versions of Microsoft QuickBasic may not compile the MLITEMP source code properly. The minimum requirements for the proper execution of MLITEMP include an 80286 processor, a math coprocessor, and an EGA or VGA graphics card and monitor. The standard distribution medium for this program is a set of three 5.25-in. (13.34-cm), 360K MS-DOS-format diskettes. The contents of the diskettes are compressed by use of the PKWARE archiving software tools. The utility program to unarchive the files, PKUNZIP.EXE, is included. MLITEMP was developed in 1992.

This program was written by William K. Rule of **Marshall Space Flight Center** *and V. Giridharan of The University of Alabama. For further information,* ***write in 51*** *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 24]. Refer to MFS-26239

Program Helps Decompose Complex Design Systems

DeMAID groups modular subsystems on the basis of interactions among them.

Langley Research Center, Hampton, Virginia

Many engineering systems are large and multidisciplinary. Before the design of such new complex systems as large platforms in outer space can begin, the possible interactions among subsystems and their parts must be determined. Once this is done, the proposed system can be decomposed to identify its hierarchical structure.

The DeMAID (A Design Manager's Aid for Intelligent Decomposition) computer program is a knowledge-based software system for ordering the sequence of modules and identifying a possible multilevel structure for the design problem. DeMAID displays the modules in the format of an $N \times N$ matrix (called a design structure matrix). As used here, "module" denotes any process that requires input and generates an output. A module could also be a process (e.g., an initialization process) that generates an output but does not require an input. Although DeMAID requires an investment of time to generate and refine the list of modules for input, it could save a considerable amount of money and time in the total design process, particularly in a new design problem in which the order of the modules has not been defined.

The decomposition of a complex design system into subsystems depends on the judgment of the design manager. DeMAID reorders and groups the modules on the basis of the links (interactions) among the modules, helping the design manager make decomposition decisions early in the design cycle. The modules are grouped into circuits (the subsystems) and displayed in an $N \times N$-matrix format. Feedback links, which indicate an iterative process, are minimized and occur only within a subsystem. Since there are no feedback links among the circuits, the circuits can be displayed in a multilevel format. Thus, a large amount of information is reduced to one or two displays that are stored for later retrieval and modification. The design manager and leaders of the design teams then have a visual display of the design problem and the intricate interactions among the different modules.

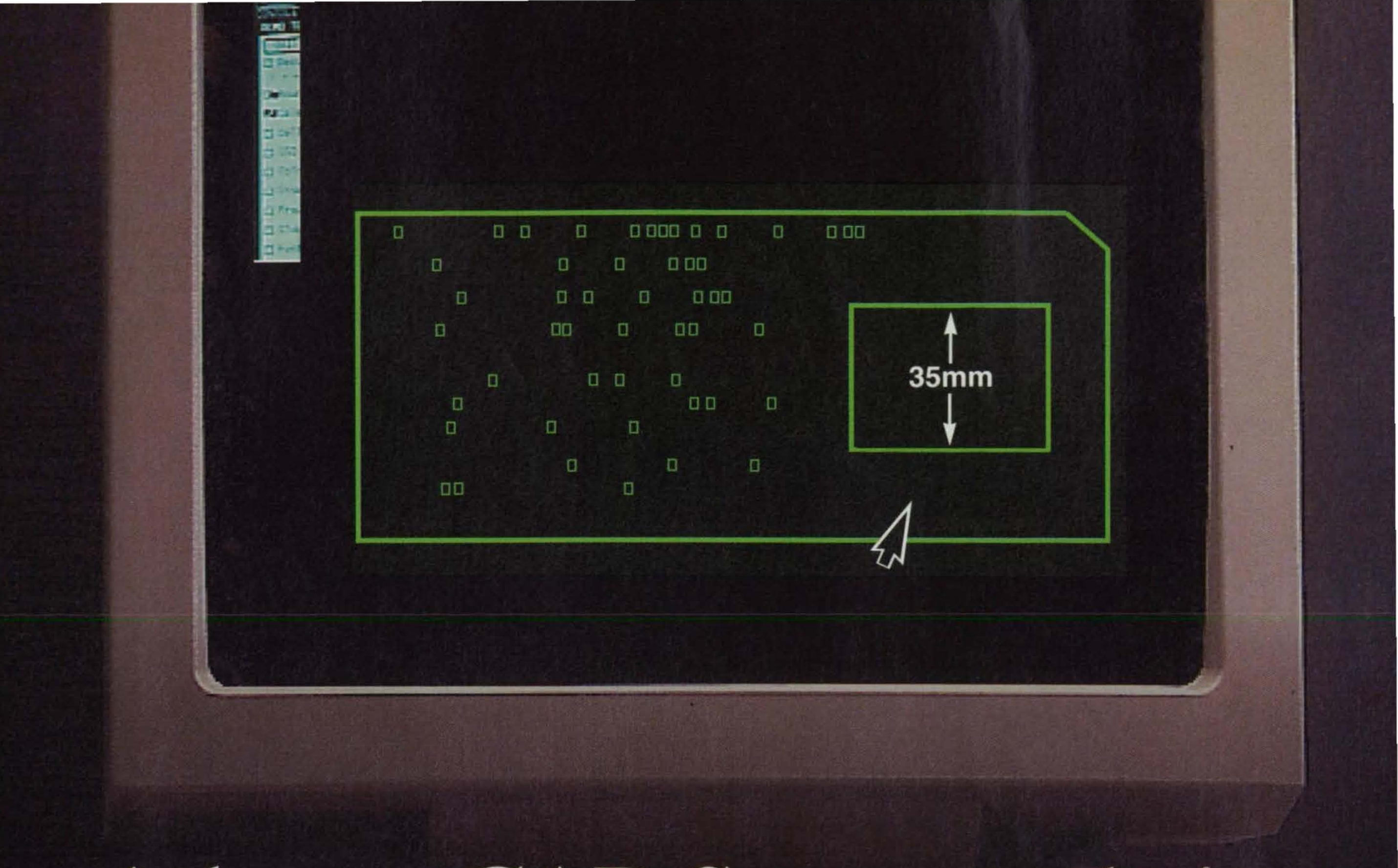
The design manager could save a substantial amount of time if circuits on the same level of the multilevel structure are executed in parallel. DeMAID estimates the time saved on the basis of the number of available processors. In addition to decomposing the system into subsystems, DeMAID examines the dependencies of a problem with independent variables and dependent functions. A dependency matrix is created to show the relationship.

DeMAID is based on knowledge-base techniques to provide flexibility and ease in adding new capabilities. Although DeMAID was originally written for design problems, it has proven to be applicable to any problem containing modules (processes) that take inputs and generate outputs. For example, one group is applying DeMAID to gain understanding of the flow of data associated with a very large computer program. In this example, the modules are the subroutines of the program.

The design manager begins the design of a system by determining the level of modules that must be ordered. The level is the "granularity" of the problem. For example, the design manager may wish to examine disciplines (a coarse model), analysis programs, or the data level (a fine model). Once the system is divided into these modules, the input and output of each model is determined, creating a data file for input to the main program.

DeMAID is executed through a system of menus. The user can choose to plan, schedule, display the $N \times N$ matrix, display the multilevel organization, or examine the dependency matrix. The main program calls a subroutine that reads a rule file and a data file, asserts facts into the knowledge base, and executes the inference engine of the artificial-intelligence/expert-system program, CLIPS (C Language Integrated Production System).

To determine the effects of changes in



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the design process, DeMAID includes a "trace effects" feature. Two methods of tracing the effects of a change in the design process are available. The first method involves tracing forward through the outputs to determine the effects of an output with respect to a change in a particular input. The second method involves tracing backward to determine what modules must be re-executed if the output of a module must be recomputed.

DeMAID is available in three machine versions: a Macintosh version written in Symantec's Think C 3.01, a Sun version in C language, and an SGI IRIS version in C language. The Macintosh version requires system software 6.0.2 or later and CLIPS 6.0. The source code for the Macintosh version is not compilable under version 4.0 of Think C; however, a sample executable code is provided on the distribution media. QuickDraw is required for plotting. The Sun version requires GKS 4.1 graphics libraries, OpenWindows 3, and CLIPS 6.0. The SGI IRIS version requires CLIPS 6.0. The documentation for CLIPS 6.0 is not included in the documentation package for DeMAID; however, it is available from COSMIC separately as the documentation for MSC-21208. The standard distribution medium for the Macintosh version of DeMAID is a set of four 3.5-in. (8.9-cm), 800K Macintosh-format diskettes. The standard distribution medium for the Sun version of DeMAID is a 0.25-in. (6.35-mm) streaming-magnetic-tape cartridge (QIC-24) in UNIX tar format. The standard distribution medium for the IRIS version is a 0.25-in. (6.35-mm) IRIX-compatible streaming-magnetic-tape cartridge in UNIX tar format. All versions include sample input. DeMAID was originally developed for use on VAX VMS computers in 1989. The Macintosh version of DeMAID was released in 1991 and updated in 1992. The Sun version of DeMAID was released in 1992 and updated in 1993. The SGI IRIS version was released in 1993.

This program was written by James L. Rogers, Jr., of **Langley Research Center** *and Laura E. Hall of Unisys Corp. For further information,* ***write in 147*** *on the TSP Request Card.*
LAR-15099

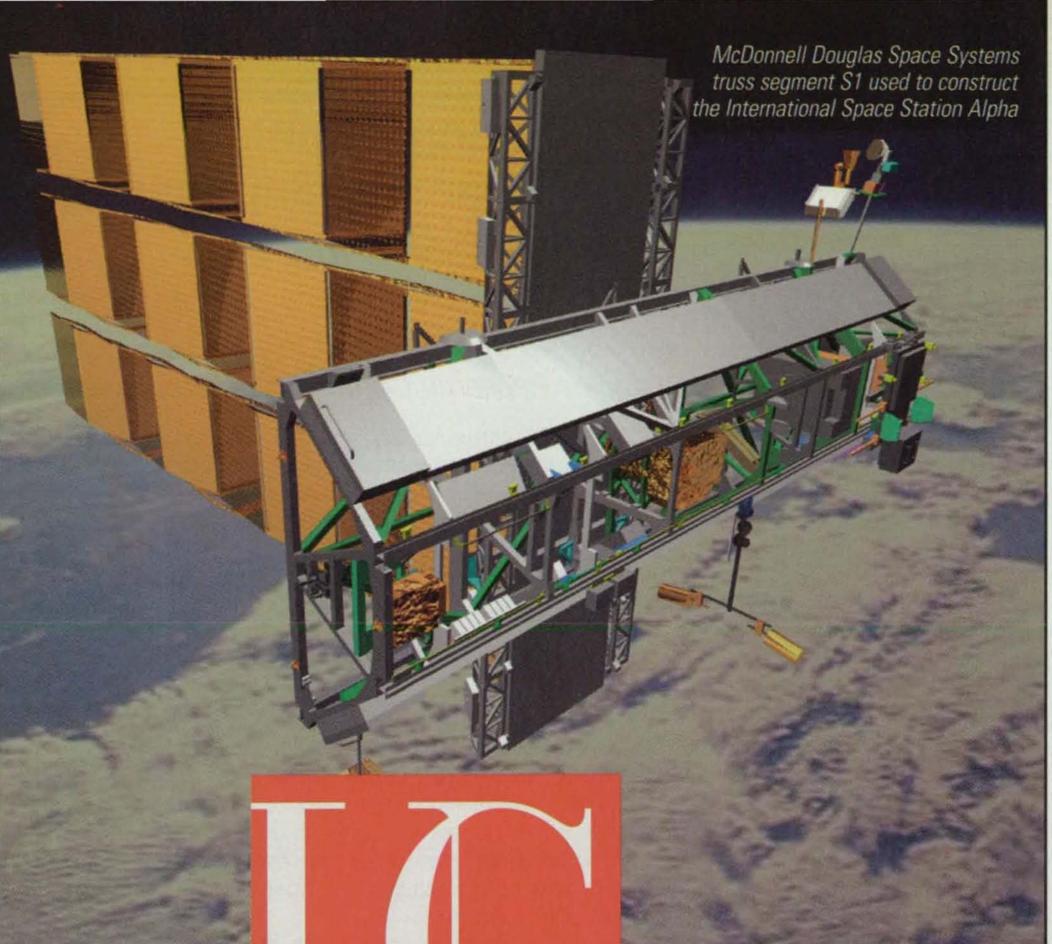
Program for Optimization of Antenna Structures

This program calculates pathlength and pointing errors.

NASA's Jet Propulsion Laboratory, Pasadena, California

The JPL-ANTOPT computer program is designed to help engineers optimize microwave antenna structures by use of path-length- and pointing-error-analysis calculations. This program is a package of codes and subroutines to be added to the MSC/NASTRAN program.

Lengths of signal-propagation paths and pointing errors are important measures of structure-related performance of an antenna. JPL-ANTOPT treats the errors as scalar displacements in static-loading cases. These scalar displacements can be subject to constraint during an optimization process. The path-



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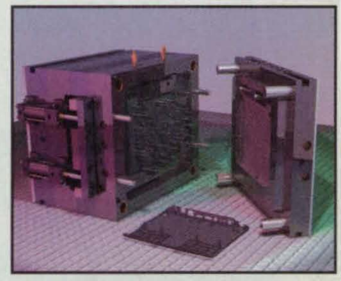

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length and pointing-error calculations in JPL-ANTOPT supplement the other optimization and sensitivity capabilities of NASTRAN. The analysis and design functions are implemented as "DMAP ALTERs" to the Design Optimization (SOL 200) Solution Sequence of MSC/NASTRAN version 67.5.

The path-length error is calculated as the weighted root-mean-square error of a paraboloid that best fits the deformed primary reflector surface in a half-path-length sense. The antenna-pointing-error calculation combines the orientation of the best-fitting paraboloid with the displaced positions of the secondary reflector and the phase center of the microwave feed. This error can be calculated relative to the position of an elevation-angle transducer on the antenna. The results of the path-length and pointing-error analyses are reported in tables for each static sub-case. The added codes for analysis and design of antennas do not modify or interfere with the operation of the original optimization code and are compatible with all the other sensitivity and design options in SOL 200.

JPL-ANTOPT is written in MSC/NASTRAN's Direct Matrix Abstraction Programming (DMAP) language for use on any computer running MSC/NASTRAN 67.5. A test problem is included on the distribution medium. All files are in ASCII format. The standard medium for distribution of JPL-ANTOPT is a 3.5-in. (8.89-cm), 1.44MB diskette in UNIX tar format. Alternate distribution media and formats are available on request. JPL-ANTOPT was developed in 1993 and is a copyrighted work with all copyright vested in NASA.

MSC/NASTRAN is a trademark of the MacNeal-Schwendler Corporation.

This program was written by Douglas Strain of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 1*** *on the TSP Request Card. NPO-19349*

Computing Trimmed, Mean-Camber Surfaces at Minimum Drag

This program utilizes a vortex lattice method mathematical model.

Langley Research Center, Hampton, Virginia

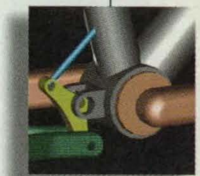
The VLMD computer program determines the subsonic mean-camber surfaces of trimmed noncoplanar planforms with minimum vortex drag at a specified lift coefficient. Up to two planforms can be designed together. The method used is that of the subsonic vortex lattice method of chord loading specification, ranging from rectangular to triangular, left to be specified by the user.

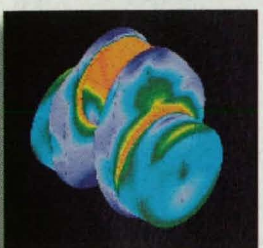
In VLMD, a Trefftz-plane analysis is used to determine the optimum span loading for minimum drag. The program then solves for the mean camber surface of the wing associated with this loading. Pitching-moment or root-bending-moment constraints can be employed at the design lift coefficient. Sensitivity studies of vortex-lattice arrangements have been made with this program and comparisons with other theories show generally good agreement. The program is very versatile and has been applied to isolated wings, wing/canard configurations, a tandem wing, and a wing/-winglet configuration.

The design problem solved with this code is essentially one of optimization. A subsonic vortex lattice is used to determine the span load distribution(s) on bent lifting line(s) in the Trefftz plane. A Lagrange multiplier technique is used to determine the required loading, which is used to calculate the mean-camber slopes, which, in turn, are then integrated to yield the local elevation surface. The problem of determining the necessary circulation matrix is simplified by having the chordwise shape of the bound circulation remain unchanged across each span, though the chordwise shape may vary from one planform to another. The circulation matrix is obtained by calculating the spanwise scaling of the chordwise shapes. A chordwise summation of the lift and pitching moment is utilized in the Trefftz-plane solution, on the assumption that the trailing wake does not roll up and that the general configuration includes specifiable chord-loading shapes.

VLMD is written in FORTRAN for IBM PC-series and compatible computers running MS-DOS. This program requires 360K of random-access memory for execution. The Ryan McFarland FORTRAN compiler and PLINK86 are necessary to recompile the source code; however, a sample executable code is provided on the distribution medium. The standard medium for distribution of VLMD is a 5.25-in. (13.335-cm), 360K MS-DOS-format diskette. VLMD was originally developed for use on CDC 6000-series computers in 1976. It was originally ported to the IBM PC in 1986, and, after minor modifications, the IBM PC version was released in 1993.

This program was written by John E. Lamar and William T. Hodges of **Langley Research Center**. *For further information,* ***write in 27*** *on the TSP Request Card.*
LAR-15160





Electronic Components and Circuits

Cheap, Easy-To-Read Frequency Monitor for Pulsed Laser

A simple bar-graph display shows the approximate relative frequency at a glance

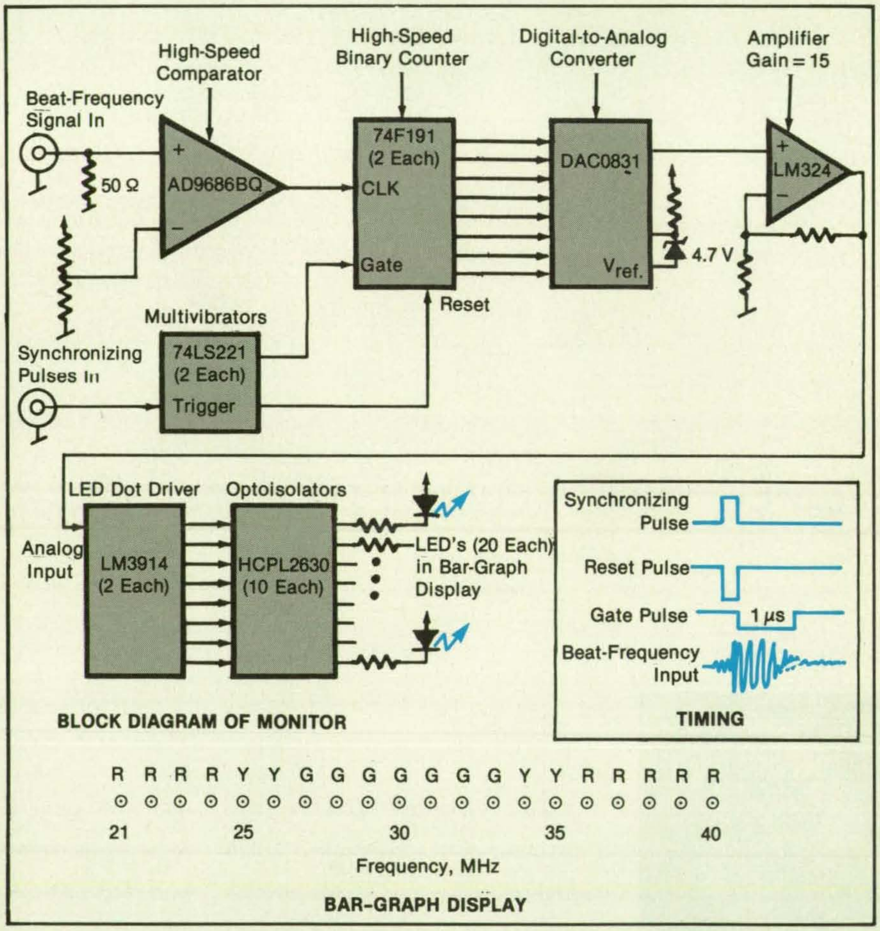
NASA's Jet Propulsion Laboratory, Pasadena, California

The figure illustrates an electronic circuit that provides a bar-graph display of the difference between the carrier frequency of a pulsed laser transmitter and the frequency of another laser that serves as the local oscillator in a receiver. The display device is a linear array of light-emitting diodes (LED's), each of which represents a 1-MHz portion of the beat-frequency range from 20 to 40 MHz. The middle LED and its neighbors are green; the LED's that represent the edges of the passband are yellow; the LED's of frequencies outside the passband are red. Thus, the operator can determine the approximate relative frequency of the transmitter at a glance by observing the color and position of the illuminated LED.

In the pulsed-lidar system for which the frequency monitor was designed, the pulse-repetition frequency is about 4 Hz. Typically, the carrier frequency jitters about 1 MHz, from pulse to pulse. It is much easier to read this bar-graph display than it would be to read a more-precise digital frequency display because the reader does not have to process mentally the many digits that would change repeatedly at the pulse-repetition rate. In addition, the incremental linear display enhances the operator's perception of the jitter and overall excursion from the middle frequency.

The monitor is based on heterodyne and gated-counter concepts. In the photodetector of the receiver, part of the scattered transmitter signal is mixed with the local-oscillator signal, producing the beat-frequency (intermediate-frequency) receiver signal. Some of the beat-frequency signal is diverted from the receiver to the monitor, where a high-speed comparator generates transistor/transistor-logic-level pulses at the beat-frequency rate. These pulses are fed to the clock-input terminal of a binary counter. The count is started, stopped, and reset to zero during each transmitter pulse by two multivibrators that are triggered by a synchronizing pulse from the transmitter. The counting period is 1 μs. If, for example, the count is 30 at the end of the period, then the average frequency during the period was about 30 MHz.

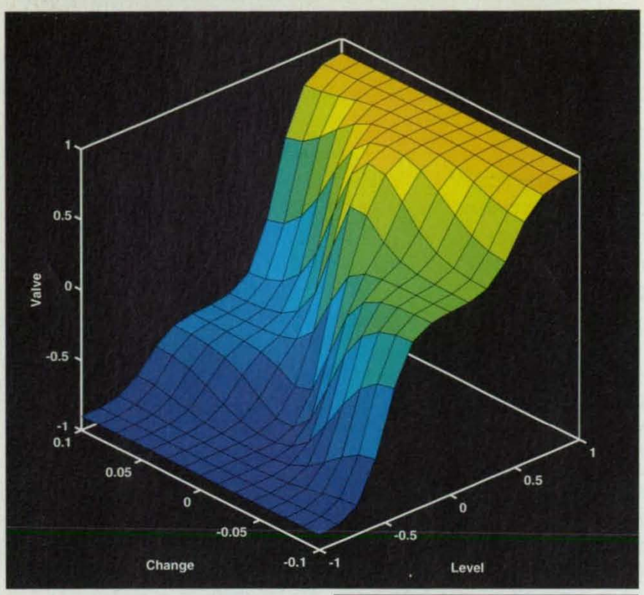
The output of the binary counter is converted to an analog voltage, then redigitized by an LED-dot-bar driver to the frequency increments of the display. (This approach results in a simpler circuit than does an all-digital approach.) The output of the LED-dot-bar driver is fed to a set of opto-isolators, which drive the LED's in the display. To enable verification that the bar-graph display is calibrated, a digital readout is also provided. However, the bar-graph display is meant to be the focus of attention at high pulse-repetition rates.



The **Frequency Monitor** counts the number of cycles during a 1-μs portion of the beat-frequency pulse associated with each transmitter pulse (which lasts somewhat longer than 1 μs). One of the LED's in the linear array is illuminated; its position represents the number of cycles and, therefore, the relative carrier frequency of the transmitter.

This work was done by Carlos Esporoles of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 43*** *of 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 20]. Refer to NPO-18596.



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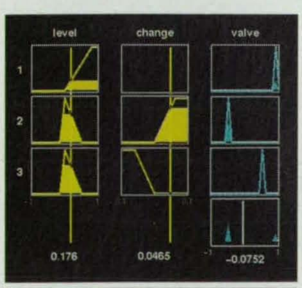

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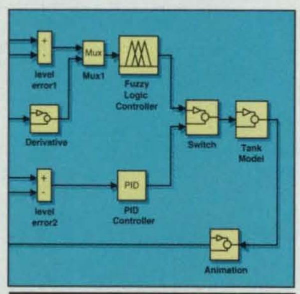

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Combining Video Memory Operations

Designs can be simplified.

Lyndon B. Johnson Space Center, Houston, Texas

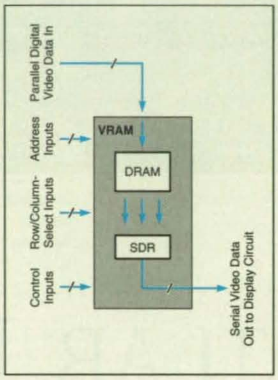
The designs of video random-access memory (VRAM) integrated circuits that operate under control by external logic circuits can be simplified according to a concept of combining two memory operations that have been performed separately heretofore.

Usually, a VRAM integrated circuit of the type in question contains a dynamic random-access memory (DRAM) that buffers parallel digital video data from the source, plus a serial data register (SDR) that loads parallel data from the DRAM prior to clocking of this data serially out to a display circuit (see figure). The four main operations of the VRAM are (1) loading the DRAM, (2) refreshing the DRAM, (3) loading the SDR, and (4) clocking data serially out of the SDR. According to older design concepts, only operations 1 and 4 can be performed simultaneously; operations 1, 2, and 3 are performed sequentially because they have to be synchronized with common control signals that an arbiter logic circuit feeds sequentially to the portions of the circuits that effect these operations.

The present simplified design concept can be applied to a VRAM that clocks data out to a display unit continuously. Because operations 2 and 3 occur periodically in continuous clocking, it is possible to combine these operations, provided that a suitable number of rows of the DRAM are refreshed on each cycle. This concept eliminates the need for DRAM-refresh timers and counters, thus reducing the amount of circuitry needed to control the VRAM and thereby also reducing the time needed to design the VRAM. This simplification also reduces the time needed to redesign the DRAM-refresh logic circuitry when adapting a VRAM design to another VRAM for which timing specifications are different.

This work was done by Michael J. Kania and Jim S. Eiche of International Business Machines Corp. for **Johnson Space Center**. *For further information,* ***write in 118*** *on the TSP Request Card.*

MSC-22417



A VRAM Performs Four Main Operations on video data during each operating cycle. Combining two of them simplifies the ancillary control and timing circuitry.

Preventing Overcharge and Overdischarge of Lithium Cells

Cathode additives act as sinks or sources of lithium.

NASA's Jet Propulsion Laboratory, Pasadena, California

Secondary lithium cells that operate at ambient temperature can be protected against overcharge and overdischarge by use of cathode additives that act as the sources and sinks of the electroactive chemical species, which is lithium. The additive in a cathode limits the excursion of the voltage of the cell during both overcharge and overdischarge. In addition to protecting the cell, the additive thus also serves as part of a state-of-charge indicator: the attainment of the greater or lesser limiting voltage indicates the end of charge or end of discharge, respectively. This concept has been applied to the Li/TiS_2 system, and should also be applicable to such other lithium systems as Li/MoS_2, $Li/NbSe_3$, and Li/V_2O_5.

The cycle-life performance of the Li/TiS_2 system is very sensitive to the limits of operating voltages, the recommended limits being 2.7 V for the end of discharge. Charging a cell to more than about 2.8 V results in oxidative degradation of the electrolyte solvent; discharging to less than about 1.5 V results in irreversible intercalation of Li into TiS_2 and reduction of the electrolyte salt. This limits the cycle-life performance of the cell. Repeated overcharge and overdischarge have also been found to result in venting or explosion of cells. Hence, there is a need for built-in means to prevent both overcharge and overdischarge.

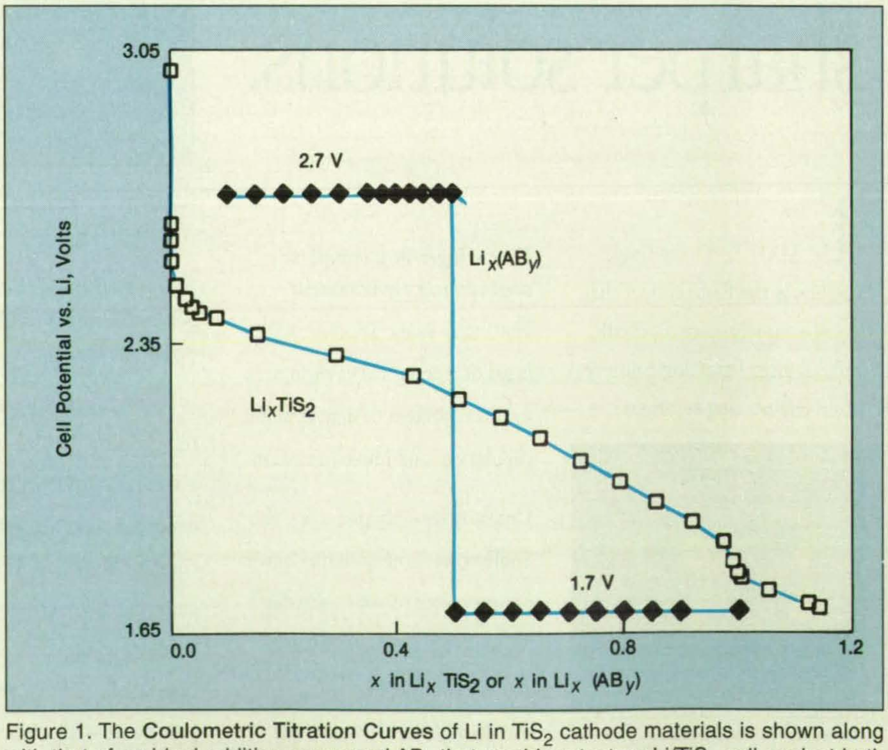


Figure 1. The **Coulometric Titration Curves** of Li in TiS_2 cathode materials is shown along with that of an ideal additive compound AB_y that would protect an Li/TiS_2 cell against both overcharge and overdischarge.

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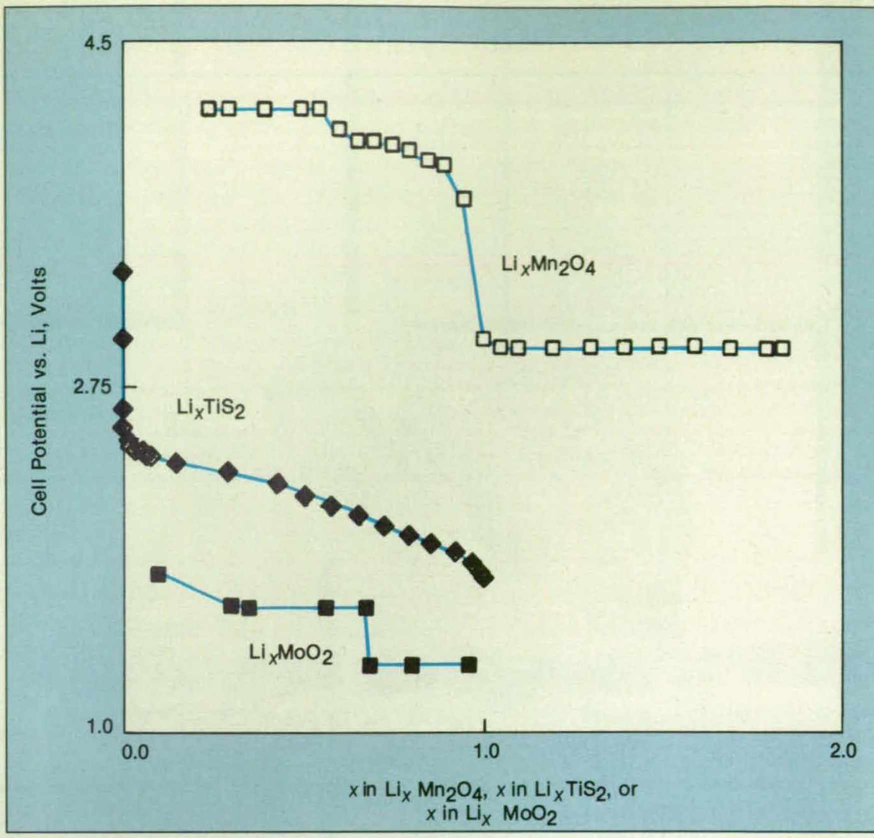


Figure 2. The **Two-Compound Additive Mixture** of $Li_2Mn_2O_4$ and $Li_{0.1}MoO_2$ protects an Li/TiS_2 cell against both overcharge and overdischarge, as can be seen from the coulometric titration curves of Li in TiS_2, Mn_2O_4, and MoO_2.

A cathode additive that can protect against both overcharge and overdischarge may contain one or two materials that, in combination, exhibit the following characteristics: (1) The additive must be capable of undergoing a reversible reaction with lithium. (2) The lithium-titration curve of the additive must contain two well-defined voltage plateaus separated by about 1 V. (3) The upper plateau voltage of the additive must slightly exceed the charge cutoff voltage of the cathode material. (4) The lower plateau voltage of the additive must be slightly less than the discharge cutoff voltage of the cathode material. (5) If the additive is a single compound, it should preferably be one that exhibits a sharp transition from one plateau to the other. (6) The additive must be chemically stable in the presence of the cathode active material and the electrolyte. (7) The additive must be highly conductive with respect to electrons and lithium ions.

The titration curve of TiS_2 cathode material and an ideal single-compound cathode additive is shown in Figure 1, which illustrates the range of operating voltages of the TiS_2 and the range of voltages that lie within the protective capability of the additive material. During overcharge (an attempt to charge the cell to more than the upper plateau value of 2.7 V), the additive material is activated and keeps the cell voltage from rising above 2.7 V. During overdischarge (an attempt to discharge the cell to less than the lower plateau voltage of 1.7 V), the additive is also activated and keeps the cell voltage from falling below 1.7 V. Theoretically, these requirements could be met by an additive that consists of one or two individual compounds (transition-metal oxides or sulfides).

One example of an additive that consists of two compounds is a mixture of $Li_2Mn_2O_4$ and $Li_{0.1}MoO_2$. The $Li_xMn_2O_4$ system exhibits an upper plateau voltage around 2.9 V (vs. Li), and thus protects the cells against overcharge; the Li_xMoO_2 system exhibits a lower plateau voltage around 1.6 V (vs. Li), and thus protects the cells against overdischarge (see Figure 2).

This work was done by Chen-Kuo Huang, Subbarao Surampudi, David H. Shen, Fotios Deligiannis, Alan I. Attia, and Gerald Halpert of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 91*** *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 20]. Refer to NPO-18343.

Tachometer Derived From Brushless Shaft-Angle Resolver

Output is directly proportional to the rate of rotation.

Marshall Space Flight Center, Alabama

The figure illustrates an analog tachometer circuit that processes the input and output signals of a two-phase, brushless, transformer-type shaft-angle resolver into a signal with instantaneous amplitude proportional to the instantaneous rate of rotation of the shaft. The processing in this circuit effects a straightforward combination of mathematical operations leading to a final operation based on the well-known trigonometric identity $[\sin(x)]^2 + [\cos(x)]^2 = 1$ for any value of x. This circuit is related to a tachometer circuit, described previously in *NASA Tech Briefs* and based on the same mathematical principles, that required two shaft-angle resolvers. By eliminating the need for a second resolver, the present circuit reduces the overall size, weight, and cost of the tachometer.

As is customary, the resolver is excited with a periodic waveform; a sinusoid is indicated in the figure, but a square, triangular, or other periodic waveform could be used instead. Thus, the two outputs of the resolver are $k_1\sin(\omega t)\sin(\theta)$ and $k_1\sin(\omega t)\cos(\theta)$, where k_1 is a constant proportional to the amplitude of excitation and to a factor that depends on the geometric and electromagnetic properties of the resolver, ω is $2\pi \times$ the frequency of excitation, t is time, and θ is the instantaneous shaft angle.

The two outputs of the resolver are then processed, along with a replica of the sinusoidal excitation, by demodulators. The two outputs of the demodulators are thus $k_2\sin(\theta)$ and $k_2\cos(\theta)$, where k_2 is a constant proportional to k_1 and to the gain of the demodulators. These signals are then differentiated with respect to time in two differentiator circuits. The outputs of these circuits are thus $k_3\cos(\theta)[d\theta/dt]$ and $-k_3\sin(\theta)[d\theta/dt]$, where k_3 is a constant proportional to k_2 and to the gain of the differentiator circuits. Note that $d\theta/dt$ is the rate of change of the shaft angle and is the quantity that one seeks to measure.

Next, a multiplier circuit forms a product of the demodulator and differentiator outputs proportional to $\sin(\theta)$, while another multiplier circuit forms the product of the demodulator and differentiator outputs proportional to $\cos(\theta)$. The outputs of the multiplier circuits are thus $+k_4[\cos(\theta)]^2[d\theta/dt]$ and $-k_4[\sin(\theta)]^2[d\theta/dt]$, where k_4 is a constant proportional to k_2k_3 and to the gain of the multiplier circuits. The output of the cosine multiplier is fed to a unit-gain inverting amplifier to obtain $-k_4[\cos(\theta)]^2[d\theta/dt]$.

The voltages $-k_4[\sin(\theta)]^2[d\theta/dt]$ and $-k_4[\cos(\theta)]^2[d\theta/dt]$ are fed to an inverting unit-gain adder circuit. By virtue of the trigonometric identity $[\sin(\theta)]^2 + [\cos(\theta)]^2 = 1$ and the inversion, the output of this circuit is simply $+k_4[d\theta/dt]$.

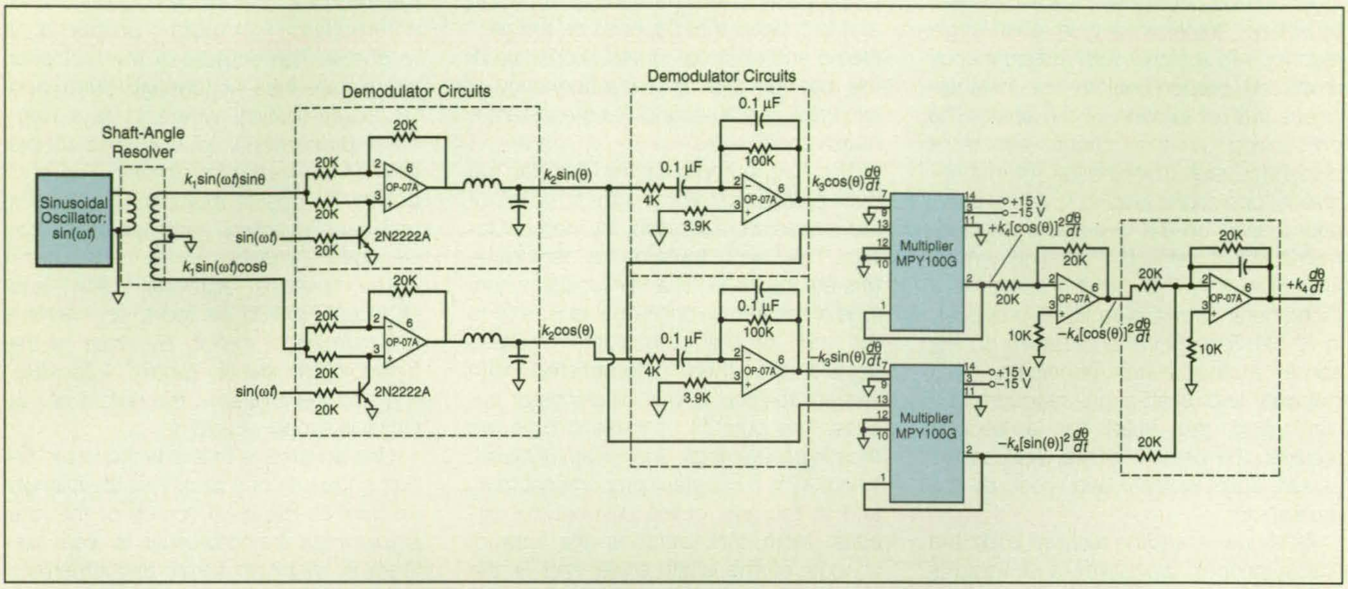
One advantage of this tachometer circuit is the use of a brushless shaft-angle resolver as the main source of the rate signal: there are no brushes to wear out, there is no brush noise, and brushless resolvers have a history of proven robustness. Unlike in some older tachometer circuits, there is no switching of signals to

For More Information Write In No. 408

generate noise. Another advantage is that in a typical application, a shaft-angle resolver is already being used as a shaft-angle sensor, and thus the tachometer input can be obtained without adding another sensor. This circuit also offers an advantage over conventional rate sensors based on permanent magnets and windings: If a winding becomes short-circuited, it gives rise to a parasitic drag torque. The present circuit is not susceptible to this type of malfunction.

This work was done by David E. Howard and Dennis A. Smith of **Marshall Space Flight Center**. *For further information,* ***write in 77*** *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 20]. Refer to MFS-28845.

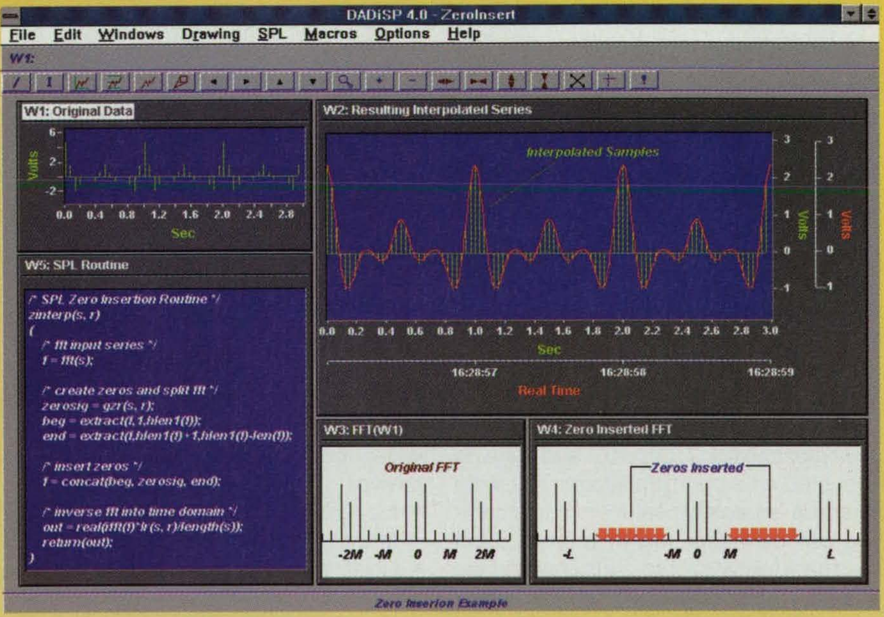


The **Tachometer Circuit** operates in conjunction with a brushless shaft-angle resolver. By performing a sequence of straightforward mathematical operations on the resolver signals and utilizing a simple trigonometric identity, it generates a voltage proportional to the rate of rotation of the shaft.

IN CASE YOU MISSED IT!

Here's what **they*** said about DADiSP 4.0

A streamlined user interface that fully conforms to Windows is the first obvious feature of a long-awaited upgrade to DADiSP, a graphical analysis program from DSP Development Corp. that's designed for the needs of scientists and engineers.



A major overhaul of the user interface, the introduction of an integrated programming language and new option modules highlight Ver. 4.0 of DADiSP...

Besides adopting a complete Windows look and feel, the overall interface scheme has gained a more streamlined look... [W]ith the flattened hierarchy on this upgrade, the software always starts up in a worksheet; indeed, when loaded, the software returns to the setup that was on the screen when the user last exited the program. Although you don't have to go through a hierarchy, the package still maintains labbooks, datasets and worksheets to provide a simple method of organizing large complex datafiles and projects.

As part of the Windows implementation, Ver. 4.0 adds support for DDE as a client or server either with functions at the command line or with Copy/Paste Link for the pulldown menu. It performs both warm and hot DDE links with either ASCII or binary datatypes...

Ver. 4.0 also gives users the ability to define their own operations and functions to a far greater extent than the macros found in the previous version. Specifically, the upgrade marks the introduction of a programming language called SPL (series processing language). Modeled on C, it provides all the expected facilities including user-defined functions, looping and iteration, conditional statements, array references and variables. Variables can be global to a session or local to a function.

An interesting feature is the hot variable, which can contain real or complex numbers, strings, data series and matrices. A hot variable links a formula to a variable so that when a dependent element of a formula changes, the hot variable automatically reevaluates. For example, the SPL code fragment:

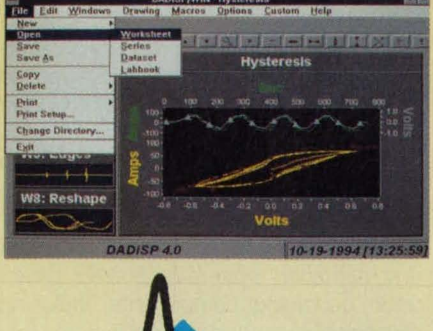
```
size := 10
W2: Movavg(W1, size)
```

performs a 10-point moving average on the waveform in Window 1 and displays the results in Window 2. The := operator establishes the hot variable. You can explore the effects of changing the moving-average length simply by reassigning size := 20 so that W2 automatically updates and shows a plot based on that new parameter.

Also improved is the package's hardcopy facility. Plot titles, legends, multiple scales, selectable fonts and a Preview mode help users produce publication-quality output...

[T]wo more modules... address advanced DSP and control applications. The AdvDSP module performs Chirp-Z transforms, N-point FFTs independent of series length and zoom FFTs. It also handles multiple forms of PSD estimation (classical, autoregressive parametric, moving-average parametric, autoregressive moving-average parametric), transfer-function estimates, Cepstrum analysis and digital interpolation. The controls module allows you to execute command line or pulldown menus, and it addresses the design, analysis and simulation of digital and continuous open- and closed-loop controllers for linear single-input/single-output dynamic systems. Among its algorithms are those that handle PID loops as well as lead and lag controllers.

* Personal Engineering & Instrumentation News 1/95



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Hazardous-Materials Robot

This mobile robot permits remote entry into areas contaminated by hazardous materials.

NASA's Jet Propulsion Laboratory, Pasadena, California

To assist hazardous-materials emergency response teams, the Jet Propulsion Laboratory has designed and built a remotely controlled mobile robot that can be used to locate, characterize, identify, and eventually mitigate incidents involving hazardous-materials spills/releases. The robot, which is based upon a commercially available robot manufactured by Remotec (Oak Ridge, TN), possesses a number of innovative features, which allow it to perform mission-critical functions such as opening and unlocking doors and sensing for hazardous materials. By virtue of its remote control, the vehicle provides a safe means for locating and identifying spills and thereby eliminates the risks of injury associated with the use of manned entry teams.

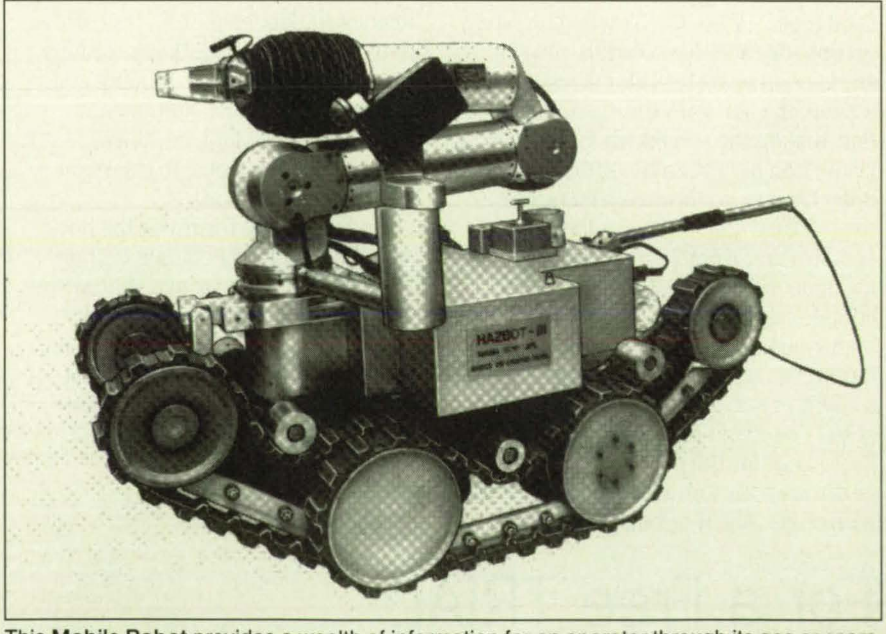
The vehicle (see figure) consists of an articulated, tracked mobile platform with a six-degree-of-freedom robotic manipulator. The articulated tracks enable the operator to control the configuration of the front and rear tracks remotely, thereby enabling the vehicle to climb stairs and similar obstacles. The manipulator provides a means for grasping objects and can lift 30 lb (13.6 kg) when fully extended [approximately 5 ft (1.5 m)]. The manipulator, which features among other things a 3 DOF anthropomorphic wrist, is extremely dexterous. When used in combination with specially designed tools, the manipulator, controlled by the operator, can reliably perform difficult mission-critical tasks, including the unlocking and opening of doors.

In addition to its basic mobility and manipulation capabilities, the current version of the vehicle, called HAZBOT III, also features a unique mechanical and electrical design that enables the vehicle to operate safely within a combustible atmosphere. The design has two complimentary components. First, the control and actuation system is entirely based upon nonarcing components, including brushless dc motors and solid state electronics. Second, all of the systems actuators and electronic components are housed within the vehicle's chassis and manipulator, which are sealed and internally pressurized via an onboard tank of dry air. During normal operation the system's electrical components do not create arcs, which could ignite a combustible atmosphere; and even if a component did fail and create an arc, the internal pressurization would prevent the combustible materials from entering the vicinity of the arc.

To operate the vehicle, an operator sits at a portable control station, which contains two video monitors, a display terminal, and a control panel with a mixture of switches and joysticks. The video monitors display images from the vehicle's two onboard cameras. One is mounted on the manipulator's gripper, and one is mounted on a pan/tilt platform. The latter image is especially useful since this camera can be independently rotated about the manipulator's torso, thus enabling the operator to obtain especially good viewing angles. The terminal is used to display, in real time, the readings obtained from onboard chemical sensors mounted within the manipulator's forearm. Air samples to these sensors are acquired through a sampling tube within the manipulator's finger tips. The control panel contains the input devices for activating various joints and onboard devices and features a unique layout to facilitate use by personnel with little or no previous experience in controlling mobile robots.

In November of 1992, the HAZBOT III vehicle was used by the JPL Fire Department HAZMAT Team to perform an end-to-end simulated response mission, and it later will be used in responding to actual HAZMAT incidents at JPL. In November of 1991, HAZBOT II, an earlier version of the vehicle, was successfully used by the JPL HAZMAT Team to perform an end-to-end response mission, which required the vehicle to do the following:

- Navigate to approximately 30–50 meters to a building;
- Unlatch, open, and fixture the building exterior door;
- Locate and navigate to a chemical storeroom;
- Sense for the presence of combustible gases and the percent level of oxygen along the storeroom doorway's jam;
- Unlock and open the chemical storeroom's door;



This **Mobile Robot** provides a wealth of information for an operator through its gas sensors, video cameras, and microphone. Audio signals, for example, give the operator clues to hissing leaks and to the contact of the tracks with the ground.

- Climb into the chemical storeroom over a 10-in. (25-cm) high berm; and
- Locate and identify the simulated hazardous-materials spill.

A completed system was delivered to the JPL Fire Department HAZMAT team for use in responding to actual HAZMAT incidents.

This work was done by Henry W. Stone and Gary O. Edmonds of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 25*** *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 20]. Refer to NPO-18690.

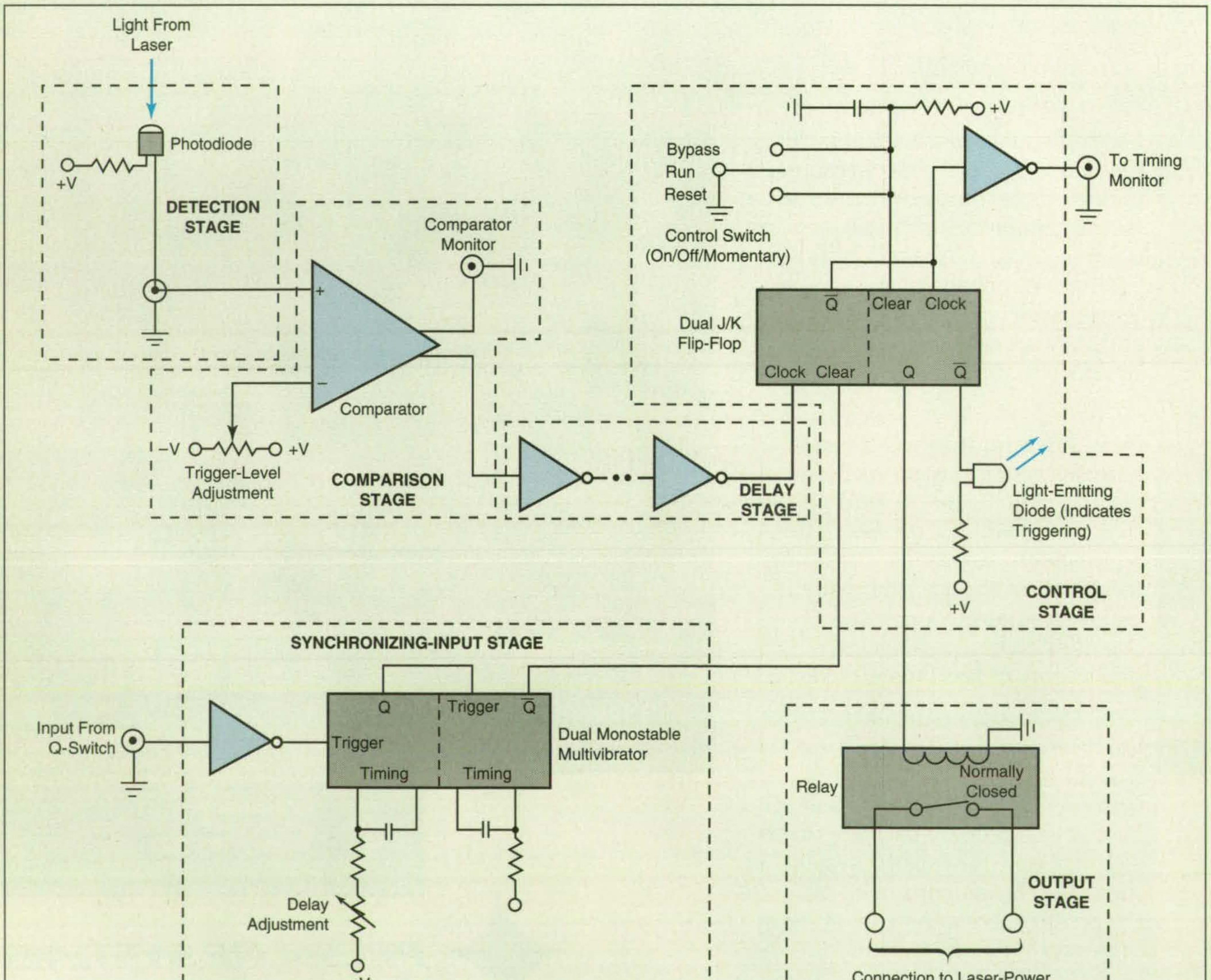
Circuit Stops Prelasing in a Q-Switched Laser

Premature emission of laser light triggers a turnoff relay.

Langley Research Center, Hampton, Virginia

A protective shutdown circuit stops prelasing in a Q-switched laser that operates at a pulse-repetition rate of about 10 Hz. During normal operation, the Q-switch prevents the emission of light from the laser cavity during the application of the Q-switch-trigger pulse. Sometimes, the Q-switch is unable to hold off emission of laser light during the Q-switch-trigger pulse; "prelasing" is the name of the resulting premature emission. Prelasing is considered undesirable because it can damage the optical components of the laser and associated equipment, and because it results in uncontrollable variations in the timing and power of the laser output.

The protective shutdown circuit is designed according to the premise that the desired laser output occurs after the Q-switch-trigger pulse, and any laser output that occurs prior to this pulse is considered to be prelasing. When this circuit detects prelasing, it triggers a relay that



The Protective Shutdown Circuit (shown here in simplified form) turns off the laser power supply when it detects laser light before the end of the Q-switch-trigger pulse.

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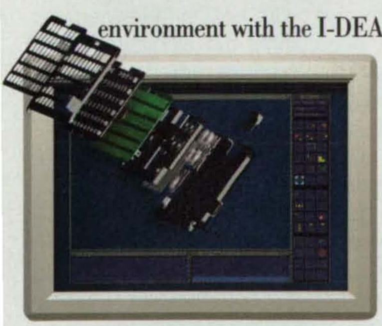

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turns off the laser power supply. The circuit can be integrated into almost any Q-switched-laser system, provided that one can gain access to the laser light, the Q-switch-trigger pulse, and the safety-interlock line of the laser power supply.

The protective shutdown circuit (see figure) consists of six sections — the detection, comparison, delay, synchronizing-input, control, and output stages. A sample of the laser output is band-pass filtered at the designated laser wavelength and fed to a photodiode in the detection stage. The output of the detection stage is fed to the comparator, which issues a logic pulse if the detected laser output exceeds a preset adjustable trigger level. This signal is fed to the delay stage, which consists of a series of inverters; the delay stage imposes a fixed delay that compensates for the difference between other delays, generated elsewhere in the circuit, between the Q-switch-trigger pulse and the photodiode signal. The delayed signal is fed to the "clock" input terminal of the control stage, which is a dual J/K flip-flop with "preset" and "clear" options.

The synchronizing-input stage samples and conditions the Q-switch-trigger pulse and provides an adjustable delay. The output of this stage is fed to the "clear" input terminal of the control stage, which compares the timing of its two inputs. If the delayed signal from the detector stage arrives before the signal from the synchronizing-input stage (representing the detection of laser output before the Q-switch-trigger pulse), then the control stage sends a turnoff signal, to the output stage, which is a normally closed relay switch connected to the safety-interlock line of the laser power supply. The turnoff signal opens this switch, causing the power to be turned off.

This work was done by George E. Lockard of **Langley Research Center**. *For further information,* ***write in 82*** *on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 20]. Refer to LAR-14790.

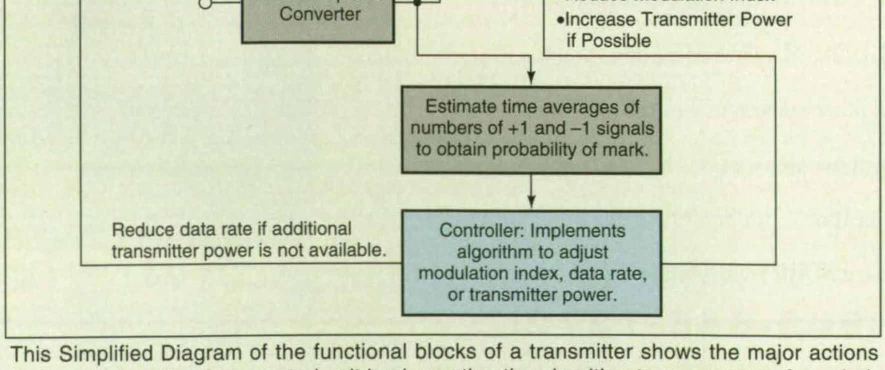
Compensating for Unbalance in Pulse-Code Phase Modulation

Modulation index or data rate can be decreased, or power can be increased.

NASA's Jet Propulsion Laboratory, Pasadena, California

An algorithm has been proposed for use in a pulse-code phase-modulation transmitter in which non-return-to-zero (NRZ) or biphase data are modulated directly onto a radio-frequency residual carrier signal. The algorithm was devised to compensate somewhat for the effect, upon a distant receiver, of unbalance in the stream of transmitted data. "Unbalance" as used here means inequality between the time-averaged number of transmitted +1s and the time-averaged number of transmitted −1s. Unbalance can give rise to spectral components that can degrade the ability of the receiver to track the phase of the carrier signal, as it must do to read the data stream correctly. Serious degradation can occur when the probability, p, of transmitting a +1 pulse (also called "probability of mark") deviates from 1/2.

The algorithm exploits the discovery that the effects of unbalance in the data can be mitigated to some extent by decreasing the modulation index: within limits, the symbol-error rate decreases with the modulation index. This is because as the modulation index decreases, (1) more power is allocated to the residual carrier (this causes phase jitter to decrease) and (2) less power is allocated to the dc component created by the unbalance (this causes interference with carrier tracking to decrease).



This Simplified Diagram of the functional blocks of a transmitter shows the major actions that would be taken by a control unit implementing the algorithm to compensate for unbalance in the data stream.

Of course, while a decrease in the modulation index increases the carrier margin, it decreases the data margin. This consideration places a limit on the improvement achievable solely by reducing the modulation index. The data margin can be increased by decreasing the data rate, and both the data and carrier margins can be increased by increasing the transmitter power. Accordingly, the algorithm is formulated to compute combinations of modulation index, data rate, and transmitter power that compensate for the measured unbalance in the transmitted data stream (see figure).

The steps of the algorithm can be summarized as follows:

1. Compute the actual carrier and data margins for the communication link for the actual modulation index, m.
2. Compute the threshold modulation index, m_T, for the required data margin and data rate.
3. Compute a modulation index, mopt, that results in a specified amount of degradation of the bit signal-to-noise ratio when $p < 0.45$.
4. If $m_T \le m_{opt} < m$, then one can reduce m to mopt without taking any other compensatory action.
5. If $m \ge m_T > m_{opt}$, then reducing m to mopt would cause the data margin to become unacceptably low. The data rate must be decreased and/or the power increased. If additional transmitter power is available, increase the power by an amount computed to maintain the required data margin.
6. If $m > m_T >$ mopt and the transmitter

power cannot be increased, then decrease the data rate by an amount that maintains the required data margin.

This work was done by Tien M. Nguyen and Sami M. Hinedi of Caltech for NASA's **Jet Propulsion Laboratory**. *For further information,* ***write in 261*** *on the TSP Request Card.*
NPO-19126

Real-Time Connected-Element Radio-Interferometer System

Receiving stations communicate data and time signals via optical fibers.

NASA's Jet Propulsion Laboratory, Pasadena, California

A real-time connected-element radio-interferometer system incorporates two receiving stations, separated by a relatively short baseline of only 21 km, that communicate via fiber-optic data and timing links. The system, located at NASA's Deep Space Network tracking complex at Goldstone, California, provides accuracies of 50 to 100 nanoradians for measuring angular positions of interplanetary spacecraft and extragalactic quasars. The overall system and various components may be adaptable to such terrestrial uses as navigation and the distribution of precise time and frequency reference signals.

Figure 1 shows the principal functional blocks of the system. A 100-MHz timing and frequency reference signal is generated at station A and transmitted to station B on one of two fiber-optic communication links. The radio signals received at each station are processed via a wideband data-acquisition terminal developed previously for use in very-long-baseline interferometry. Each data-acquisition terminal performs downconversion, sampling, 1-bit quantization, time-tagging, and formatting. The output of each data-acquisition terminal is a 112-Mbit/s bit stream, which is sent to a real-time correlator at station B; in the case of the bit stream that originates at station A, the other fiber-optic link is the medium for transmission to the correlator at station B.

The real-time correlator performs cross-correlation of the A and B quantized radio signals in as many as 14 different receiving frequency channels simultaneously. Bit streams from the 2 sets of 14 channels first enter bit synchronizers, which recover the radio-signal data and clock components, then pass to a 28-by-28 crossbar switch, which can be set by the user to connect any frequency channel to any correlator channel. The radio-signal data are then passed through digital delay lines, which are driven by 28 separate delay models sent from an external control computer to a station processor that is part of the correlator. The outputs of the delay lines are fed to both a tone-extractor circuit board and a cross-correlator circuit board. On the tone-extractor board, there is 1 tone extractor for each channel, but it is time-multiplexed to enable 4 different tones to be extracted from each channel, and hence 112 different phase polynomial tone models are sent by the control computer to the station processor.

The connections from the delay lines to the cross-correlator board are arranged to correlate the 14 A channels with the

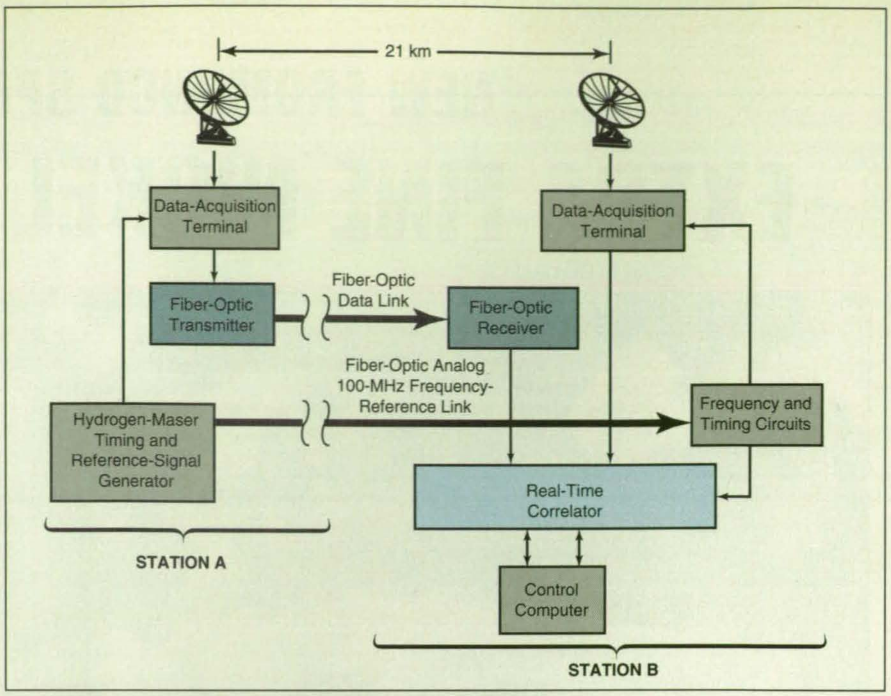


Figure 1. **Fiber-Optic Links and a Real-Time Correlator** make it possible to compute radio-interferometric delays in real time. Even though the baseline is much shorter than in very-long-baseline interferometry, the delay measurement is precise enough to provide acceptable angular precision.

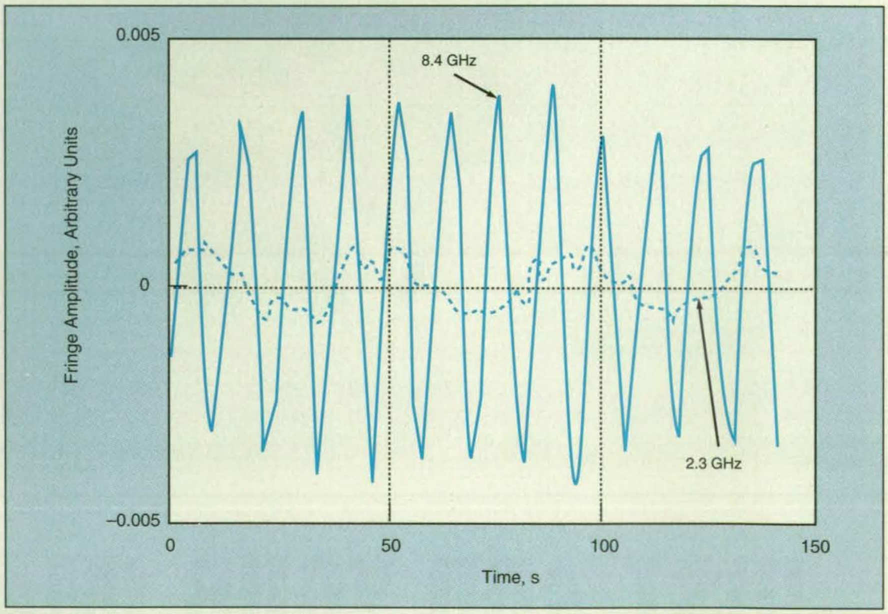


Figure 2. These **Correlation Fringes** were obtained in an initial test of the system, using 2.3- and 8.4-GHz signals transmitted by the Magellan spacecraft on June 18, 1991.

corresponding 14 B channels. The user can choose to correlate 14 channels with 8 lags each, 7 channels with 16 lags each, or 1 channel with 112 lags. The 112-lag option would normally be used for searching clock delay with a delay range of 28 µs. The cross-correlation board is driven by 14 phase models and 14 fractional delay models for each of the 2 receiving stations; these models are also generated by the external control computer and sent to the station processor.

The output of the correlator, displayed in real time on a video terminal, shows the state and quality of the data being received from each station, plots of the correlation fringes for all channels versus time (see Figure 2), plots of the phases of all tones for one channel versus time, and plots of integrated delay and rate-of-change-of-delay patterns for one channel.

This work was done by Charles D. Edwards, David H. Rogstad, David N. Fort, Leslie A. White, and Byron A. Iijima of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 80*** *on the TSP Request Card. NPO-18777.*

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Liquid-Feed Methanol Fuel Cell With Membrane Electrolyte

Advantages include relative simplicity and elimination of corrosive electrolytic solutions.

NASA's Jet Propulsion Laboratory, Pasadena, California

The figure illustrates a fuel cell that generates electricity from a direct liquid feed stream of methanol/water solution circulated in contact with an anode, plus a direct gaseous feed stream of air or oxygen in contact with a cathode. This cell offers an advantage of simplicity over some prior methanol fuel cells in which the methanol must be vaporized and humidified to form gaseous fuel feed streams. Unlike other prior liquid-feed methanol fuel cells, this one does not contain a corrosive acid or alkaline electrolyte solution, which is hazardous and can react with other cell materials to form contaminants that degrade performance. The operation of this cell does not involve the complex water- and thermal-management systems of prior cells. Overall, this fuel cell offers the potential for reductions in the size, weight, and complexity, and for increases in safety of fuel-cell systems.

The electrolyte in this cell is a perfluorinated polymeric membrane than can be maintained conductive by contact with the methanol/water solution. The membrane serves as both a proton-exchange medium and a barrier that resists diffusion of methanol to the cathode. The membrane also acts as a separator between the anode and cathode. The use of such a membrane electrolyte instead of liquid electrolytes mitigates the problem of parasitic shunt currents in a fuel cell stack. Unlike corrosive liquid electrolytes, the solid electrolyte membrane does not form contaminants that can degrade operation.

The membrane electrolyte and the electrodes are formed into a unit by hot-pressing them together. The anode contains a platinum/ruthenium alloy that acts as a catalyst for the anode half-cell reaction (electro-oxidation of methanol). The anode is structured to permit the methanol, water, carbon dioxide, and hydrogen ions to diffuse through it. The cathode contains platinum, which acts as a catalyst for the cathode half-cell reaction (electroreduction of oxygen). The cathode is also structured to permit gases to diffuse through it. Carbon dioxide generated in the anode half-cell reaction diffuses out of the anode and forms bubbles that escape by rising through the methanol/water feed stream. Thus, disposal of the carbon dioxide does not present a problem.

This work was done by Subbarao Surampudi, S. R. Narayanan, Gerald Halpert, Harvey Frank, and Eugene Vamos of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 106*** *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

William T. Callaghan, Manager
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JPL-301-350
4800 Oak Grove Drive
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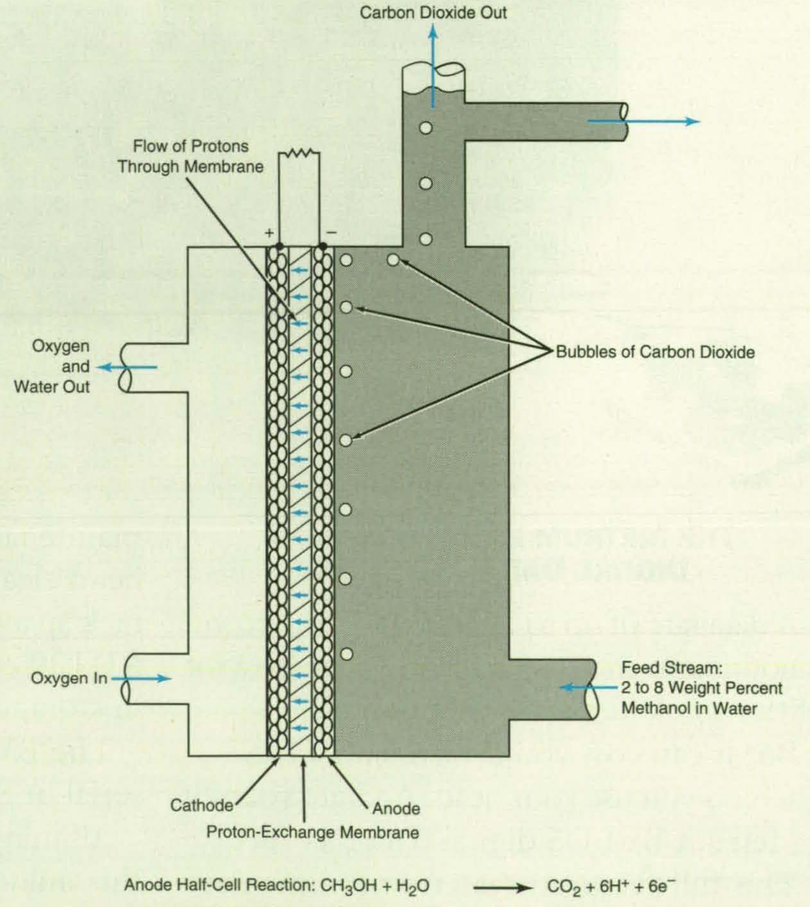
Refer to NPO-19046, volume and number of this NASA Tech Briefs issue, and the page number.

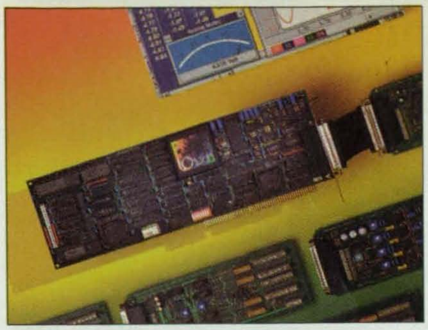


Anode Half-Cell Reaction: $CH_3OH + H_2O \longrightarrow CO_2 + 6H^+ + 6e^-$

Cathode Half-Cell Reaction: $O_2 + 4H^+ + 4e^- \longrightarrow 2H_2O$

Overall Cell Reaction: $CH_3OH + 1.5\ O_2 \longrightarrow CO_2 + 2H_2O$

This **Fuel Cell** is fed directly by streams of methanol/water solution and air (or oxygen). A laboratory version of this cell delivered a potential of 0.53 V at a current density of 100 mA/cm^2 and 0.48 V at 300 mA/cm^2. These voltage and current levels are higher than those of prior direct-oxidation methanol fuel cells and are high enough to warrant consideration for practical applications.



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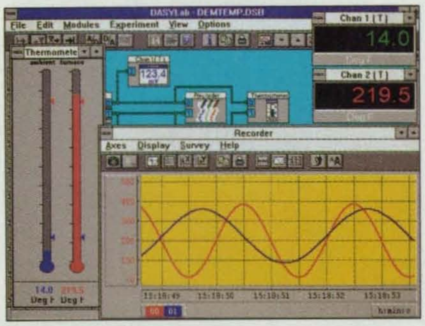

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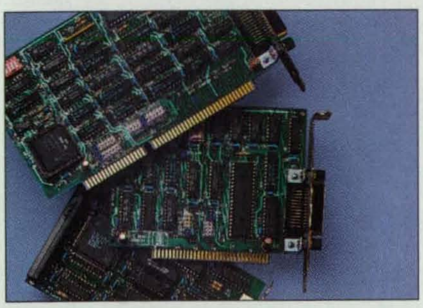

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Improved Linear-Ion-Trap Frequency Standard

Some previous design constraints could be relaxed.

NASA's Jet Propulsion Laboratory, Pasadena, California

An improved design concept for a linear-ion-trap (LIT) frequency-standard apparatus has been proposed. The improved design is intended to increase the long-term frequency stability of the apparatus while reducing its size, mass, and cost.

To explain the improved design, it is necessary to first explain the basic principle of operation. A linear-ion-trap frequency standard of the type now in use (see Figure 1) includes a four-bar linear ion trap in a precisely defined magnetic field shielded from disturbance by the ambient magnetic field. Mercury ions are created in the trap by a pulse of electrons onto a weak vapor of neutral mercury atoms. The basic operation of this and other atomic frequency standards is a comparison between (1) a stable reference frequency of the trapped ions acting as an atomic oscillator and (2) the frequency, multiplied by a known integer, of a local or "flywheel" oscillator that one seeks to standardize by making it resonate with the atomic oscillator.

The ions must be prepared for this comparison in a way that creates a difference between the populations of ions in the hyperfine levels of the ground state. This preparation is effected by optical pumping with ultraviolet light from a laser or a discharge lamp. After preparation, the laser or lamp is turned off and the ions are irradiated by a microwave pulse at the multiplied local-oscillator frequency. After the microwave pulse, the laser or lamp is turned on again and the intensity of fluorescent light emitted by the ions is measured to determine whether the microwave radiation has changed the population of the hyperfine levels: Any deviation of the multiplied frequency of the local oscillator from the reference atomic frequency changes the intensity of the fluorescent light measured when the laser or lamp is turned on. These changes are converted to a voltage that is fed back to the frequency-control port of the local oscillator to keep it tuned to the reference atomic frequency.

The physical basis for the improved design lies in the observation that ions can be moved along the axis of the trap by use of applied dc voltages. This makes it possible to separate the state-preparation/fluorescence-interrogation region from the more critical microwave-resonance region. The separation would make it feasible to relax some of the constraints on the designs of present units. For example, the microwave-resonance region could be designed with no consideration of optical issues. A simple set of cylindrical shields and solenoid could supply a very nearly uniform and stable magnetic environment; in the proposed configuration shown in Figure 2, the volume of the microwave-resonance region would be about a hundredth of that of present units because the diameter of the magnetic shields would be about a tenth that of present units. Inasmuch as the temperature of the apparatus must be regulated and the temperature of the microwave-resonance region must be regulated most strictly, the reduction in size could simplify the problem of thermal control.

Similarly, the optical state-preparation/interrogation region could be designed without concern for magnetic fields that could perturb the microwave/atomic resonance. In practice, this means that the optical components would no longer be required to be nonmagnetic as in the previous design and that as a

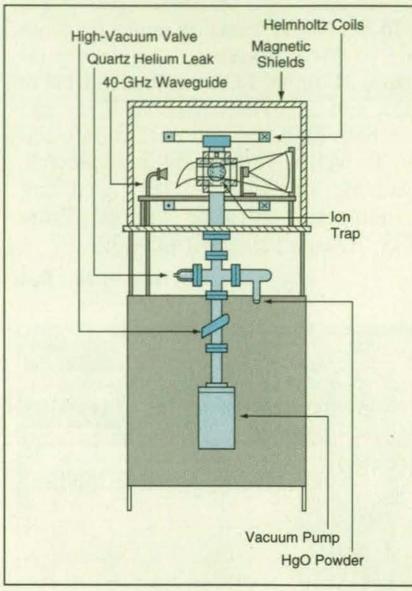


Figure 1. In the **Present Frequency-Standard Apparatus**, $^{199}Hg^{+}$ ions are prepared in the appropriate quantum-state populations, exposed to microwaves from a local oscillator, and interrogated optically for deviation of the microwaves from resonance with a hyperfine transition of the ions. All processing of ions takes place in the same volume in a linear ion trap in an applied magnetic field in a magnetically shielded housing. The apparatus is about 2 m high by 1 m on a side.

consequence, cheaper and smaller optical components and associated hardware could be used. Relaxation of the requirement of nonmagnetism in this region would also simplify the design of the electron gun and its power supply because of reduction in concern about suppressing stray magnetic fields generated by filament supply currents.

Finally, the largest shift in frequency and the potential instability could be reduced greatly by selecting a somewhat greater trapping length in the resonance region. The shift in frequency stems from the nonzero diameter of the ion cloud: ions spend time in regions of large radio-frequency trapping fields, where their motions result in frequency pulling via the second-order Doppler or relativistic time-dilatation effect. The magnitude of this shift is proportional to the linear ion density; that is, the number of ions per unit length. An increase in the resonance trapping length to about 200 mm would reduce, to about a fourth of the present value, the sensitivity of the apparatus to variations in the number of ions.

This work was done by John D. Prestage of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 15*** *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 20]. Refer to NPO-19081.

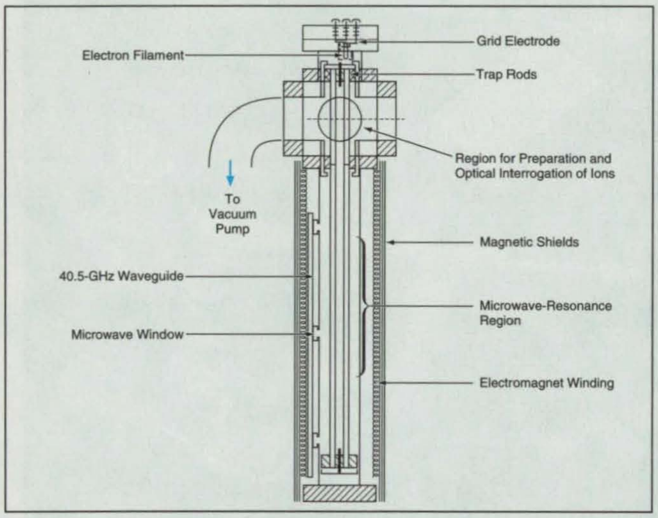


Figure 2. The **Proposed Frequency-Standard Apparatus** would contain a lengthened linear ion trap, and ions would be processed alternately in two regions: the ions would be prepared in the upper region of the trap, then transported to the lower region for exposure to the microwave radiation, then returned to the upper region for optical interrogation. The overall dimensions of the apparatus would be about 10 by 50 cm.

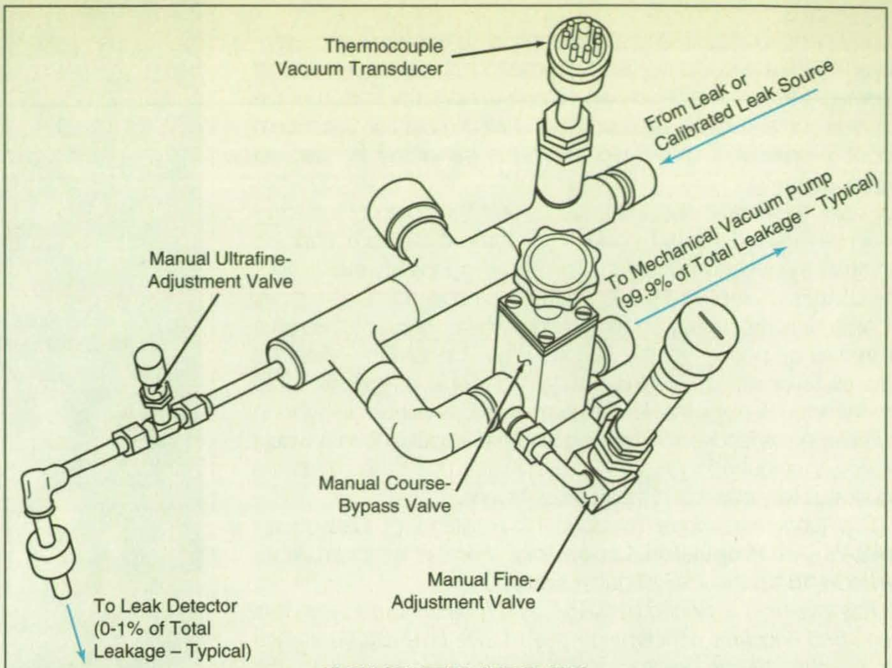
Flow Splitter for Measuring Large Leaks

The range of a sensitive leak detector is extended.

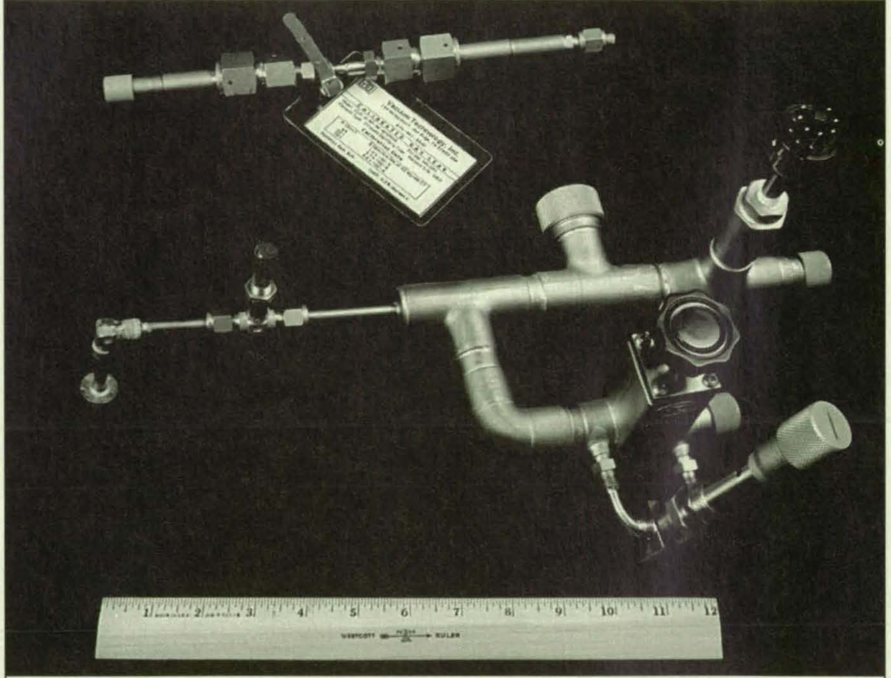
Lyndon B. Johnson Space Center, Houston, Texas

A flow splitter increases the size of a leak that can be measured by a helium mass-spectrometer leak detector. Ordinarily, such a leak detector can measure leakage of helium at rates no greater than 1×10^{-5} standard cm^3/s. The flow splitter multiplies the maximum measurable rate of leakage by a factor of 1,000.

The flow splitter is a manifold that can be adjusted to send only a small portion of the flow — typically 0.1 percent — to the leak detector. The manifold (see figure) contains three valves and a



FLOW SPLITTER AND FLOWS



FLOW SPLITTER AND CALIBRATED LEAK SOURCE

Leaking Gas Flows into the manifold, where a small fraction of the flow is diverted to a leak detector. The bulk of the flow — typically 99.9 percent — is removed by the mechanical vacuum pump.

thermocouple vacuum transducer. It includes compression O-ring fittings that provide for quick attachment to the source of the leak, the leak detector, and a large-capacity mechanical vacuum pump.

The setup is calibrated prior to measurement of a leak. First, a multirate calibrated leak source is connected to the manifold in place of the source that contains the leak to be measured. A technician adjusts the valves to make the desired fraction of total flow register on the leak detector. Then by use of all the calibrated rates of the calibrated leak source, the technician creates a calibration error curve. Typically, the curve is nearly linear. A leak of unknown size within the range of this curve can be quantified.

Maintaining the same valve settings, the technician then replaces the calibrated source with the true source that contains the leak to be measured. The rate of leakage is determined by relating the leak-detector reading to the calibration curve. The vacuum transducer monitors manifold pressure.

This work was done by William S. Hyatt of Ball Corp. for **Johnson Space Center**. *No further documentation is available.*
MSC-22042

Pulsed-Microwave Electrothermal Thrustors

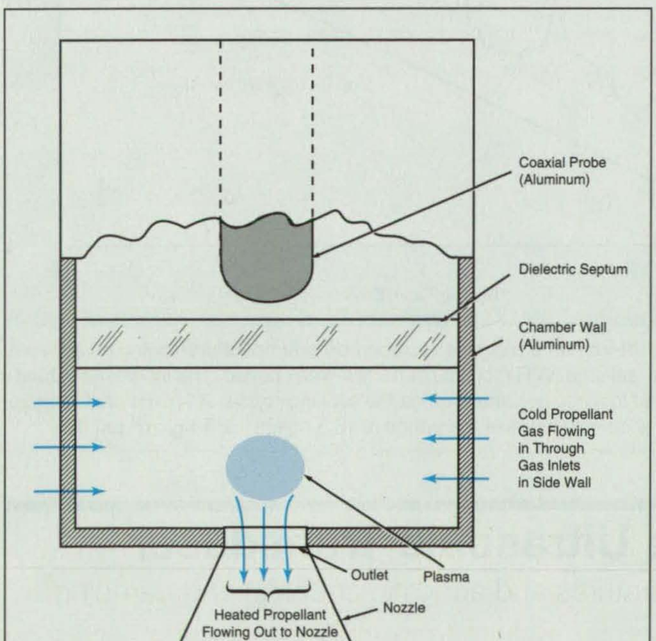
Pulsed operation is expected to suppress instabilities seen in continuous operation.

NASA's Jet Propulsion Laboratory, Pasadena, California

Pulsed-microwave electrothermal thrustors are being investigated as alternatives to continuous-microwave electrothermal thrustors. (An electrothermal thrustor is a device in which a propellant gas is heated electrically in a chamber, causing it to expand and flow out of the chamber through a nozzle to create thrust.) Although the pulsed-microwave electrothermal thrustors were originally intended for use in spacecraft propulsion systems, they may also prove useful on Earth in some material-processing and manufacturing applications.

The design of a microwave-heated electrothermal thrustor involves, among other things, a choice of microwave frequency and dimensions of the chamber (regarded as a waveguide or resonant cavity) to support a specified electromagnetic mode in which the microwave electrical field is concentrated in a region away from the walls. The microwave power supplied to the chamber must be sufficient to initiate and sustain an electric discharge in the propellant gas in this region. Cold propellant gas that flows across the discharge plasma is heated by a combination of conduction, diffusion, radiation, and convection. Placement of the discharge away from the walls reduces the loss of heat and erosion of the walls.

In experiments in which microwave power was supplied to the chambers continuously, the discharges exhibited instability in that they tended to move toward the microwave power sources. This phenomenon gave rise to the present concept of using pulsed instead of continuous microwave power: after each short heating pulse, the discharge is extinguished and thereby prevented from moving a significant distance toward the microwave power source. Any ionized gas remaining upstream after the pulse would be swept back downstream,



Pulsed Microwave Power, delivered via the coaxial probe, would be focused in a region near the outlet, where it would heat the propellant gas and form a plasma. Pulsing would suppress the tendency of the plasma to move upstream toward the probe.

into and through the discharge region, by the flow of cold propellant gas.

The figure illustrates part of a conceptual cylindrical pulsed-microwave electrothermal heater similar to one that is being used in experiments to test the feasibility of the concept. Microwave power would be supplied to the chamber by a coaxial probe. The probe and cavity would be designed to support the TM_{011} mode, which features two maximums of the electromagnetic field on the cylindrical axis: one in the vicinity of the probe and one at the lower end of the chamber, just above the outlet to the nozzle. By use of a dielectric (e.g., quartz) septum, the propellant gas could be kept away from the probe, thus allowing the discharge to occur only at the desired position near the outlet.

This work was done by Juergen Mueller and Joel C. Sercel of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 78*** *on the TSP Request Card.*
NPO-18766

A Real-Time Nonvolatile Residue (NVR) Monitor

Preliminary measurements confirm expectations.

John F. Kennedy Space Center, Florida

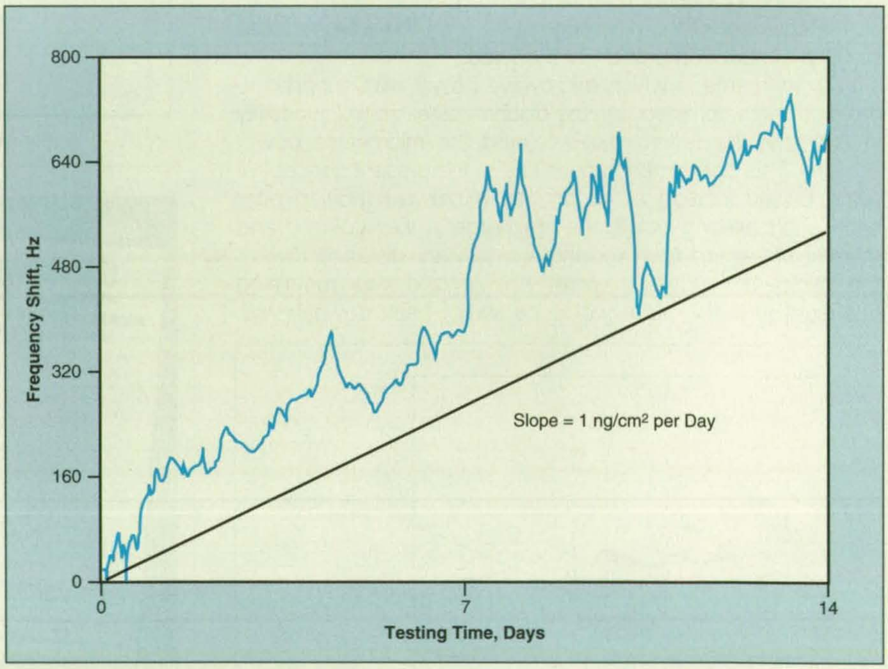
This work is a new development and application of the device described in "Surface-Acoustic-Wave Piezoelectric Microbalance," NASA Tech Briefs, Vol. 17, No. 4 (April, 1993), page 42. The active sensing element of the Real-Time NVR Monitor comprises a pair of piezoelectric surface-acoustic-wave resonators that resonate at a frequency of 200 MHz. A bare, uncoated resonator is exposed to the atmosphere and directly in contact with airborne volatile and nonvolatile materials that leave residues on its surface. The resonant frequency of the exposed resonator decreases with increasing mass of adsorbed residue; the resulting beat frequency between the two resonators increases with the mass and thus serves as a sensitive real-time indication of airborne contaminants or nonvolatile residue. A two-week test of a prototype instrument inside a Kennedy Space Center clean room confirmed that the device performed well and according to design calculations. A gradual increase in the beat-frequency shift with superimposed fluctuations was observed (see figure). The gradual monotonic increase in signal was attributed to the accumulation of background nonvolatile residues, whereas the fluctuations were attributed to a combination of (1) variations in the levels of both volatile and nonvolatile contaminants correlated with daily work schedules, and (2) adsorption and desorption of the volatile contaminants.

This work was done by William D. Bowers and Raymond L. Chuan of Femtometrics for **Kennedy Space Center**. *No further documentation is available.*

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

Dr. W. D. Bowers
Femtometrics
1001 W. 17th St. Suite R
Costa Mesa, CA 92627

Refer to KSC-11614, volume and number of this NASA Tech Briefs issue, and the page number.



This **Beat-Frequency Shift-vs.-Time** plot was recorded on a temperature-controlled surface-acoustic-wave-resonator real-time NVR monitor over a two-week period. The increases in beat-frequency shift correspond to mass accumulation on the sensing crystal. A 100-Hz shift is equal to 2 ng/cm^2. Total mass accumulation over the period is 15.3 ng/cm^2 or 1 ng/cm^2 per day.

Broadband, High-Temperature Ultrasonic Transducer

Materials are chosen for endurance at high temperatures and acoustic coupling and damping.

Langley Research Center, Hampton, Virginia

An acoustic transducer is designed to exhibit broad frequency response and to survive temperatures close to the melting points of brazing alloys. It can be attached directly and continuously to a hot object to be monitored ultrasonically: for example, it can be attached to a relatively cool spot on a workpiece during brazing for taking ultrasonic quality-control measurements.

The transducer is a layered structure based on a piezoelectric layer of lithium niobate. A 1000-Å layer of platinum is deposited on one surface of the piezoelectric layer. Brazing alloy is melted onto a layer of copper 1/16 in. (about 1.6 mm) thick, which serves as a substrate and an acoustic-coupling material. The brazing-alloy-coated copper is polished flat.

A shim of brazing alloy is placed between the platinum-coated surface of the lithium niobate and the polished brazing-alloy-coated copper, and then the copper is brazed to the platinum. Bumps of brazing alloy are applied to the copper at various positions near the lithium niobate to provide for subsequent attachment of the ground braid (shield) of a coaxial cable and of a cover to hold the assembly together. After brazing, the exposed face of the copper is repolished flat.

On the face of the lithium niobate opposite the platinum-coated face, the following layers are added: graphite foil; a flat, parallel electrode plate with a coaxial lead; and an electrical insulator. Optionally, a ceramic frame can be placed around the assembly to insulate the layers electrically and hold them in place. The ground braid of the coaxial cable is then spot-welded to the brazing-alloy bumps.

The polished copper layer is left exposed and is pressed directly against the object to be monitored ultrasonically. Copper was selected as the acoustic-coupling material because its thermal expansion nearly equals that of lithium niobate; this minimizes differential-thermal-expansion stresses that could otherwise be large enough to crack the transducer during heating or cooling. In addition, the acoustic impedance of copper lies midway between those of lithium niobate and steel (a typical object to be monitored could be made of steel) so that it couples acoustic signals between the two materials with minimum loss.

The graphite-foil layer helps to distribute the coupling pressure evenly over the lithium niobate. The graphite is soft and electrically conductive and withstands high and low temperatures. The braze between the copper and the platinum coat on the lithium niobate gives rise to sufficient damping to provide the desired broadband frequency response.

This work was done by F. Raymond Parker, William P. Winfree, and Danny A. Barrows of **Langley Research Center**. *For further information,* ***write in 38*** *on the TSP Request Card.* *LAR-14615*

Higher-Sensitivity Ionization Trace-Species Detector

The electron source and electron optics are modified to increase output.

NASA's Jet Propulsion Laboratory, Pasadena, California

The electron source and electron optics of a reversal electron-attachment detector have been modified to increase its sensitivity. The original version of this apparatus was described in "High-Sensitivity Ionization Trace-Species Detector" (NPO-17596), NASA Tech Briefs, Vol. 14, No. 2 (February 1990) page 38. The apparatus is used to detect molecules of a particular chemical species of interest (e.g., narcotics, explosives, or organic wastes) that may be present in the air at low concentrations, and which are known to attach extremely low-energy electrons. The apparatus does this by ionizing molecules from the sampled atmosphere, then detecting the ions of the species of interest.

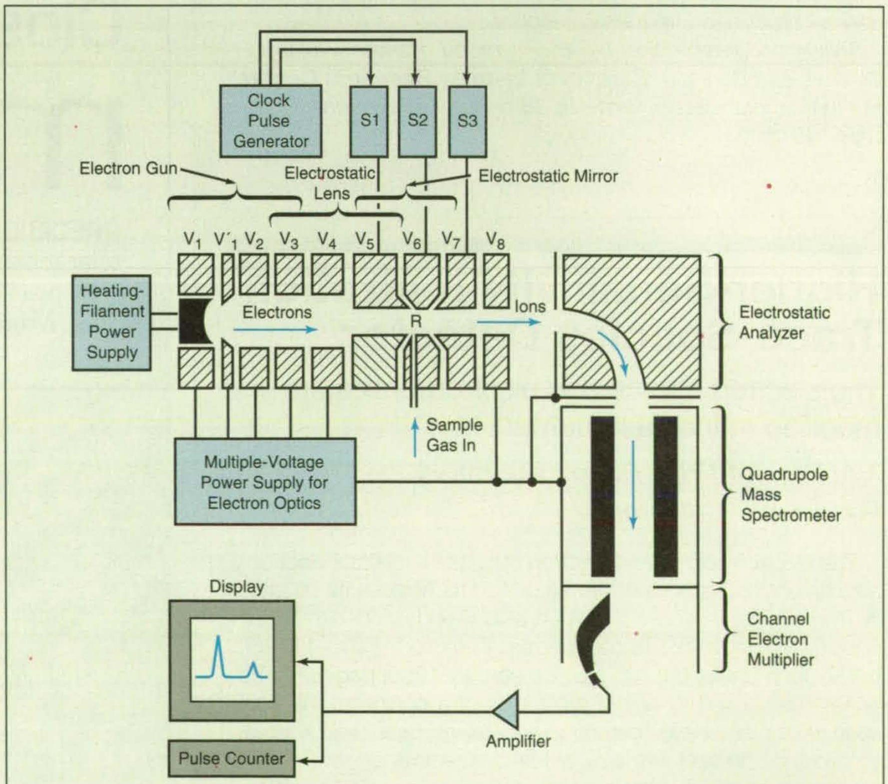
Like the original version of the apparatus, the modified reversal electron-attachment detector (see figure) includes a cathode at electrostatic potential V_1 that is heated to emit electrons, plus a number of other electrodes at various electrostatic potentials. Together, these other electrodes act as an electron-optical system that extracts electrons from the cathode, then accelerates and focuses the electrons into an electrostatic mirror, wherein the electrons are decelerated to zero longitudinal velocity and nearly zero radial velocity at reversal plane *R*. A small sample of the atmosphere to be tested is injected into the vacuum of the apparatus at *R*. The kinetic energy of the electrons at *R* is low enough that some electrons become attached to the molecules of interest, forming either parent negative ions, and/or fragment ions through dissociative attachment.

The voltages V_5, V_6, and V_7 on the electrodes of the electrostatic mirror are square-wave modulated by electronic switches S1, S2, and S3 in such a way that during the first half of the modulation cycle, the electron beam is brought to *R* to ionize the molecules in a field-free region, then during the second half of the cycle, the negative ions are extracted. The extracted ions are deflected by a 90° electrostatic analyzer (which helps to ensure that only negative ions pass through) and focused into a quadrupole mass spectrometer. The ion signal of the mass spectrometer is produced by a channel electron multiplier, amplified, and fed to a pulse counter and a multichannel analyzer.

The electron emitter in the original version of the apparatus was planar. The emitter in the modified apparatus is an indirectly heated spherical cathode, which has a larger emission area and therefore emits a larger electron current than did the planar cathode. Because of the larger current, the electrode system had to be redesigned: this was done with the help of a computer program written specifically to analyze electrostatic fields and trajectories of electrons in those fields, including the effects of space charge. The apparatus was tested to determine its sensitivity in the detection of small amounts of known molecules carried in nitrogen gas. For example, in the case of 10 parts per trillion of carbon tetrachloride in nitrogen, the modified apparatus put out a signal about 25 times that of the original version.

This work was done by Said Boumsellek and Ara Chutjian of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 83*** *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 20]. Refer to NPO-*18870.



The **Modified Reversal Electron-Attachment Detector** features an indirectly heated spherical cathode and redesigned electron optics that, together, deliver more electrons at low kinetic energy to the reversal plane, *R*. The greater electron current generates more ions for detection.

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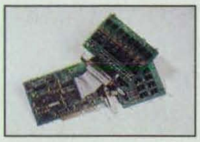
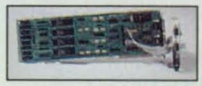


NEW DIGITAL I/O INTERFACES UNIQUE TO PC PLUG-IN DATA ACQUISITION AREA

OMEGA's new **OMD-5600** Series digital input/output (I/O) boards are unique. The design simplifies signal connections and eliminates costs associated with external signal conditioners, cables and power supplies. Models are available with up to 32 I/O lines and support a variety of input and output voltage levels. Priced from $295. For more information, contact OMEGA Engineering, Inc.; or request **OMEGAfax℠ Document #6260** by calling 800-848-4271 from any Touch-Tone phone.

For More Information Write In No. 301



ISOLATED TWO/FOUR SERIAL PORT I/O WITH EXTENDED AT INTERRUPTS

OMEGA's new **OMG-ISO-COMM** boards have two or four isolated RS-422/485/232 ports with extended AT interrupts for DOS and Windows software. Based on the 16550 UART, these boards provide two or four serial ports each with 500 V of electrical isolation. For more information on this new product, contact OMEGA Engineering, Inc.; or use our **OMEGAfax℠** service to request **Document #6292** by calling 800-848-4271 from any Touch-Tone phone.

OMEGA Engineering, Inc.

For More Information Write In No. 302

NEW ULTRA-HIGH PERFORMANCE DATA ACQUISITION BOARD

OMEGA's new **WIN-30D** board is an ultra-high performance multifunction analog and digital input/output board designed for PC-AT compatible computers. The WIN-30D offers full 1 MHZ throughput using advanced technology, including data packing and a choice of DMA, 1-bit rep string operation or 32-bit rep string operation for the ultimate in performance. Contact OMEGA Engineering, Inc.; or use our **OMEGAfax℠** service to request **Document #6266** by calling 800-848-4271 from any Touch-Tone phone.

OMEGA Engineering, Inc.

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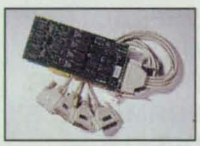

FOUR-CHANNEL ASYNCHRONOUS SERIAL COMMUNICATION CARD

OMEGA brings you the **OMG-VERSA-COMM4** RS232 serial communication card for IBM PC/XT/AT and compatibles. Based on the 16550 FIFO-buffered UART, this card is compatible with the IBM asynchronous serial adapter. It also provides an enhanced mode to support maximum data transmission rates. Contact OMEGA Engineering, Inc.; or use our **OMEGAfax℠** service to request **Document #6300** by calling 800-848-4271 from any Touch-Tone phone.

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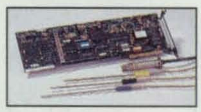


UNIVERSAL INPUT PLUG-IN CARD FOR DATA ACQUISITION AND CONTROL

OMEGA's new **UPC-600** Series plug-in cards for the IBM PC/XT/AT and compatible computers support sample rates up to 20,000 samples per second with 14-bit resolution. UPC-600 series plug-in cards accept up to 16 analog sensor inputs directly without any external signal conditioning. Thermocouples, RTD's, potentiometers, thermistors, strain gages, and LVDTs may be wired directly to the card. Contact OMEGA Engineering, Inc.; or use our **OMEGAfax℠** service to request **Document #6256** by calling 800-848-4271 from any Touch-Tone phone.

OMEGA Engineering, Inc.

For More Information Write In No. 305

HIGHLY ACCURATE TEMPSCAN... HIGH-SPEED TEMPERATURE AND PROCESS MONITORING

OMEGA's new **OMB-TEMPSCAN-1000** monitoring system for temperature and other process sensors can monitor up to 992 channels at rates as high as 960 samples per second with 16-bit resolution. This is the first 32-channel monitor under $2000. Contact OMEGA Engineering, Inc.; or use our **OMEGAfax℠** service to request **Document #6255** by calling 800-848-4271 from any Touch-Tone phone.

OMEGA Engineering, Inc.

For More Information Write In No. 306

OMB-MULTI-SCAN-1200 HIGH SPEED ISOLATED TEMPERATURE/ VOLTAGE INTERFACE

The unit features channel-to-channel isolation for temperature and voltage measurements. Its high speed scan rate allows the operator to scan inputs at a rate of 147 channels per second. System expansion up to 744 channels is available. On-board memory storage of 256 kBytes is standard and is expandable up to 8 MBytes. Contact OMEGA Engineering Inc., or use our **OMEGAfax℠** service to request **Document #6321** by calling 800-848-4271.

OMEGA Engineering, Inc.

For More Information Write In No. 307

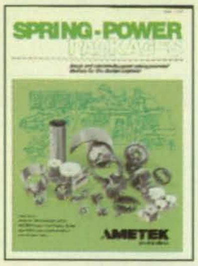
HIGH-SPEED DATA ACQUISITION SYSTEM FOR NOTEBOOK AND DESKTOP PCS

OMEGA's new **OMB-DAQBOOK-100** system provides high-speed multi-function data acquisition capability for portable test applications. Features include: 16 analog inputs, expandable to 256; 2 analog outputs; 24 general-purpose I/O channels, expandable to 192; 16 high-speed digital inputs; and 5 frequency/pulse I/O channels. Contact OMEGA Engineering, Inc.; or use our **OMEGAfax℠** service to request **Document #6256** by calling 800-848-4271 from any Touch-Tone phone.

OMEGA Engineering, Inc.

For More Information Write In No. 308

Design Engineering Product Showcase



SPRING POWER DESIGN LITERATURE

Ametek Hunter Spring Bulletin FS-201 provides complete descriptive and technical data for broad line of stock and custom spring powered devices. Product information covers SPIR'ATOR prestressed spiral springs. NEG'ATOR constant force extension springs and spring motors, as well as other power spring packages and stock mechanical reels. Tel: 215-257-6531; Fax: 215-257-4711.

AMETEK U.S. Gauge Division

For More Information Write In No. 310

The NEC vibration isolators effectively remove turbomolecular and cryopump vibrations. Two models are available in elastomer and air isolated versions. They are UHV compatible, have short insertion lengths and high conductance. A wide variety of flanges are available.

National Electrostatics Corp.

For More Information Write In No. 311

'SMART' HIGH-POWERED ACTUATORS

Get fast-acting, high-force actuators driven by ETREMA TERFENOL-D®, the magnetic shape change metal with the highest strain of any commercial transducer material. ETREMA offers standard and custom actuators, TERFENOL-D materials, and complete custom design and manufacture. Call 800-327-7291 for applications assistance. ETREMA Products Inc., 2500 North Loop Drive, Ames, IA 50010; Tel: 515-296-8030; Fax: 515-296-7168.

ETREMA Products Inc.

For More Information Write In No. 312

FREE CATALOG "OPTICS FOR INDUSTRY"

Free 130 page catalog from Rolyn, world's largest supplier of "Off-the-Shelf" optics. 24-hour delivery of simple or compound lenses, filters, prisms, mirrors, beamsplitters, reticles, objectives, eyepieces, plus thousands of other stock items. At off-the-shelf prices. Rolyn also supplies custom products and coatings in prototype or production quantities.

Rolyn Optics

706 Arrow Grand Circle, Covina, CA 91722-2199
Tel: 818-915-5707; Fax: 818-915-1379.

For More Information Write In No. 313

PROGRAMMABLE FIBER OPTIC BEAM SENSOR

Brochure on the new SUNX FX7 fiber optic beam sensor which offers high sensitivity at the touch of a button. Setting the sensitivity is a 2-step process: press the "on" button when the object to be sensed is present; press the "off" button when the object is absent. The DIN railmount amplifier requires 12 to 24 Vdc and has an NPN open collector output with a response time of 0.5 msec. Tel: 800-280-6933; Fax: 515-225-0063.

SUNX Sensors

For More Information Write In No. 314

CUSTOM ELECTRO-FORMS

Rugged, light weight electroforms can be used down to -423 °F or up to 1000 °F. Diameters from 0.030" - 8" with wall thicknesses from 0.0003" to 0.025" can be supplied. Can be made an integral unit with a bellows, eliminating welding or soldering. Servometer Corporation, 501 Little Falls Rd., Cedar Grove, NJ 07009-1291; Tel: 201-785-4630; Fax: 800-785-0756; Fax (outside USA): 201-785-0756.

Servometer Corporation

For More Information Write In No. 315

DE-STA-CO

The World of Clamping Catalog 894 describes and illustrates toggle and special clamps with vertical and horizontal hold-down, straightline, latch, and squeeze action. Spacing products, hydraulic devices, and CAD database are covered along with applications. De-Sta-Co, Box 2800, Troy, MI 48007; Tel: 810-589-2008; 800-245-2759.

De-Sta-Co

For More Information Write In No. 316

REFRACTORY METALS DELIVER PERFORMANCE BY DESIGN

Climax Specialty Metals is the world's largest totally integrated source for molybdenum, from the mine to fabricated products. We make molybdenum billets, forging bar, rod, plate, sheet, foil, and extrusions, plus molybdenum powder for powder metallurgy spray applications. Also available are tungsten products, clad-metal systems, and machined and stamped components. Tel: 216-692-3007; Fax: 216-692-0029.

Climax Specialty Metals

For More Information Write In No. 317

STROBOSCOPES, TACHOMETERS & PAPERLESS RECORDERS

Portable/Machine Stroboscopes 1-32,500 FPM, Phase Shifting/internal rechargeable batteries/mains. Portable/Panel Tachometers/Counters/Timers. Optical, Laser, Infrared, Proximity, Magnetic Sensors. 1-999,999 RPM, Outputs & Alarms. DataChart® one/two channel Paperless Recorder. Graphics/Digital/Date/Time on high resolution LCD and PC Compatible Memory Card.

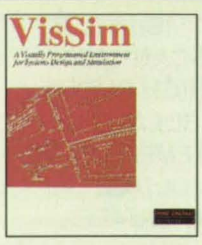
Monarch Instrument

For More Information Write In No. 318

COMPACT ULTRASONIC THICKNESS GAUGE

The T-Mike ES brings the latest technological dimension to StressTel's product line. Features: High Speed Scanning; LED Alarm lights; Differential Function; Data Send; amber colored aircraft-style display; Auto Probe Zero; Size is 2.5" X 4.5" X 1.25"; weighs 11 oz. with batteries; extended battery life; and 2 year warranty. StressTel offers a complete line of ultrasonic nondestructive testing equipment. Tel: 408-438-6300; Fax: 408-438-7917.

For More Information Write In No. 319

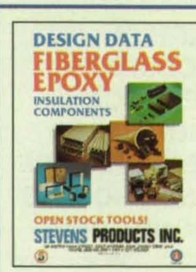


QUIT GUESSING, SIMULATE IT WITH VisSim™

VisSim is the ideal environment for nonlinear dynamic simulation. The highly interactive visual Windows™ interface lets you develop complex models and test new ideas quickly and easily without writing a line of code. Call: 508-392-0100; Fax: 508-692-3102. FREE WORKING DEMO. Visual Solutions, Inc., 487 Groton Rd., Westford, MA 01886.

Visual Solutions, Inc.

For More Information Write In No. 320

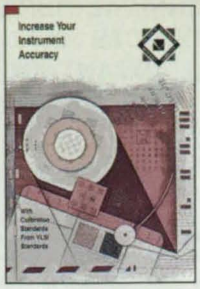


FIBERGLASS LAMINATED EPOXY 155 °C

Design Data pamphlet featured materials, properties, and tolerances for glass epoxy components. It shows designers how to specify from open stock tools, for potting forms, bobbins, coil forms, structurals, and circuit board manufacturing aids. Stevens Products, Inc., 128 N. Park St., E. Orange, NJ 07019. Tel: 201-672-2140.

Stevens Products, Inc.

For More Information Write In No. 321



CALIBRATION STANDARDS CATALOG

Free 1995 catalog of metrology calibration standards for surface contamination, critical dimensions, film thickness, surface profiling, characterization and more. Important for ISO 9000 certification. From VLSI Standards, 3087 North First St., San Jose, CA 95134; Tel: 408-428-1800; Fax: 408-428-9555.

VLSI Standards

For More Information Write In No. 322

MINIATURE STROKE BALL BEARINGS

- Compact bearings with high accuracy that can achieve rolling motion and reciprocating motion at the same time.
- Can obtain stable performance through long time operation without stick slip.
- Suitable for the equipments of very high accuracy and/or compact parts.

IKO International Inc.

For More Information Write In No. 323

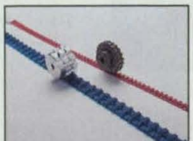
MINIATURE LINEAR WAYS

- Evolution of linear way.
- Steel balls are securely retained.
- Slide units can be separated from the rail freely.
- Installation and assembly on the equipment are easy.
- Trouble-free is achieved.

IKO International Inc.

For More Information Write In No. 324

PIC BELTS AND PULLEYS... THE MOST COMPLETE LINE



PIC Design now offers a complete line of belts and pulleys for precision positioning and light power transmission. PIC No-Slip™ Series features backlash-free operation, while No-Slide™ belts are ideal for space-saving designs. Other belts are available for almost any range of applications. PIC Design; Tel: 800-243-6125; or 203-758-8272; Fax: 203-758-8271.

PIC Design

For More Information Write In No. 325

PRECISION LINEAR SLIDE

- Superior corrosion resistance: stainless steel made.
- Lightweight and compact.
- Smooth and quite motion.
- High accuracy and stable performance.
- Contaminant-free quality control.
- High safety.

IKO International Inc.

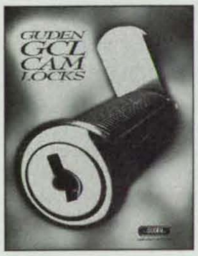
For More Information Write In No. 326

STAINLESS LINEAR WAY

- Excellent corrosion resistance.
- Large load capacity in any direction.
- Excellent strength under moment load and complex load.
- High accuracy with simple structure.
- High rigidity and good absorption of vibration.

IKO International Inc.

For More Information Write In No. 327



GCL CAM AND DRAW LOCKS

New Brochure presents Guden's complete line of GCL Cam and Drawer Locks to complement their hinge, latch, handle and gas spring products. Full variety of stock items ready for immediate shipment, plus customized locks. Guden is celebrating their 75th Anniversary, and is now certified by UL to ISO 9002. H.A. Guden Co., Inc., 99 Raynor Ave., Ronkonkoma, NY 11779; Tel: 800-344-6437; 516-737-2900; Fax: 516-737-2933.

H.A. Guden Co., Inc.

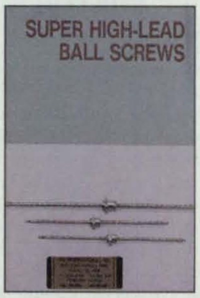
For More Information Write In No. 328

STAINLESS CROSSED ROLLER WAY

- Superior corrosion resistance/stainless steel made.
- Extremely high accuracy.
- Very smooth operation.
- Easy mounting.

IKO International Inc.

For More Information Write In No. 329



SUPER HIGH-LEAD BALL SCREWS

- Three-start thread grooves for well-balanced movement.
- Newly developed end cap recirculating system provides smooth movement.
- Hardened end cap ensures long life.
- Low rotary speed results low level vibration, noise, heat generation on high linear speed.

IKO International Inc.

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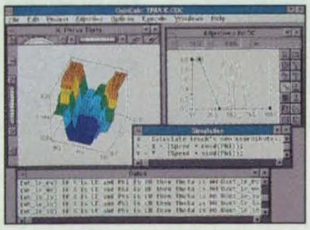


FUZZY LOGIC TOOLS

Apply fuzzy logic interactively with CubiCalc's built-in simulation language, plots, file I/O and other features. Or use CubiCard's integrated data acquisition board and drive external hardware directly.

HyperLogic Corporation

Tel: 619-746-2765; Fax: 619-746-4089.

For More Information Write In No. 331

CROSSED ROLLER BEARING: HIGH RIGIDITY TYPE

- The inner and outer rings of this bearing are one piece construction (non-separate type) respectively.
- Widely used in applications requiring high rigidity, high rotation accuracy and compact size such as industrial robots, rotational tables of machine tools/medical equipment.

IKO International Inc.

For More Information Write In No. 332

NEEDLE ROLLER CAGES FOR ENGINE CONNECTING RODS

- High performance needle bearing for challenging engine applications.
- High rigidity.
- High load capacity.
- High rotational speed.
- The bearing cage has high rigidity because of a special section shape resembling that of a gantry gate.

IKO International Inc.

For More Information Write In No. 333

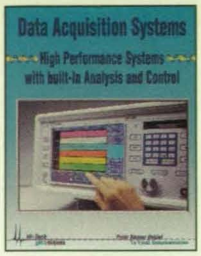
Design Engineering Product Showcase

PRECISION CROSSED ROLLER STAGES

ALM features **NEW** motor ready linear positioning stages featuring our **MADE IN USA**, Precision Crossed Roller Linear Bearings. **ALM** stages are characterized by smooth, noiseless, repeatable, frictionless motion, minimal torque requirements, torsional stiffness, long life and zero sideplay in any attitude. Wide range of actuator options available. Expert applications engineering staff. Tel: 800-892-3991; 516-338-5741; Fax: 516-333-1729.

American Linear Manufacturers

For More Information Write In No. 334



High Speed DATA ACQUISITION SYSTEMS are designed to meet exacting measurement requirements. Components feature fast throughput and highly accurate digitizers (overall 0.1% accuracy with 100 ksps to 200 Msps, and 32 Megapoints/channel). Automatic setups, analysis and touch screen controls in PC-based software add excellent user interfaces for high speed dynamic measurements in the physical and material sciences. Booth number at Design Engineering Show: 320. Hi-Techniques, Inc., 152 Owen Road, Madison, WI 53716; Tel: 608-221-7500; 800-248-1633.

Hi-Techniques, Inc.

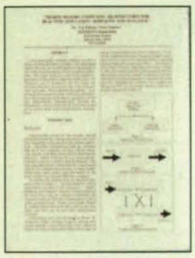
For More Information Write In No. 335

TECHNICAL FIBRE PRODUCTS MATERIAL ADVANTAGE

TFP is an Advanced Fiber Nonwoven Manufacturer that produces veils varying from 0.2-8.0 oz/yd^2 from virtually any fiber type. Examples are Carbon, Aramid, Quartz, Silcon Carbide, Metal-coated and Glass. TFP's accurate fiber blending technology can result in a hybrid, provide a specific resistivity level or utilize a thermoplastic fibre for molding. TFP also produces Intumescent mat for fire protection. Tel: 914-355-4190; Fax: 914-355-4192.

Technical Fibre Products Limited

For More Information Write In No. 336



SIMPLIFIED REAL-TIME NETWORK APPROACH

The SCRAMNet™ Network, a real-time communications system based on a replicated shared-memory concept, is optimized for the high-speed transfer of data among computers. Call for this **FREE** Technical Paper. SYSTRAN Corp., Sales Tel: 800-252-5601; Tel: 800-252-5601; Fax: 513-258-2729; E-mail: info@systran.com.

Systran Corp.

For More Information Write In No. 337

PROGRAMMABLE MULTI-AXIS CONTROLLER

SLO-SYN® MX2000 is a powerful modular, 32-bit DSP-based stand-alone motion/machine control for step or servo motors. Available as an enclosed 2-axis unit or up to 8-axis 19-inch rack systems. Uses BASIC language with math functions and provides multi-tasking up to 7 concurrent tasks. Provides for linear and circular interpolation plus splining. Up to 352 inputs and outputs separately scanned for control; Tel: 800-787-3532. Tel: 203-585-4500.

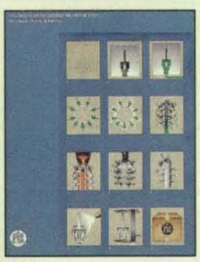
Superior Electric

For More Information Write In No. 338

Design software delivers NURBS-based surface modeling of mechanical parts. Easy to learn graphical interface with on-line help. Multi-tasking under Windows and Windows NT. Photo-realistic shading and fast dynamic graphics. Compatible with all CAD/CAM systems. Easy upgrade to NC programming.

Surfware Incorporated

For More Information Write In No. 339



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Our value-added services make our investment castings the total lower cost parts you need for many commercial & aerospace applications. Near net shape, close tolerances, excellent surface means less finishing for you. Nearly 200 ferrous and non-ferrous alloys include aluminum, ductile iron, steel, stainless, copper-based. Preproduction prototyping, engineering, and finishing services available. Parts up to 10 pounds are our specialty. Write for our new literature.

Precision Metalsmiths, Inc.

For More Information Write In No. 340

PCMCIA DESKTOP ADAPTORS

The PCMCIA standard is the newest technology in data storage and I/O for desktop and mobile computers. Now ENVOY DATA offers the most complete line of PCMCIA Databook adaptors (reader/writers) for your desktop computer. External models connect through the parallel port while internal models use an ISA interface card. All models read and write Types I, II, or III memory cards. Tel: 602-892-0954; Fax: 602-892-0029.

Envoy Data Corporation

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EQUIPMENT HOUSING HARDWARE

Small quantities/immediate shipment. Design Standards offers an international selection of operational hardware for control and access of equipment and machinery. Our knobs, handles, levers, handwheels, spring plungers, levelers and wheels possess superior production, functional and aesthetic qualities. **Design Standards**: a division of Rogan Corporation, 3455 Woodhead Dr., Northbrook, IL 60062. **Tel: 800-388-5656; Fax: 708-509-1705.**

Design Standards

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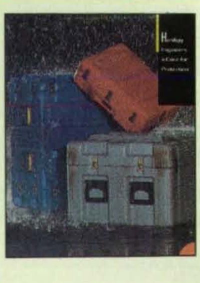

Hardigg Cases offers over 225 standard rotationally molded transit cases, including a full line of 19" EIA rack mount cases, deck cases, and flangemount cases. Hardigg's expert engineering, manufacturing, and test facilities provide start to finish custom design capability. A complete list of standard cases allows for rapid delivery...as few as three working days! Take advantage of over forty years of experience...design a Hardigg case into your next project!

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For More Information Write In No. 343

New DA95 catalog offers 288 different "ready to use" precision acme and precision ball screw drives. Screw drives come totally assembled with machined ends, precision end bearings and feature standard NEMA motor mounts and couplings. Complete linear slides featuring precision rail assemblies are offered in seven sizes with strokes to 135 inches. CAD files are available to speed designs. Contact: Greg Traeger, Sales Manager, Ball Screws & Actuators, San Jose, CA 95136. Tel: 800-882-8857.

Ball Screws & Actuators

For More Information Write In No. 344

NEW BOOK HELPS YOU USE FEA IN THE "REAL WORLD"

A comprehensive finite element analysis reference/textbook offers a unique blend of theory and real world engineering examples. Dr. Constantine Spyrakos—well-known finite element stress and vibration analysis expert—has created a reference for all mechanical engineers from designers to "gurus." This richly illustrated, hardcover book includes a disk with every example problem. Subjects include: FEA basics, element types, modeling, types of analysis and interpretation of results.

APD

For More Information Write In No. 345

Design Engineering Product Showcase

Parts Libraries - Computervision

Libraries of compiled macros for **CADDS 5 & CADDS 4X** create a wide variety of standard hardware items.

SOLIDS & WIREFRAME, INCH & METRIC

Programs will create all fastener holes • hex nuts • bolts all screws (soc. hd., slotted, phillips) • washers (flat, lock, spring) • pins (dowel, split, cotter, spiral) • retaining rings & grooves • structural beams (all) • pipe fittings • springs (compression, extension, torsion) • thread inserts & holes. 1000's of parts. Bill of Materials programs **automate** the process of tracking and creating BOMs, including **creation of graphic BOM table** and **part labels,** works without CADDS Data Extract. Full 30 day **DEMO available.**

□ Also available: **Layer Management System** - automates layer lists, layer changes to models, much, much more.

Design Solutions Software Co.
Glen Mills, PA 19342 (610) 358-4054

For More Information Write In No. 358

BORESCOPIC VIDEO SYSTEM MCV-8000 SERIES

The MCV-8000 borescopic video system couples any Machida borescope to a miniature high quality color camera to create the clearest images for review on a monitor screen. Designed to be portable, the MCV-8000 is a quick set-up unit that is fully protected in a rugged shock-mounted, shippable carrying case. The half-inch VHS record/playback unit with microphone, allows inspections to be easily recorded with narration. Tel: 800-431-5420.

Machida, Inc.

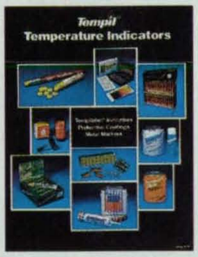
For More Information Write In No. 359

CATALOG OF ENGINEERING FINDINGS

352 pages of components, materials, and precision tools in hard-to-get small quantities. A single source for a wide variety of stainless steel items such as miniature gauge type 304 and 316 hypodermic tubing, luer fittings, guide wire, and miniature machine screws (000 and up); also PEEK, Tygon and Teflon tubing, Polyimide Rod, Steel, and Brass gears, phase adjusters, nitinol wire and noise and vibration isolators and sheet materials. For your free catalog, call: 800-422-2020; or Fax: 800-423-9009.

Small Parts, Inc.

For More Information Write In No. 360



TEMPERATURE INDICATORS AND MONITORS

This most extensive line of temperature indicating products includes sticks, label monitors, indicating liquids and pellets for pre-heat/post-heat welding. The 8-page catalog discusses hand test kits, metal markets and protective coatings. Applications cover welding, metal-working, electronics, nuclear and machinery. Tempil Division, Tel: 908-757-8300; Fax: 908-757-9273.

Air Liquide America Corp.

For More Information Write In No. 397

CLOCKS AND TIME CODE

(IRIG, NASA, XR3, SMPTE, ESE)

Generate, read or convert any of the above codes, display them on several sizes of L.E.D's, superimpose them on video, or interpret a code for your computer!

HERE'S ONE OF OUR MORE POPULAR IRIG B READERS

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56" L.E.D. Display Viewable at 20'

AVAILABLE WITH AN ASSORTMENT OF DISPLAY SIZES!

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142 Sierra St., El Segundo, CA 90245 USA

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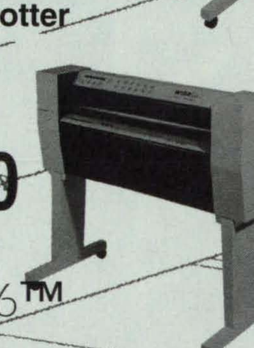

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Antisymmetric Layup of Precise Composite Laminates

Ply-orientation errors would be redistributed to cancel their effects.

NASA's Jet Propulsion Laboratory, Pasadena, California

Warping of precise composite-material (graphite-fiber/epoxy-matrix) laminated panels would be reduced, according to a proposal, by an improved combination of design and method of fabrication. The essence of the proposal is to stack the plies during fabrication in such a pattern that the effects of unavoidable ply-orientation errors in individual layers would cancel each other out, on the whole, in the final product.

The proposal emerged from a study of warping of composite-material laminated face sheets that are undergoing development for use as lightweight substrates for precise, curved mirrors in submillimeter-wave astronomical telescopes and optical communication systems. Fabrication of a typical laminated composite-material face sheet usually includes a layup of a number (usually 8 to 32) of plies of prepreg material (sheets of parallel fibers embedded in uncured or partially cured matrix material). During layup, the various plies are oriented with their fibers at various angles from a reference direction. Of course, the prepreg plies are resinous materials that are difficult to handle and align precisely.

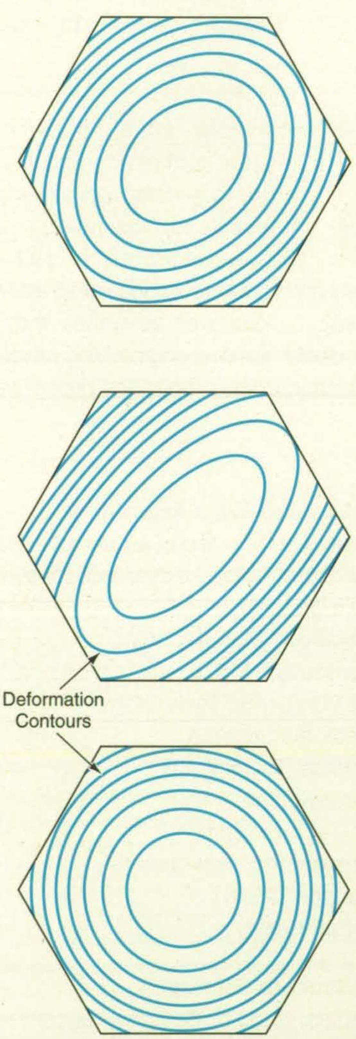
After layup, the face matrix material is cured — usually by heating. Experimental observations indicate that such face sheets tend to warp immediately after curing. In the case of a face sheet to be used as a mirror substrate, warps result in optical aberrations and in changes in curvature (which cause changes in focal lengths). In the study, experience and intuition led to the hypothesis that random ply-orientation errors constitute a major cause of warping. This hypothesis was tested by detailed finite-element mathematical modeling of a typical 12-ply face sheet, using the best available data on the properties of the matrix and fiber materials. It was found that the magnitudes of figure errors caused by random ply-orientation errors of a few tenths of a degree to a degree were comparable to those observed experimentally. Inasmuch as random ply-orientation errors of as much as 1° are expected to routinely occur during layup, it was therefore concluded that random ply-orientation errors can account for major parts of manufacturing errors.

The proposed method is not intended to accomplish the impossible task of eliminating these errors but, instead, to reduce or eliminate the net effects of these errors on the surface figures of the face sheets. The plies in a given panel would be laid up in such a way that even though random ply-orientation errors exist, these errors would be symmetrically placed about the mid-plane of the panel, so that the effects of these errors would tend to cancel each other.

To demonstrate the effectiveness of this method, a finite-element mathematical model was used to compute the deformations, under a uniform thermal load, of a 12-ply curved, hexagonal-outline mirror face sheet in which successive plies were nominally oriented at angles of [0°,60°,–60°,60°,0°,0°,60°,–60°,60°,0°]. The figure shows deformation contours predicted by the model. The top part of the figure shows the warp that occurs in the case of a 1° orientation error in the top ply. The middle part of the figure shows that the warp is approximately doubled when the same 1° orientation error exists in the top and bottom plies. The bottom part of the figure shows that the warp is essentially zero when 1° orientation errors occur in both plies but the errors are in opposite directions: as desired, the effects of the errors in the top and bottom plies have canceled each other.

The method could be implemented by a proposed layup procedure that would include folding to distribute the ply-orientation errors antisymmetrically about the mid-plane of a laminate. For a 12-ply laminate, one should stack the first three plies at the usual angles 0°, 60°, and –60°, but the length of each ply should be four times the width. The resulting elongated stack of three plies would be folded to produce a 6-ply laminate, then folded again to produce a 12-ply laminate. As a result of the folding, there would be two sets of three plies with opposite orientations of ply errors on both sides of the midplane, providing for cancellation of the effects of ply errors on the laminate as a whole.

This work was done by Donald Rapp, Michael C. Lou, and Chin-Po Kuo of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 63*** *on the TSP Request Card.* NPO-19162



Deformation Contours computed for a 12-ply hexagonal-outline curved mirror-substrate panel demonstrate the effectiveness of the method proposed for reduction of warp.

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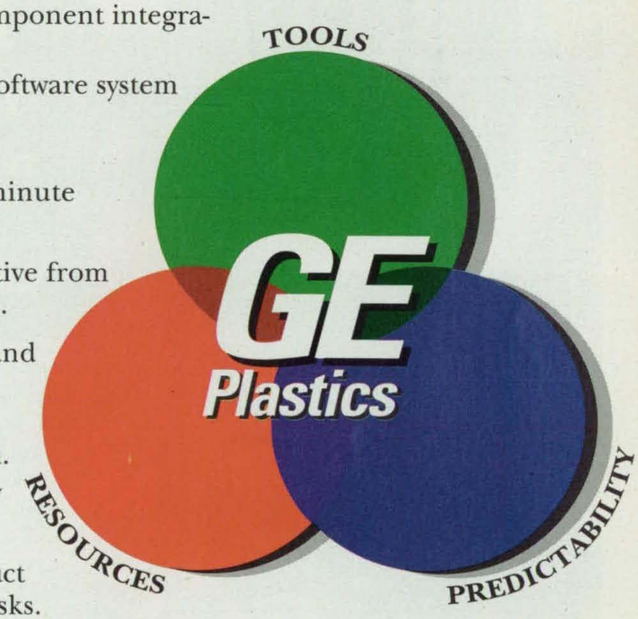

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Material Removes Heavy Metal Ions From Water

Unlike other ion-exchange resins, it can even remove metal ions from hard water.

Lewis Research Center, Cleveland, Ohio

A new high capacity ion-exchange polymer material has been shown, in laboratory tests, to remove toxic metal cations from contaminated water. This material offers several advantages. It has high sensitivities for such heavy metals as lead, cadmium, and copper and is capable of reducing their concentrations in aqueous solutions to the parts-per-billion range. Another important feature of the material is that, unlike many commercial ion-exchange materials (resins), it removes the cations even when calcium is present. The calcium present in water saturates the commercial resins, thereby blocking the adsorption of heavy metal ions. Thirdly, the material can be made into a variety of forms, such as thin films, coatings, pellets, and fibers. As a result, it can be adapted to many applications to purify contaminated water, which usually is hard wherever it is found, whether in wastewater-treatment systems, lakes, ponds, industrial plants, or homes.

The electroplating and mining industries, for example, produce large amounts of wastewater that contain hazardous amounts of mercury, lead, cadmium, silver, copper, and zinc ions. They are required by law to reduce the concentrations of these toxic metals in their wastewater before it is discharged into sewers, lakes, and streams. The technology that existed prior to the development of the high-capacity ion-exchange material appeared to be inadequate for meeting new, lower limits.

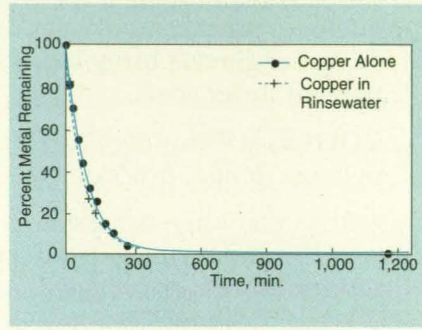


Figure 1. **Copper Is Adsorbed** in the ion-exchange polymer material at nearly equal rates from both a solution in which it appears alone and from rinsewater from a copper-electroplating process, in which it appears along with other elements.

Tests of the adsorption capacity of this material were conducted on laboratory samples of aqueous solutions, each contaminated with only one of the following ions: lead, copper, mercury, cadmium, silver, chromium(III), nickel, zinc, yttrium, and mercury, without calcium. Two solutions — one containing copper and one containing lead — also contained calcium. Tests were also conducted with samples of rinse water, obtained from an electroplater, that contained a mixture of heavy-metal ions

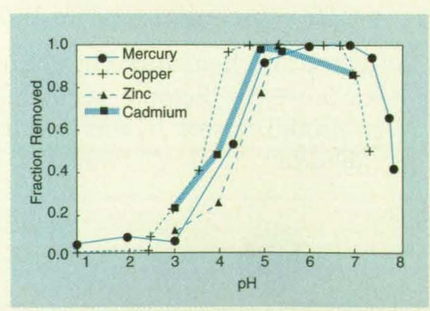


Figure 2. The **Adsorption of Metal** by the ion-exchange polymer material depends on the pH of the solution.

and some unknown contaminants, e.g., brighteners and chelating agents.

The most noteworthy conclusions drawn from the tests are the following:

- The rates of adsorption and the mass adsorbed per gram of the ion-exchange polymer depended on the pH levels of the solutions and on the initial concentrations.
- The adsorption of an ion is not affected by the presence of other ions (including calcium) in the mixture, so long as there is sufficient ion-exchange material present to adsorb all ions. This is shown in Figure 1.
- The amount of an element adsorbed varies with the pH of the solution. This is shown in Figure 2 for cadmium, mercury, copper, and zinc.
- The final concentrations of most of the elements tested are below the allowable limits for the concentrations of those elements in discharge water as specified by the Environmental Protection Agency.

Another important feature of the ion-exchange polymer material is that the adsorbed metals can be easily reclaimed by either a destructive or a nondestructive process. In the destructive process, the spent ion-exchange polymer is burned, thereby producing carbon dioxide, water vapor, and oxides of the adsorbed metals, which can be recycled. In the nondestructive process, the heavy metals are removed from the polymer and reclaimed by an acid stripping process. The polymer is then reusable and the metal concentrate can be recycled.

Other tests have shown that the ion-exchange polymer can be made inexpensively and is

- Easy to use;
- Strong, flexible, and not easily torn; and
- Chemically stable in storage, in aqueous solutions, and in acidic or basic solution.

Although no toxicity tests have been performed, it is anticipated that this is safe and nontoxic to handle.

This work was done by Warren H. Philipp, Jr., and Kenneth W. Street of **Lewis Research Center**, *Carol Hill of the University of Akron, and Joseph M. Savino of Cleveland State University. For further information,* ***write in 37*** *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, Lewis Research Center [see page 20]. Refer to LEW-15576.

High-Temperature Graphite/Phenolic Composite

Pressure lower than usual in curing prevents high-temperature damage by trapped moisture.

Marshall Space Flight Center, Alabama

A graphite-fiber/phenolic-resin composite material retains relatively high strength and modulus of elasticity at temperatures as high as 1,000°F (538°C) (see figure). The material costs only 5 to 20 percent as much as refractory materials do. The fabrication of the composite includes a curing process in which the application of full autoclave pressure is delayed until after the phenolic resin gels. This modified curing process allows moisture to escape, so that when the composite is subsequently heated in service, there will be much less expansion of absorbed moisture and thus much less of a tendency toward delamination. In contrast, internal pressure caused by the expansion of moisture absorbed in other composite materials like graphite/epoxies and graphite/polyimides causes delamination at temperatures in the range of 500 to 700°F (260 to 370°C).

The high-temperature graphite/phenolic composite was developed for the nose cone of the external fuel tank of the Space Shuttle. Wind-tunnel tests; high-temperature subcomponent tests; and full-scale structural, dynamic, acoustic, and damage-tolerance tests have shown that it can withstand the severe environments encountered by the nose cone in flight. Other potential aerospace applications for this material include leading edges, parts of nozzles, parts of aircraft engines, and heat shields. Potential terrestrial and aerospace applications include structural firewalls and secondary structures in aircraft, spacecraft, and ships. (Phenolic laminates have traditionally been used for secondary structures on aircraft because of their resistance to burning and low emission of smoke and toxic gases when exposed to flame; the present high-temperature graphite/phenolic material would add retention of strength at high temperature to these advantages.)

The modified curing process used to make the high-temperature graphite/-phenolic composite can be adapted to composites of phenolic with other fiber reinforcements like glass or quartz. These composites might be useful as high-temperature circuit boards and electrical insulators.

The modified curing process consists of the following steps:

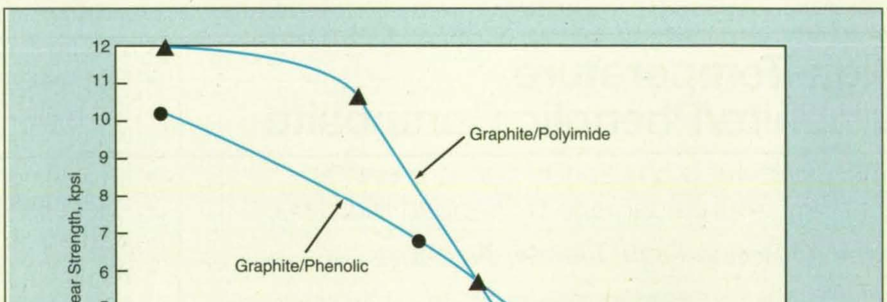
1. Full vacuum is applied to the composite part in an autoclave.
2. The autoclave is heated gradually, during 160 minutes, to a temperature of 175°F (79°C), then held at that temperature for 60 minutes.
3. The temperature is increased, at a rate of 1.0 to 1.5°F (about 0.6 to 0.8°C) per minute, until 220°F (104°C) is reached, then is held at that level for 78 minutes.
4. At 78 minutes, the applied autoclave pressure is ramped up to 5 psi (34 kPa) in 6 minutes, then the temperature is held for an additional 36 minutes.
5. The temperature is increased, at a rate of 1.0 to 1.5°F (about 0.6 to 0.8°C) per minute, to 240°F (116°C) and held there for 30 minutes.
6. At the same rate as in step 5, the temperature is increased to 350°F (177°C), then held there for 60 minutes.
7. The part is cooled, at a rate of 1 to 4°F (about 0.6 to 2.2°C) per minute, to 150°F (66°C).
8. The part is removed from the autoclave but kept under vacuum until it has cooled to 100°F (38°C).
9. The part is then subjected to a 42-hour postcure at atmospheric pressure in which its temperature is increased in steps, eventually reaching 415°F (213°C).

This work was done by Ellis C. Seal, Venu P. Bodepudi, Robert W. Biggs,Jr., and John A. Cranston of Martin Marietta Corp. for **Marshall Space Flight Center**. *For further information,* ***write in 96*** *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 Martin Marietta Co. Inquiries concerning licenses for its commercial development should be addressed to

Martin Marietta Corporation
Attn: Gay Chin, Associate
General Counsel
6801 Rockledge Drive
Bethesda, MD 20817

Refer to MFS-28759, volume and number of this NASA Tech Briefs issue, and the page number.



The Shear Tensile Strength of a Graphite-Fiber/Phenolic-Matrix Composite made by the modified process decreases with increasing temperature, but at 1,000°F, it remains greater than that of a composite made of the same fiber material with a matrix of polyimide.

Making Composite-Material Parts at Moderate to High Rates

Production lines and electron-beam curing would replace batch processing and heat curing.

Langley Research Center, Hampton, Virginia

Composite-material (matrix/fiber) structural components would be manufactured at moderate to high rates in production-line-style processes, according to a proposal. Until now, most composite-material parts have been made in labor-intensive batch processes that include time-consuming steps like curing in autoclaves. In the proposed method, the production lines would be largely automated and would take advantage of the fact that matrix resins can be cured by electron beams in addition to heat. The net result should be reductions in production times and costs.

The automation and the continuous nature of the proposed processes would depend on the availability of fabric preforms impregnated with matrix material. The yarns used to make the preforms could be coated with matrix material by any of several commercial processes, then woven into the preforms by use of advanced techniques for producing fabric components with complicated shapes.

Figure 1 illustrates a quasi-continuous press-forming process according to the proposal. Impregnated net-shape fabric destined to become layers of composite structural components would be supplied on multiple rolls. The fabric is unwound from the rolls and drawn through a series of rollers and guides to assemble them into a thicker, multilayer continuous preform. Unit lengths of the multilayer preform would be processed, in succession, through a partial-debulking tool. As its name implies, this tool would compress the unit lengths of preform part way toward its final dimensions, by use of a combination of mild pressure and mild heating. Because of the mildness of the partial-debulking conditions, the partial-debulking tool and associated equipment should be relatively inexpensive. Typical debulking times would be on the order of 1 min.

After partial debulking, each unit length of preform would be drawn out of the partial-debulking tool and cut from the continuous assembled fabric strip. Each resulting unit preform, now destined to become a composite structural component, would be placed in a staging tool and using heat and pressure would melt the matrix material and facilitate debulking of the preform to final dimensions. Depending on the type of matrix material, the heating of the preform in the staging tool could partially heat-cure the matrix material to such a degree that the preform could retain its final shape without support from tooling. Non-heat curable matrix materials that are electron-beam curable could be solidified without curing to such a degree that the preform could also retain its final shape without support from tooling. The time needed for staging would be on the order of 5 min; because of greater duration of the staging cycle in comparison with the debulking cycle, a number of staging tools would be kept running simultaneously to keep up with the output of the partial-debulking tool.

The composite structure would be removed from the staging tool and placed in a chamber where the matrix material would be cured by exposure to an electron beam. Typical electron-

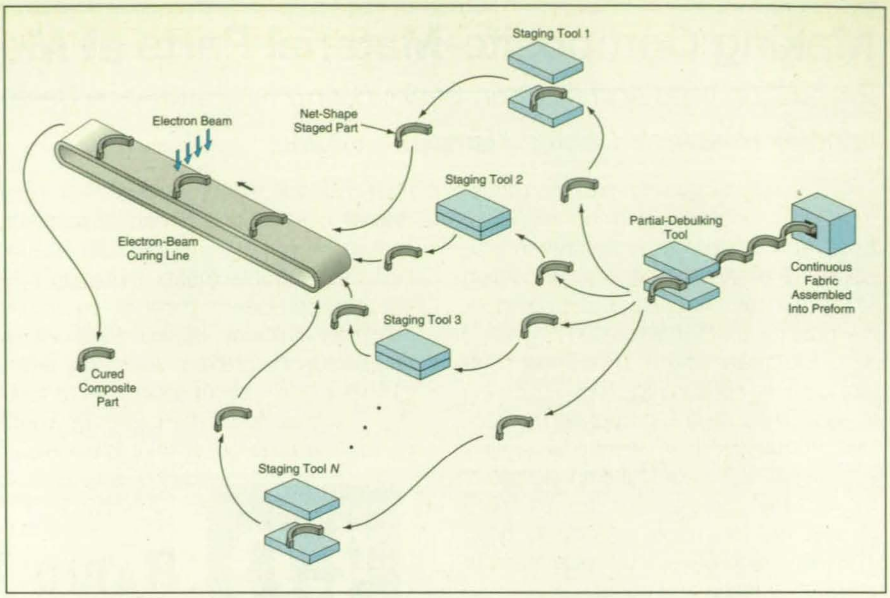


Figure 1. This **Press-Forming Process** would produce composite-material parts at moderate to high rates, in production-line fashion instead of by batches as is done now.

beam-curing times are expected to be of the order of several minutes — significantly shorter than typical autoclave cure cycles. Another advantage of the proposed method is that unlike heat curing, electron-beam curing does not cause chemical reactions of the type that forms voids and other anomalies, which can weaken the finished composite parts.

Figure 2 illustrates a continuous pultrusion process, according to the proposal, for making composite I-beams. As in the proposed press-forming process, impregnated net-shape fabric would be drawn from rolls and assembled into a thicker, multilayer continuous preform. The continuous preform would be fed into a heated die, the cross section of which would taper down to the desired I-beam cross section, so that the preform would be gradually debulked to the final cross section as it moved along. The preform would continue along a constant-final-cross-section length of the die, where it would be partially cured or allowed to solidify. The composite structure would be pulled continuously from the die and cut to length as unit lengths emerge. The staged I-beams would then be electron-beam cured.

This work was done by Gary L. Farley of the U. S. Army Vehicle Structures Directorate at **Langley Research Center**. *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Langley Research Center [see page 20]. Refer to LAR-15128.

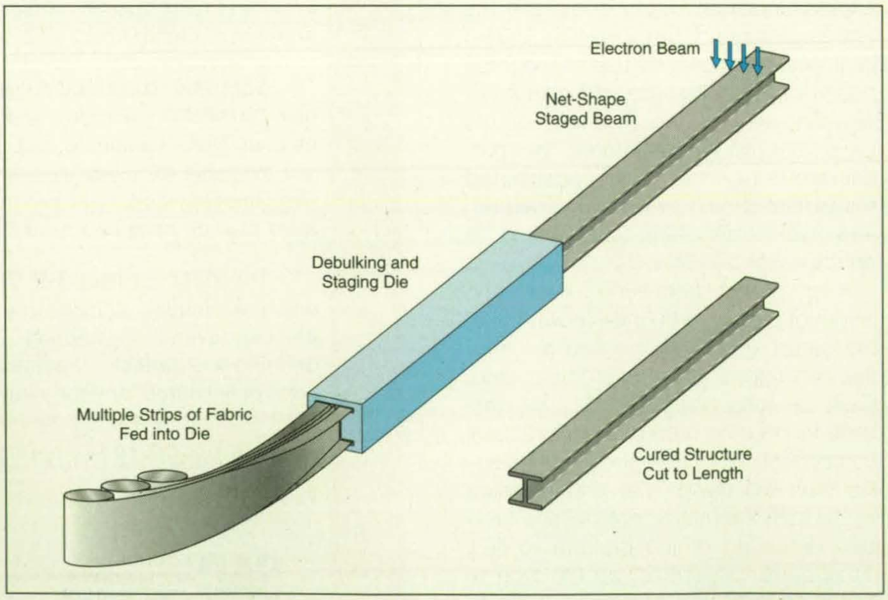


Figure 2. This **Pultrusion Process** would incorporate features of both conventional pultrusion and of the press-forming process shown in Figure 1.

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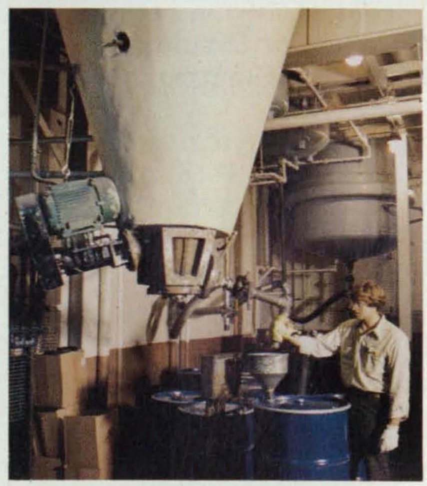

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Physical Sciences

Program for Displaying Computed Electromagnetic Fields

EM-ANIMATE displays and animates near-field and surface-current outputs of programs like MOM3D.

The EM-ANIMATE computer program is a specialized visualization program that displays and animates the output data on near fields and surface currents computed by an electromagnetic-field program — in particular MOM3D (LAR-15074, page 78). The EM-ANIMATE program is based on windows and contains a user-friendly, graphical interface for setting viewing options, selecting cases, manipulating files, and the like.

EM-ANIMATE displays the magnitudes of fields and surface currents as smooth, shaded color fields (color contours), ranging from minimum to maximum values. The program can display either the total or the scattered electric field in either time-harmonic animation mode or in root-mean-square (rms) average mode. The default setting is an initial setting that matches the maximum and minimum values within the sets of field and surface-current data. The user can also optionally control the setting. Field and surface-current values are animated by calculating and viewing the solution at increments of time that correspond to increments of phase selectable by the user in the range from 0 to 2π radians.

The surface currents can also be displayed in either time-harmonic animation mode or in rms average mode. In rms mode, the color contours do not vary with time, but show the time-averaged magnitudes of the field and surface-current solutions. In either time-harmonic or rms average mode, the magnitude and direction of the electric field and of the surface current can be displayed as a scaled vector arrow at each field grid point or surface node point. The vector-arrow display for the field and the vector-arrow display for the surface current can be put on separately or concurrently. The speed of animation is increased by turning off the display of vector arrows. The vector arrows must be shown as varying with time even in the rms mode because otherwise the time-averaged vectors would have zero lengths.

Optionally, some properties of surfaces can be viewed. These include surface grids, the value of resistance assigned to each element of the grid, and the power dissipated in each such element.

The EM-ANIMATE program accepts as many as 10 different surface-current cases, each consisting of as many as 20,000 node points and 10,000 triangle definitions, and animates one of these cases. This capability is used to compare distributions of surface currents in the presence of initial excitations incident from various directions and/or various orientations of the electric fields. The program can accept as many as 50 planes of field data, each plane containing a grid of 100 by 100 field points. These planes of data are selectable by the user and can be viewed individually or concurrently.

With the preset limits described above, the program requires 55 megabytes of core memory to run. These limits can be changed in header files to accommodate the available core memory of an individual work station. The amount of memory needed to store the field and surface-current data can be estimated as follows: Approximate memory in bytes equals [the number of nodes on each surface × the number of surfaces × 14 (the number of variables) × the number of bytes per word (typically 4 bytes per floating point)] + [the number of field planes × the number of nodes per plane × 21 (the number of variables) × the number of bytes per word]. The total size of memory needed then equals approximately 400,000 bytes plus the amount for data estimated as explained above.

The animation calculations are performed in real time at any time step set by the user. For Silicon Graphics work stations that include multiple processors, this program has been optimized to perform these calculations on multiple processors to increase the speed of animation. The optimized program uses the SGI PFA (Power FORTRAN Accelerator) library. On single-processor computers, the parallelization directives are seen as comments in the program and have no effect on compilation or execution.

EM-ANIMATE is written in FORTRAN 77 for implementation on SGI IRIS work stations running IRIX 3.0 or later. A minimum of 55Mb of random-access memory is needed for execution of this program. However, the code can be modified to accommodate the available memory of an individual work station. For execution of the program, 24-bit, double-buffered color capability is suggested but not required. Sample input and output files and a sample executable code are provided on the distribution medium. Electronic documentation is provided in PostScript format and includes ASCII help files. The standard distribution medium for EM-ANIMATE is a 0.25-in. (6.35-mm) streaming-magnetic-IRIX-tape cartridge in UNIX tar format. EM-ANIMATE is also available as part of a package, COS-10048, that includes MOM3D, an IRIS program that computes near-field and surface-current solutions of electromagnetic-field equations. This program was developed in 1993.

This program was written by Kam W. Hom of **Langley Research Center**. *For further information,* ***write in 166*** *on the TSP Request Card.*
LAR-15075

Method-of-Moments Code for Electromagnetic Scattering

This program computes scattered and total near fields and scattering matrices.

MOM3D is a FORTRAN computer program that implements a method-of-moments algorithm for analysis of electromagnetic waves on open or closed three-dimensional, perfectly conducting or resistive surfaces. The primary emphasis in analysis is upon computation of radar cross section under plane-wave illumination. However, the program also provides for excitation via local ports for computation of gain patterns and input impedances of antennas.

The electric-field-integral form of Maxwell's equations is solved by use of a local triangle couple basis and testing functions with a resultant system impedance matrix. The emphasis in analysis is not only upon routine predictions of radar-cross-section patterns, but also on phenomenological diagnostics: bistatic imaging, currents, and both scattered and total near electric fields. The output data on images, currents, and near fields are in a form suitable for animation.

MOM3D computes the full backscatter and bistatic radar-cross-section polarization scattering matrix (amplitude and phase), body currents, and scattered and total near fields under plane-wave illumination. MOM3D also incorporates a new bistatic k-space imaging algorithm for computing down-range/cross-range diagnostic images by use of only matrix inversion in each case.

MOM3D has been made efficient, with respect to memory and central-processing-unit time, by use of symmetric matrices, symmetric geometry, and partitioned fixed and variable geometries suitable for design-iteration studies. MOM3D can be run interactively or in batch mode on IBM 486 and compatible personal computers, UNIX work stations, or larger computers. A 486 personal computer that has 16 megabytes of memory has the potential to solve the equations for a 30-square-wavelength symmetric configuration, which involves 3,000 unknowns. The geometry of a given problem is described by use of a triangular-mesh input in the form of a list of vertex points and a triangle-join-connection list.

MOM3D is written in FORTRAN 77. Two machine versions are available from COSMIC. One of them is the UNIX version (LAR-15074), which is designed to be executed on SGI-series computers running IRIX and, with modifications that are described in the documentation, has been implemented successfully on a Sun4-series computer running SunOS. The other version is the IBM PC version (LAR-15130), which has been implemented successfully on a IBM-PC-compatible computer running MS-DOS and version 5.1-EM32 of Lahey FORTRAN. The amount of random-access memory needed for MOM3D varies with the size of the problem being solved. Sample input and output files are provided for each version. The UNIX and PC versions include an SGI executable code and an MS-DOS executable code, respectively. The UNIX version also includes electronic documentation in PostScript format, while the PC version includes electronic documentation in WordPerfect format.

The standard distribution medium for the UNIX version is a 0.25-in. (6.35-mm) streaming-magnetic-IRIX-tape cartridge in UNIX tar format. It is also available on a 0.25-in. (6.35-mm) streaming-magnetic-tape cartridge (SUN QIC-24) in UNIX tar format. The standard distribution medium for the PC version (LAR-15130) is a set of four 5.25-in. (13.335-cm), 360K MS-DOS-format diskettes. The contents of the diskettes are compressed by use of the PKWARE archiving software tools. The utility software to unarchive the files, PKUNZIP.EXE, is included. The UNIX version of MOM3D is also available as part of a package, COS-10048, that includes EM-ANIMATE, an IRIS program capable of displaying and animating MOM3D results. This program was developed in 1992.

This program was written by John F. Shaeffer of Denmar, Inc., for **Langley Research Center**. *For further information,* ***write in 165*** *on the TSP Request Card. LAR-15074/15130*

Computing Interactions of Free-Space Radiation With Matter

A user-friendly program provides dosimetric information for use in design.

The High Charge and Energy Transport (HZETRN) computer program is a computationally efficient, user-friendly package of software that addresses the problem of transport of, and shielding against, radiation in free space. HZETRN is designed as a "black box" for design engineers who are not concerned with the physics of the underlying atomic and nuclear radiation processes in a free-space environment, but rather are primarily interested in obtaining fast and accurate dosimetric information for the design and construction of modules and devices for use in free space. Computational efficiency is achieved by a unique algorithm based on a deterministic approach to the solution of the Boltzmann equation rather than the computationally intensive statistical Monte Carlo method.

HZETRN is based on a space-marching formulation of the Boltzmann transport equation with a straight-ahead approximation. Furthermore, due to the long range of the Coulomb force and the large percentage of volume of material occupied by electrons, the interaction of radiation with electrons is treated as a continuous slowing process. In developing the formalism for HZETRN, the nature of the transport coefficients (atomic and nuclear stopping power, nuclear scattering and absorption cross sections, and nuclear fragmentation cross section) had to be considered. Atomic (electronic) stopping powers with energies above a few MeV were calculated by use of Bethe's theory including Bragg's rule, Ziegler's shell corrections, and effective charge. At sufficiently low energies, at which nuclear stopping power becomes important, the nuclear stopping power theory of Lindhard, Scharff, and Schiott as modified by Ziegler was used. Nuclear absorption cross sections were obtained by use of fits to quantum calculations, and total cross sections were obtained by use of a Ramsauer formalism. Nuclear fragmentation cross sections were calculated from a semiempirical mathematical model of fragmentation by abrasion and ablation.

HZETRN includes a numerical algorithm for interpolation, extrapolation, and integration and for generation of grids. This algorithm also controls local truncation and the propagation error. Consideration is given to minimization of the number of energy grids to maintain efficiency. Since fluxes of cosmic rays vary most rapidly at energies below 1 A GeV, HZETRN has been made to select a uniform logarithmic scale for the range grid, and the corresponding energy grid is calculated on the basis of this selection.

A design engineer using HZETRN can quickly obtain the integral flux, absorbed dose, or dose equivalent in tissue (water) in units of either centiGray (cGy) or centiSivert (cSv). These calculations are based on ICRP26 and ICRP60 quality factors behind various thicknesses of aluminum shield exposed to GCR at seven provided solar minima or maxima taken from 1958 to present. The flux and dosimetric results are presented for 59 individual particle field isotopes. Cumulative results are presented for six charge groups (the values of Z, the atomic number, being 0, 1, 2, 3–10, 11–20, and 21–28) or as total dose for the entire transported particle field at various thicknesses. Furthermore, flux and absorbed doses are calculated as functions of linear energy transfer for biological studies. Typical run time for the case of an aluminum shield of 20 grams per square centimeter and a tissue (water) target of 5 grams per square centimeter is a few minutes on a VAX 4000 computer.

HZETRN is written in FORTRAN for DEC VAX-series computers running VMS version 5.5. The amount of random-access memory needed depends on the size of the problem being solved. Documentation for HZETRN consists of six pages that detail the operation of the program, setup of input files, and how to interpret output. An electronic copy of the documentation is available in ASCII format on the distribution medium. The standard medium for distribution of this software is a 1,600 bit/in. (≈630-bit/cm), 9-track magnetic tape in DEC VAX BACKUP format. It is also available on a TK50 tape cartridge in DEC VAX BACKUP format. HZETRN was developed in 1992.

This program was written by J. W. Wilson, F. A. Cucinotta, J. L. Shinn, and L. W. Townsend of **Langley Research Center**; *F. F. Badavi and R. K. Tripathi of Christopher Newport University; R. Silberberg and C. H. Tsao of the Naval Research Laboratory; and G. D. Badwar of Johnson Space Center. For further information,* ***write in 3*** *on the TSP Request Card. LAR-15225*

Mathematics & Information Sciences

Program Implements Variable-Sampling Procedures

Tedious procedures are automated.

The MIL-STD-414 Variable Sampling Procedures (M414) computer program has been developed to automate the calculations and the acceptance/rejection procedures of MIL-STD-414, "Sampling Procedures and Tables for Inspection by Variables for Percent Defective." Prior to the development of M414, the use of MIL-STD-414 could be cumbersome and confusing to a non-statistician: MIL-STD-414 requires some calculations plus extensive referral to the tables in making a decision to accept or reject a lot. The process of calculation and reference to the tables is tedious and confusing and can, therefore, result in errors. These difficulties have probably discouraged the use of MIL-STD-414 and led to mistakes in applying it.

M414 automates the entire calculation-and-decision process by use of computational algorithms that determine threshold acceptability values for lots. M414 is menu-driven and user-friendly. The use of M414 can reduce the burden of manual operations, thus promoting variable-sampling practice in industry in lieu of "go/no-go" inspection.

M414 is written in BASIC for IBM PC-series and compatible computers running MS-DOS. The program requires 512K of random-access memory, an 80 × 87 math coprocessor, and a CGA monitor for execution. The Microway 87SFL Math Function Software Library (Kingston, MA; 508-746-7341) and Microsoft QuickBasic v2.0 are needed to compile the source code. The standard distribution medium is one 5.25-in. (13.335-cm) diskette in MS-DOS format. Documentation is included in the price of the program. M414 was developed in 1993.

This program was written by Zhaofeng Huang of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information,* ***write in 14*** *on the TSP Request Card. MFS-30004*

Mechanics

Service Cart for Engines

This unit assists a lone worker in moving an engine.

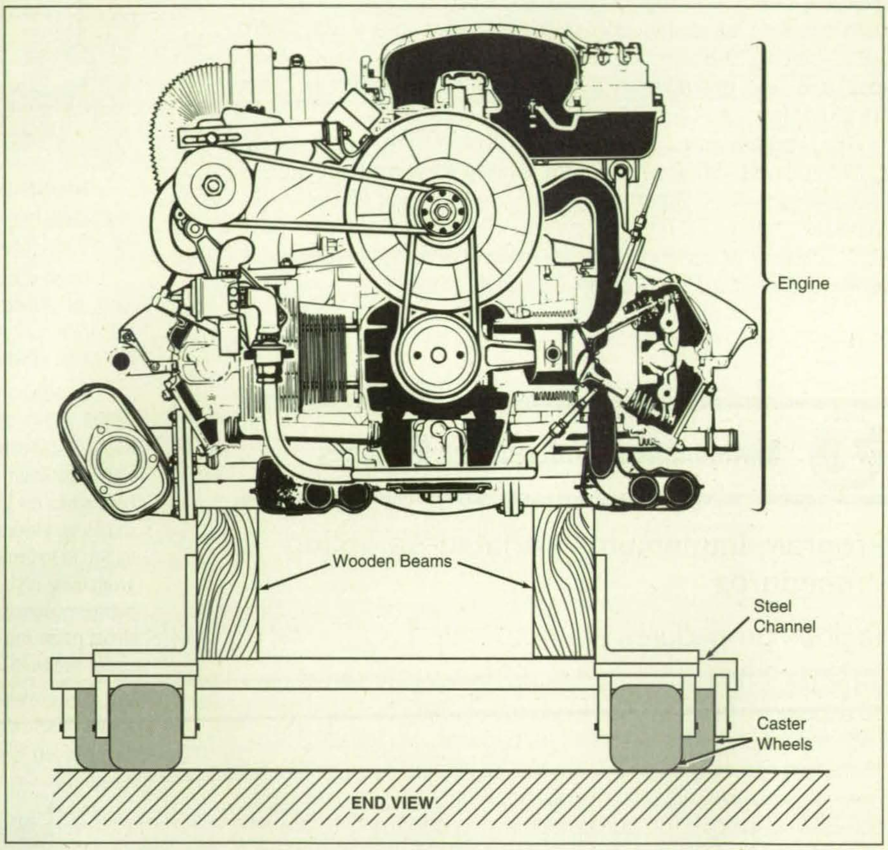
Langley Research Center, Hampton, Virginia

A cart supports the rear-mounted air-cooled engine from a Volkswagen or Porsche automobile (see figure). With it, one person can remove, repair, test, and reinstall the engine of a car, van, or home-built airplane.

The cart consists of a framework of wood, steel, and aluminum components supported by four wheels. The engine is lifted from the vehicle by a hydraulic jack and gently lowered onto the waiting cart. The jack is then removed from under the engine. The rear of the vehicle is raised just enough that the engine can be rolled out from under it. The cart cradles the engine without denting or scratching it. The cart holds the engine low enough to clear the car and high enough to clear the jack.

Once loaded on the cart, the engine is accessible for removal and installation of parts. The engine can also be tested in operation on the cart. The cart easily supports a 200-lb (90-kg) engine. It can also be used to hold a transmission. With a removable sheet-metal top, the cart can also be used as portable seat.

This work was done by Gim Shek Ng of **Langley Research Center**. *For further information,* ***write in 164*** *on the TSP Request Card.*
LAR-14858



The **Service Cart** is made from readily available materials. Fabrication of the cart involves only straight cuts and no complicated machining.

Detecting Structural Failures via Acoustic Impulse Responses

Adaptive lattice filtering of echoes yields data on sizes and locations of failures.

NASA's Jet Propulsion Laboratory, Pasadena, California

An advanced method of acoustic pulse reflectivity testing is being developed for use in determining the sizes and locations of failures within structures. The method is related to electronic, optical, and acoustic pulse reflectivity methods that have been used successfully to detect breaks in electrical transmission lines, detect faults in optical fibers, and determine mechanical properties of materials, respectively.

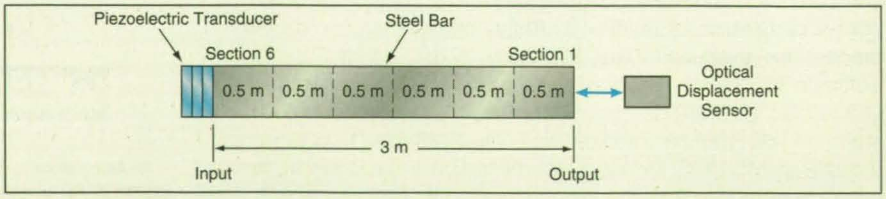


Figure 1. The **Bar Is Vibrationally Excited** at one end by using the piezoelectric transducer to apply an acoustic pulse. The resulting lengthwise acoustic displacements are measured optically at the other end. For purposes of analysis of the response, the bar is arbitrarily divided into $M = 6$ sections; more or fewer than 6 could be used.

In this method as in other acoustic pulse methods, the structure is vibrationally excited with an acoustic pulse (a "ping") at one location and the acoustic response is measured at the same or a different location (see Figure 1). The measured acoustic response is digi-

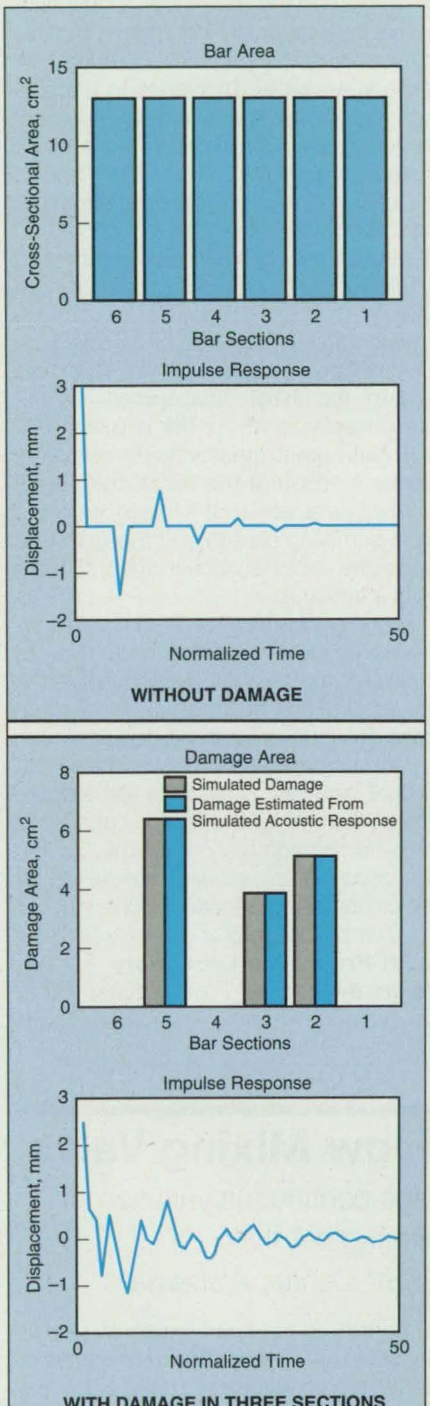


Figure 2. In a **Computational Simulation of the Test Illustrated in Figure 1**, the acoustic responses of the bar without and with damage in three sections were analyzed by the method described in the text. The analysis was successful in identifying the damaged sections and in estimating the extent of damage (reduction in cross-sectional area) in each damaged section.

tized, then processed by a finite-impulse-response (FIR) filtering algorithm that is unique to this method and that is based on the acoustic-wave-propagation and -reflection properties of the structure.

One important feature of the underlying wave-propagation and -reflection theory is that the cross-sectional areas of structural elements can be computed directly in terms of the reflection coefficients of an optimal (adaptive) FIR Wiener filter realized in lattice form. This is fortunate in that many practical on-line techniques for estimating the parameters of optimal Wiener FIR filters are already available. This leads to the present elegant method for detecting and localizing structural failures by using recursive, on-line techniques of estimation. This method offers several advantages over older failure-detection methods: it does not require training, does not require prior knowledge of a mathematical model of the acoustic response of the structure, enables the detection and localization of multiple failures, and yields data on the extent of damage at each location.

Figure 1 illustrates schematically the application of the method to a simple bar, which was the structure that was mathematically modeled in the initial development of the method. First, the impulse response of the bar is measured. By use of the acoustic input/output measurement data, the optimal FIR inverse transfer function of the bar is computed. The bar is then represented as a series of M sections (M is constrained by the output-sampling period) and the reflection coefficient (proportional to the cross-sectional area) of each section is calculated as in a lattice filter.

Ideally, the acoustic impulse response of the bar is measured repeatedly and used to update the reflection coefficients and/or cross-sectional areas at the M-1 locations of the boundaries between the M sections of the bar. When some damage occurs, the cross-sectional area at the damage location changes, resulting in a corresponding change in the reflection coefficient for that location. Thus, from the amount of change in, and identity of, the changed reflection coefficient, the extent and location of the damage are immediately known (see Figure 2). If damage occurs between two boundary locations, the reflection coefficients for both locations change.

This work was done by David S. Bayard and Sanjay S. Joshi of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 64*** *on the TSP Request Card.* *NPO-19167*

Constant-Flow Mixing Valve

A ball valve provides continuous variation of mixture without altering net flow.

Marshall Space Flight Center, Alabama

The ball valve shown partially in the figure mixes two liquid flows in any desired proportion. The valve admits the liquids at ports A and B and releases the combined liquids at the outlet (port C). Turning the ball adjusts the outlet flow continuously from 100 percent liquid A to 100 percent liquid B.

The orifices in the ball are contoured so that, together, they provide a constant rate of flow at the outlet and a constant pressure drop through the valve of the ball.

This work was done by Joe Sega and Neil A. M. Peters of Allied Signal, Inc., for **Marshall Space Flight Center**. *For further information,* ***write in 47*** *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 Allied-Signal Aerospace Inc. Inquiries concerning licenses for its commercial development should be addressed to*

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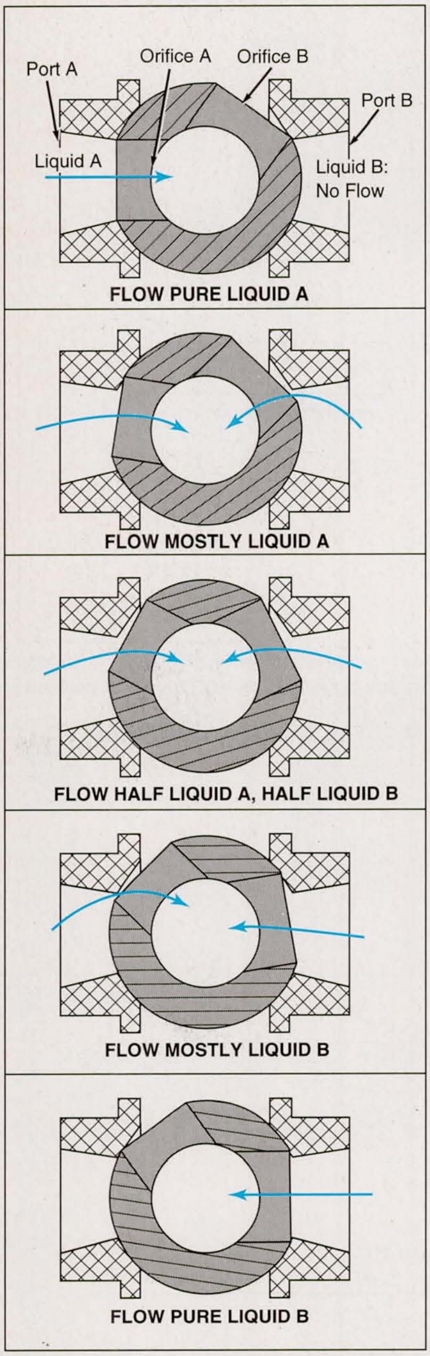
Refer to MFS-28864, volume and number of this NASA Tech Briefs issue, and the page number.



When Orifice A of the Ball Is Coaxial with inlet port A, the outlet flow consists entirely of liquid A. As the ball is rotated clockwise, the part of orifice A exposed to port A decreases and the part of orifice B exposed to port B increases. The proportion of liquid B therefore increases, and that of liquid A decreases. The outlet flow (to port C) is not shown.

Computing Propagation of Sound in Engine Ducts

An updated computer program is easier to use.

Marshall Space Flight Center, Alabama

The Frequency Domain Propagation Model (FREDOM) computer program accounts for acoustic loads applied to components of engines. In particular, the program models the propagation of noise through fluids in ducts between components and through passages within components. It can be used not only to analyze hardware problems, but also for design purposes. FREDOM is an updated version of the FREQPL program, which was first developed in 1959.

These programs were devised specifically for use in analyzing the acoustic loads in rocket engines, where noise generated in pumps, combustion chambers, and duct bends can be so intense as to cause mechanical failures, and where resonances in ducts can amplify the effects of noise. The underlying physical and mathematical concepts implemented in these programs should also be applicable to acoustic propagation in other enclosed spaces; they might be useful, for example, in analyzing process plumbing and ducts in industrial buildings with a view toward reducing noise in work areas.

The older program, FREQPL, is basically a matrix solver with plotting capabilities. Before running FREQPL, the user had to do all the preparatory theoretical and computational work, which included (1) writing the often complicated wave equations, flow equations, and other equations as they apply to the system to be analyzed, (2) putting the equations into matrix•vector form, and (3) entering the matrix elements into the computer by responding to program prompts one element at a time. This preparatory work required an engineer with a high level of sophistication in acoustics and detailed knowledge of the system, consumed much time, and was highly susceptible to theoretical and typing errors. Also, the matrix for FREQPL was set up to solve for a specific variable. Most of the time, results are needed at many locations (different variables) of the system. When using FREQPL, the preparatory work had to be repeated for each new variable.

FREDOM incorporates the matrix solver of FREQPL, but it also automates the preparatory theoretical work, thereby greatly reducing the

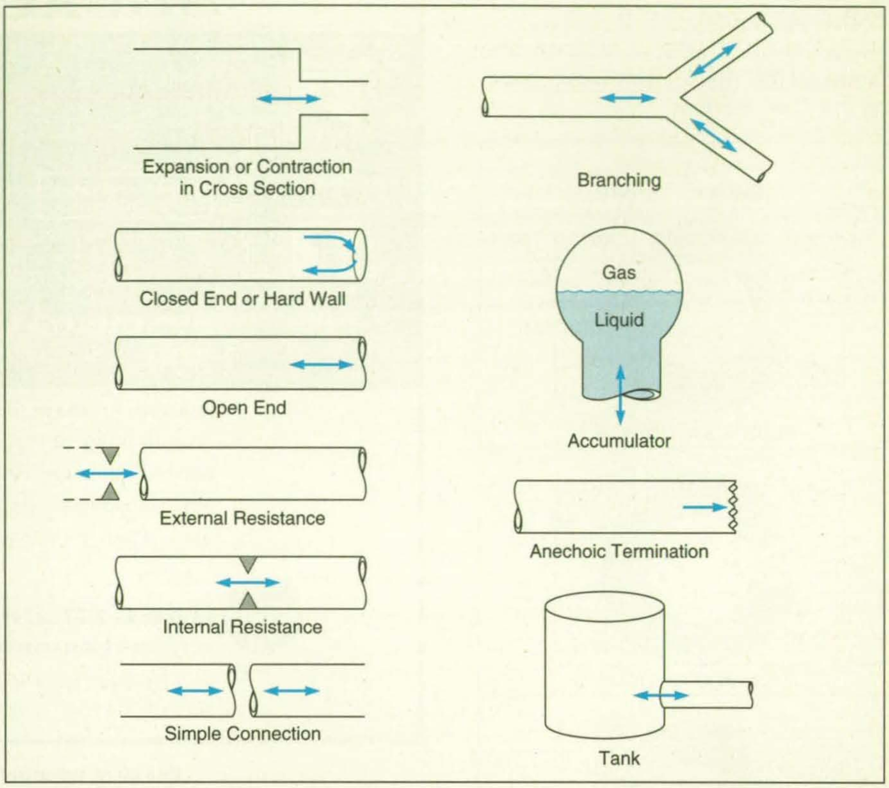


Figure 1. **Various Boundary Conditions** are treated automatically and routinely. FREDOM even provides for small changes in cross-sectional area of a duct due to the distensibility of the duct material.

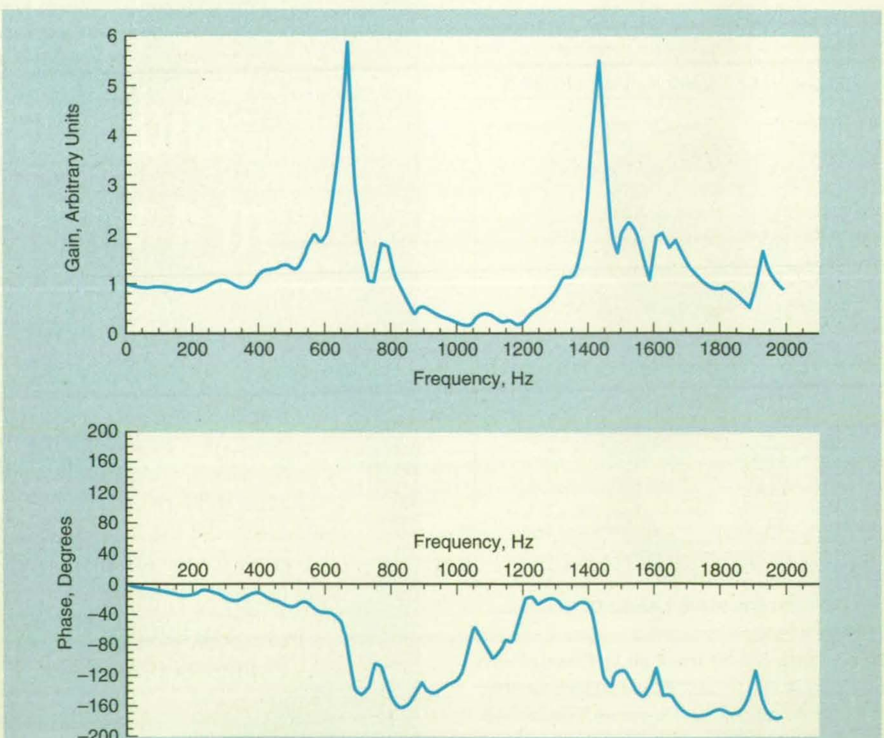


Figure 2. The **Frequency Response** plotted here is a transfer function that represents the acoustic response at one point along a duct to an acoustic excitation at another point along the duct. The peaks in the gain plot indicate the resonances of the duct. Also note a customary phase change in the accompanying phase plot at the resonance peaks.

probability of errors. FREDOM is a user-friendly and menu-driven code. It guides the user step by step through the analysis. The user needs only a good knowledge of acoustics.

The user provides data that describe the duct or passage geometry, connections, and properties of the fluid in the system via four input files. FREDOM also accounts for boundary conditions of the system automatically. The user merely states the type(s) of boundary condition(s) and the code incorporates the coefficients of the corresponding equation(s) into the coefficient matrix. Figure 1 shows the variety of boundary conditions handled by FREDOM. For example, if an accumulator is needed, the user need merely specify its location, the type of gas, and initial pressure and volume. For most boundary conditions, it suffices to specify locations only.

FREDOM then constructs the matrix from the data provided by the user — that is, FREDOM automatically does the equivalent of what the user would do in writing the acoustic equations for the system, but does it faster and more accurately. The matrix in FREDOM differs from that in FREQPL: the FREDOM matrix contains the coefficients of the system equations that have been manipulated to put all variables on the left side; that is, the right sides of all the equations are set equal to zero. This matrix, along with the information used to create it, is stored in a "system file". Once the system file is obtained, any of the variables can be set on the right side of the equations for calculation of the applicable frequency response, without having to create a new matrix for each variable. Results can be plotted (see Figure 2) and/or tabulated.

FREDOM works directly in the frequency domain. In this respect, FREDOM offers a great advantage over a time-domain code, the output data of which would have to be postprocessed to convert them into the frequency domain. Postprocessing could add several hours to the overall computational process. In a large iterative analysis (for example, probabilistic analysis of a system), a frequency-domain approach takes several days less than does a time-domain approach.

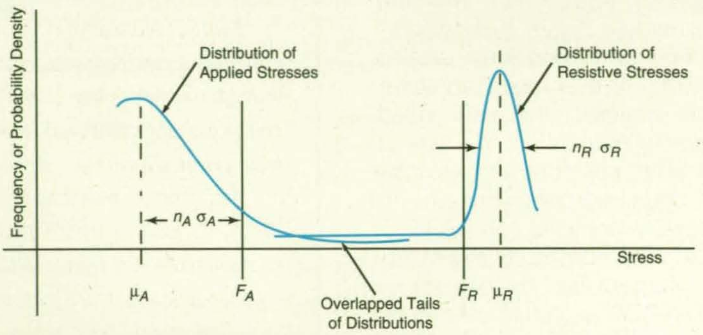
This work was done by Silvia Saylor of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information,* ***write in 248*** *on the TSP Request Card.*
MFS-29971

Improved Selection of Structural-Load Safety Factors

A more rational approach offers potential for optimization of design.

Marshall Space Flight Center, Alabama

An improvement in the deterministic method of selection of structural-load safety factors should make it possible to design structures that are more nearly optimum with respect to competing demands for both reliability and attributes that detract from reliability (principally lighter weight, smaller size, and lower cost). Safety factors are the factors by which structures and components thereof are strengthened in design to withstand loads greater than nominal design loads, the purpose being to ensure against failures under initially unknown but reasonably foreseeable overloads. In the deterministic method (which is really partly subjective, despite its name), safety factors are selected arbitrarily or on the basis of experience. For example, the conventional safety factor for tensile strength of a component is the ratio between the ultimate tensile stress that the material can resist and the stress applied by the nominal maximum design load. Normally, the maximum design load would not be allowed to exceed the tensile yield stress, so that the lower limiting value of the conventional deterministic safety factor (called the "lean" safety factor) is the ratio between the ultimate and yield tensile stresses.



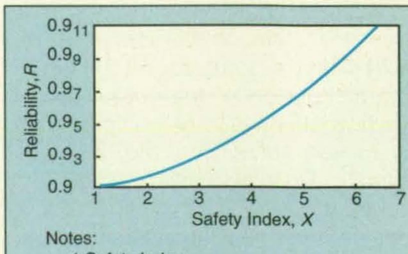
μ_A = mean value of applied stress.
σ_R = standard deviation of applied stress.
n_A = safety factor for stress (probability range factor for load-induced stress).
F_A = design maximum applied stress = $\mu_A + n_A \sigma_A$.
μ_R = mean value of resistive stress = nominal value of ultimate tensile strength of material.
σ_R = standard deviation of resistive stress (standard deviation of ultimate tensile strength of material).
n_R = safety factor for material (probability range factor for ultimate tensile strength of material).
F_R = design minimum tensile strength = $\mu_R - n_R\sigma_R$.
S = safety factor = $\frac{F_R}{F_A}$

The safety factors SF, n_A, and n_R are related to the statistical quantities by the following equation:

$$\mu_R - \mu_A = \mu_A(S-1) + Sn_A\sigma_A + n_R\sigma_R$$

Figure 1. A **Margin of Safety** can be considered to lie in the middle region of overlap of the tails of the statistical distributions of the applied and resistive stresses.

In the deterministic method as practiced until now, strengths of materials and load-induced stresses have been treated as single-valued parameters, while universal safety factors that are not equally realistic for all structural materials have been used to account for uncertainties. This practice has led to overdesign of some noncritical components; on occasion, it has led to underdesign of critical components and consequent failures. In the improved deterministic



Notes:

1. Safety Index =

$$Z = \frac{(S-1) + S(n_A C_A) + (n_R C_R)\mu_R/\mu_A}{[C_A^2 + [C_r\mu_R/\mu_A]^2]^{\frac{1}{2}}}$$

where $C_A = \frac{\sigma_A}{\mu_A}$ and $C_R = \frac{\sigma_R}{\mu_R}$.

2. $R = \Phi(Z)$ is the cumulative normal distribution function.

Figure 2. The **Reliability of a Component** (in terms of the probability that the stress caused by an applied load will not exceed its strength) is a cumulative probability density function of the safety index.

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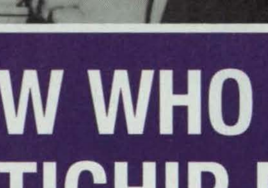

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method, the selection of safety factors is guided partly by statistical data on deviations of loads, stresses, and strengths of materials from expected values. Instead of considering the single safety factor of the conventional deterministic method, one considers three safety factors, which are specified independently with respect to loads, stresses, and materials respectively. These safety factors are combined into a single safety index, which is then used to support design trades among them and to compare the safety of different stressed regions in the same structure or in different structures.

By incorporating the use of some statistical data, the improved deterministic approach involves some probabilistic elements, but not the complexity of a fully probabilistic approach. Figure 1 presents an example of a simple component under uniaxial tensile stress to illustrate the statistical and probabilistic aspects of the improved approach and the relationships among the various safety factors. The deterministic safety index is computed from the safety factors and the statistical parameters indicated in Figure 1; the deterministic safety index summarizes the information on the anticipated reliability of the stressed component in the following way: the probability that the applied stress will not exceed the ultimate tensile stress that the material can resist is a function (typically, a cumulative normal distribution function) of the safety index (see Figure 2).

This work was done by Vincent Verderaime of **Marshall Space Flight Center**. *For further information,* ***write in 45*** *on the TSP Request Card. MFS-28825*

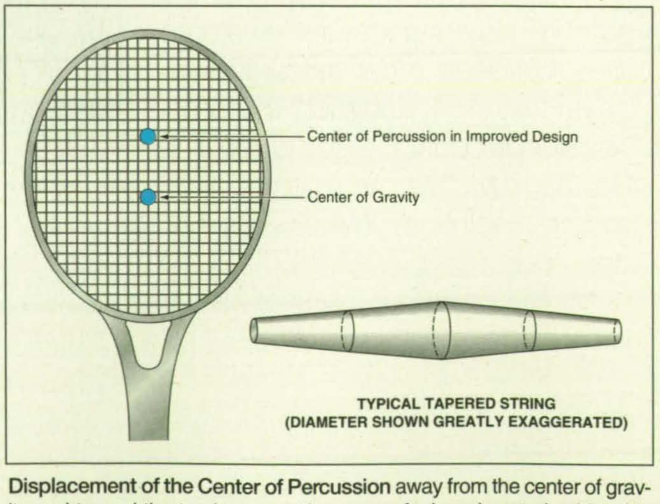
Improved Tennis Racquets Have Tapered Strings

The center of percussion is moved outward for better performance.

Marshall Space Flight Center, Alabama

One of the unexpected benefits of research in outer space is a design concept for a better performing tennis racquet. The essence of the concept is to taper the strings in such a way as to shift the center of percussion (also called the "sweet spot") toward the toe (the outer end of the racquet, farthest from the player's hand).

This concept originated more than 20 years ago in NASA studies of networks of strings for connecting platforms in outer



Displacement of the Center of Percussion away from the center of gravity and toward the toe improves the power, feel, and control achievable with the racquet. The improvement involves the use of tapered strings.

space. Researchers found that changing the diameters of strings could radically change the stability of a network against vibration. This idea was inspired by an experiment in which a space-borne spider was coaxed to spin a good web and was observed to make its web with threads of nonuniform size.

The major difficulty in designing a high-performance tennis racquet arises from the difference between the position of maximum speed (the toe) and the position of optimum vibration (the sweet spot). In a typical older design, the sweet spot is at the geometric center of the strung area of the racquet. The impact of the ball on the sweet spot causes minimal kick or jar to be transmitted to the player's hand. However, the average player tends to strike the ball farther out toward the toe, and to obtain maximum power on serves, it is necessary to strike the ball as close as possible to the toe. Thus, performance can be improved by moving the sweet spot outward (see figure).

In addition to increasing power on serves, tapering the strings to move the sweet spot outward improves the player's control and the feel of the racquet in the player's hand. An important element of improved control is increased stability: the racquet is less likely to twist in the player's hand on off-center shots. An important element of better feel is better absorption of vibrations; this is especially important for players who have chronic arm problems.

The optimization of the tapers of the strings for a given racquet design is based on the fundamental physics of vibrating strings. A computer performs the optimization numerically, by use of a genetic algorithm. As its name suggests, a genetic algorithm implements a mathematical evolutionary process that resembles biological evolution in some respects and that arrives at an optimized design (distribution of mass along each string) by following a sequence of random design changes and preserving those changes that improve performance.

The string material can be nylon, animal gut, or other naturally or artificially spun threads. The string can be attached to a conventional racquet frame. The required distribution of mass along each string can be achieved by spinning the string thicker or bonding different string materials along a central braid in the string.

This work was done by David A. Noever of **Marshall Space Flight Center**. *For further information,* ***write in 11*** *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 20]. Refer to MFS-28922.

Active Suppression of Vibrations on Aircraft Structures

Sensors, controllers, and actuators generate compensatory vibrations.

Langley Research Center, Hampton, Virginia

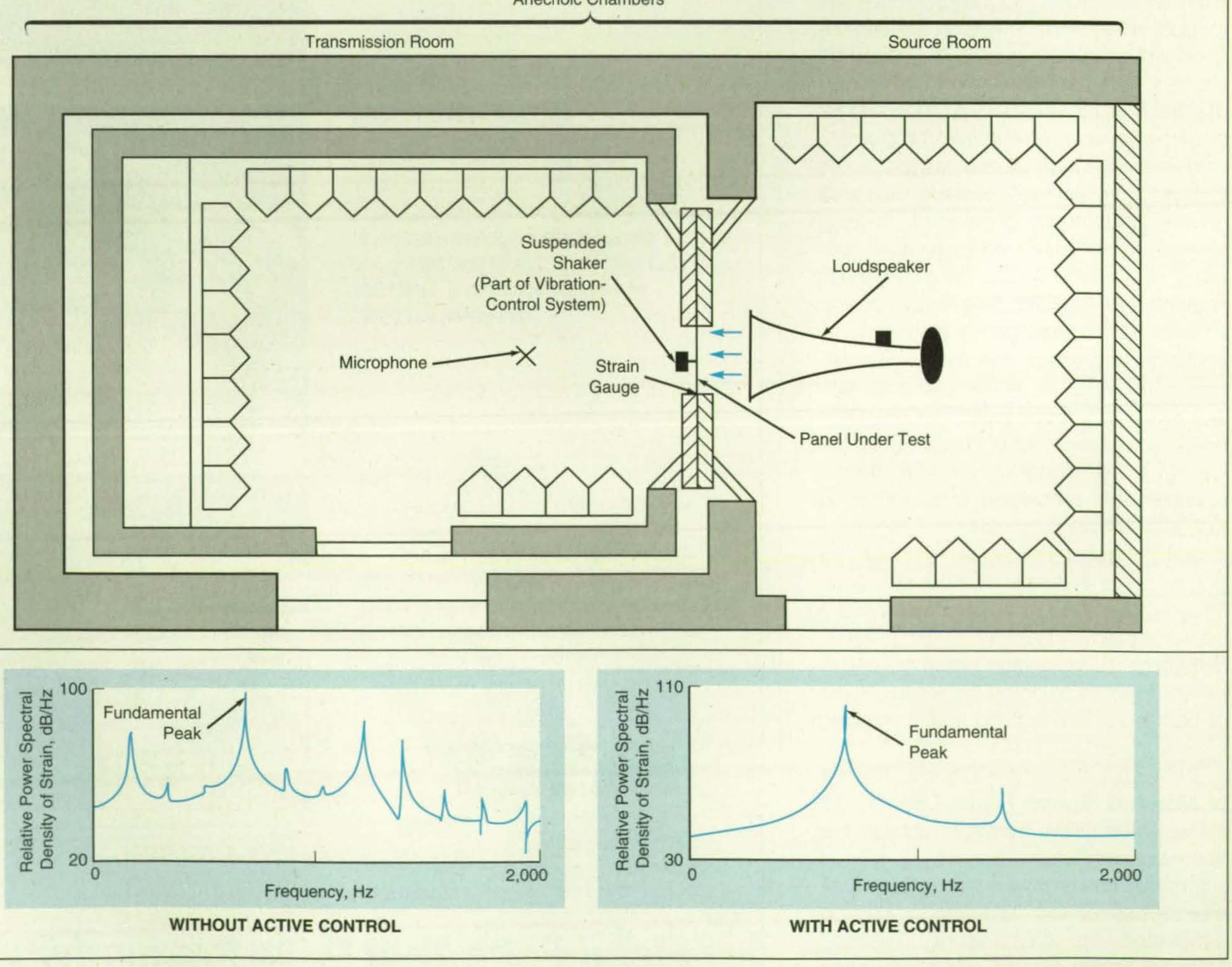
A method of active suppression of nonlinear and nonstationary vibrations is being developed to reduce sonic fatigue and interior noise in high-speed aircraft. The structure of such an aircraft exhibits periodic, chaotic, and random vibrations when forced by high-intensity sound from jet engines, shock waves, turbulence, and separated flows. The developmental method of suppressing vibrations involves feedback control: Strain gauges or other sensors mounted in the paths of propagation of vibrations on the structure sense the vibrations; the outputs of the sensors are processed into a control signal that is applied to the actuator mounted on the structure, inducing compensatory forces.

The basic active-vibration-suppression concept describes a feedback technique applied to the control of nonlinear vibration. One approach is directed toward the control of periodic motion of a panel that responds nonlinearly in the sense that it vibrates in harmonic and subharmonic modes, as well as in a fundamental mode, when acoustically excited at its resonant frequency (the frequency of the fundamental mode). The number, positions, and orientations of the sensors are chosen so that the array of sensors yields sufficient information on the directions of arrival, amplitudes, and phases of vibrations. In response, the control circuitry chooses amplitudes and phases of the compensatory vibrations such that the net amplitudes of the subharmonic and harmonic vibrations decrease, while the amplitude of the fundamental vibration increases. That is, the energy in the harmonics and subharmonics is channeled into the fundamental (see figure) with conservation of overall vibrational energy. Stated in yet another way, the state of vibration is converted from nonlinear to linear.

A second approach is directed toward suppression of vibrations that are both nonstationary and nonlinear — e.g., vibrations forced by impingement of shocks or from exhaust from a nearby supersonic jet engine. It is the first time that nonlinear, nonstationary structure response has been successfully controlled. In this approach, opposing vibrations are generated at whichever frequency is momentarily that of the greatest vibrational spectral peak. In this approach, energy is not conserved: instead, energy is channeled from the greatest spectral peak to its harmonics, but with a net overall reduction in vibrational energy and in acoustic radiation from the structure.

This work was done by Lucio Maestrello of **Langley Research Center**. *For further information,* ***write in 81*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Langley Research Center [see page 20]. Refer to LAR-15071.



Vibrational Spectra were measured in an experiment with and without active control. Active control channeled energy from the fundamental to the harmonics and subharmonics via phase cancellation.

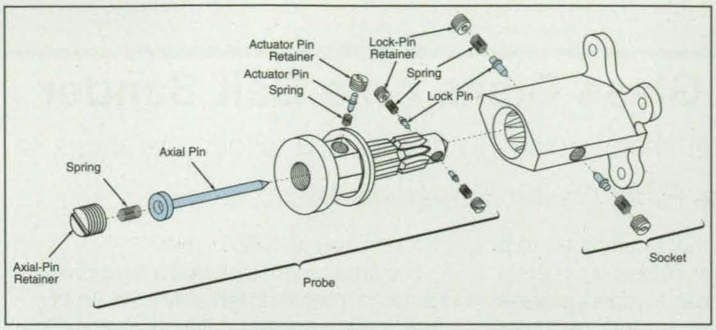
Probe-and-Socket Fasteners for Robotic Assembly

Self-alignment and simplicity of actuation make this mechanism amenable to robotic assembly.

Lyndon B. Johnson Space Center, Houston, Texas

A probe-and-socket fastening mechanism is designed to be operated by a robot. The mechanism is intended to enable a robot to set up a workstation in a hostile environment, for example. The workstation can then be used by an astronaut, aquanaut, or other human, who would thus spend minimum time in the environment. The human can concentrate on performing quality work rather than on setting up equipment, with consequent reduction of risk.

The mechanism (see figure) includes (1) a socket, which would be mounted on a structure at the worksite, and (2) a probe, which would be mounted on a piece of equipment to be attached to the structure at the socket. The probe-and-socket mechanism is intended to be used in conjunction with a fixed target that would aid in the placement of the end effector of the robot during grasping, and with a handle or handles on the structure. The robot would move the probe near the socket and depress the actuator pin in the probe. The inward motion of the actuator pin would cause rearward motion of the axial pin, thereby allowing two spring-loaded lockpins to retract into the probe. The robot would then begin to insert the probe into the socket.



Lockpins in the Probe engage radial holes (not shown) in the socket. Depressing the actuator pin temporarily retracts the lockpins into the probe so that the probe can be inserted in the socket.

Tapered grooves in the socket mesh with tapered ridges on the probe, thereby aligning the fastener parts and preventing binding. When the probe bottoms out in the socket, the robot releases its grip on the actuator pin. The resulting forward motion of the axial pin pushes the lockpins of the probe outward into mating holes (not shown) in the socket. Also, when the probe bottoms in the socket, additional lockpins in the socket spring into detents at about the midlength of the tapered ridges on the probe.

This work was done by Karen Nyberg 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 20]. Refer to MSC-22028.

Grinding Glass Disks on a Belt Sander

An attached unit shapes disks to dimensions within tolerances of most uses.

Goddard Space Flight Center, Greenbelt, Maryland

A small machine that is attached to a table-top belt sander makes it possible to use the belt sander to grind a glass disk quickly to a specified diameter within a tolerance of about ±0.002 in. (about 0.05 mm). The belt sander with this machine attached is intended to be used in place of a production-shop glass grinder, which is more versatile (able to grind tapers, cones, and other shapes as well as cylindrical disks), but is far more expensive, slower, larger, and more accurate than necessary for most applications. Whereas a typical production-shop glass grinder costs about $100,000, the attachment-and-sander combination costs only about $6,000 (1993 prices).

The belt sander is a standard commercial unit equipped with a gravity-feed water-drip system that cools and lubricates the disk and belt at the point of contact. The belt is of a diamond-abrasive type that cuts faster and lasts about 1,000 times longer than carborundum-type belts. A motor turns the 64-in. (1.63-m) belt at 1,725 r/min.

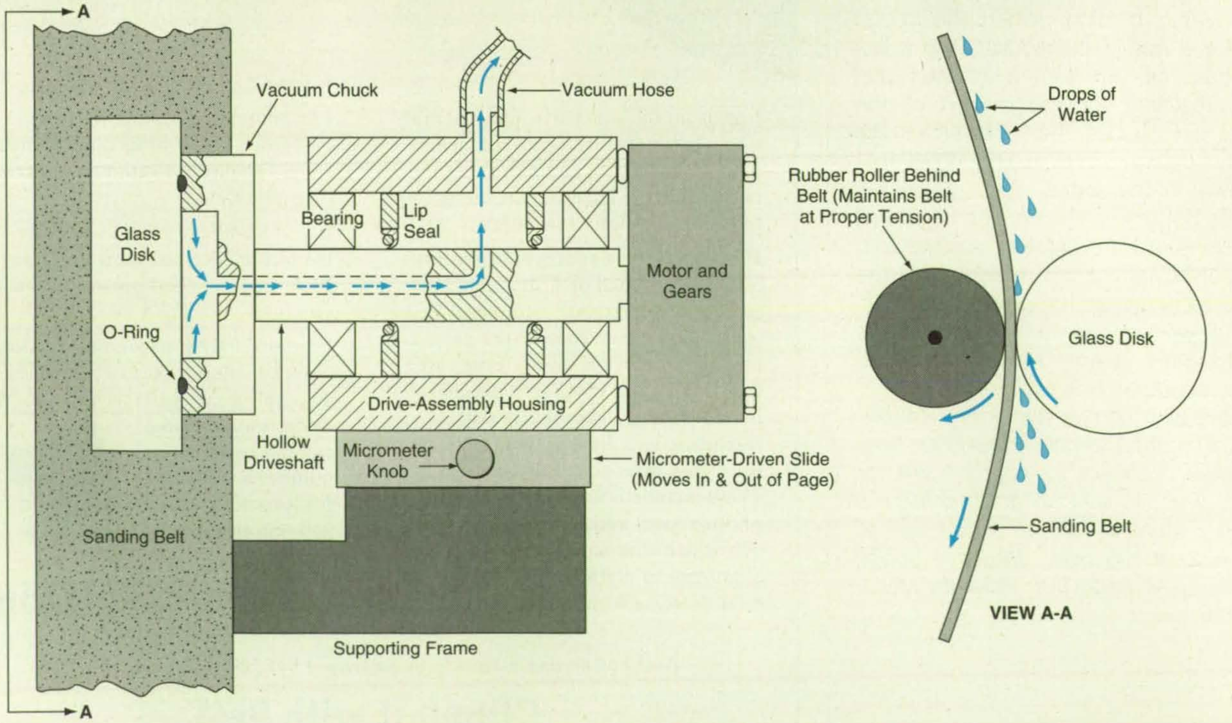
The attachment includes a supporting frame, a motor-driven drive assembly, and a micrometer-driven slide that is used to adjust the position of the drive assembly (see figure). The drive assembly holds the glass disk to be ground, pressing the edge of the disk against the sanding belt and rotating the disk in a direction opposite the motion of the belt. A technician adjusts the micrometer, which is graduated in increments of 0.001 in. (0.0254 mm), until the glass disk has been ground down to the specified diameter.

The glass disk is held by a vacuum chuck on the outer end of a hollow driveshaft that protrudes from the drive assembly. The drive assembly rotates the shaft to turn the glass disk against the sanding belt at 18 r/min. An O-ring seals the glass disk to the vacuum chuck. The vacuum is supplied by an external vacuum pump through a hose to a cavity in the drive-assembly housing, then through a side hole into the axial hole in the hollow driveshaft. A pair of pressure-assisted lip seals around the driveshaft in the cavity of the drive-assembly housing prevents leakage of air into the vacuum line.

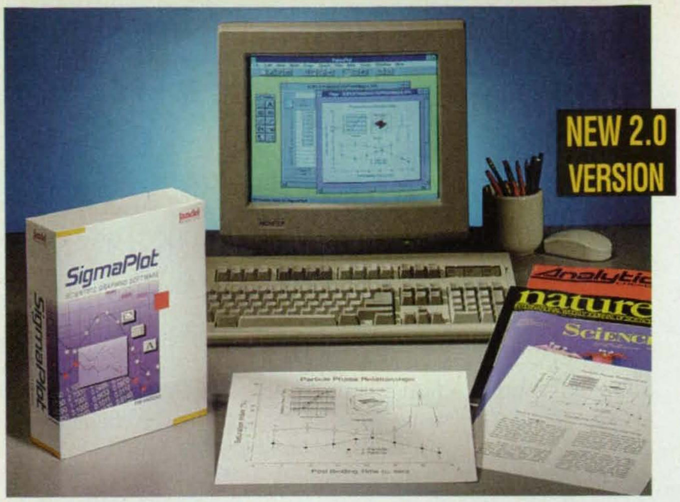
The vacuum chuck makes it unnecessary to fasten the disk with wax, as is done on production-shop grinders. Mounting the disk on the vacuum chuck takes only seconds instead of as much as a half hour when wax is used. The disk is released just as quickly, and there is no wax to clean from either the chuck or the disk.

This work was done by James J. Lyons III of **Goddard Space Flight Center**. *For further information,* ***write in 6*** *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 20]. Refer to GSC-13580.



Held on the Driveshaft by Vacuum, the glass disk is rotated while its periphery is ground by a continuous sanding belt.



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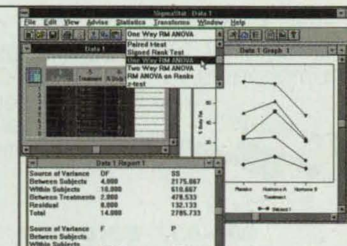

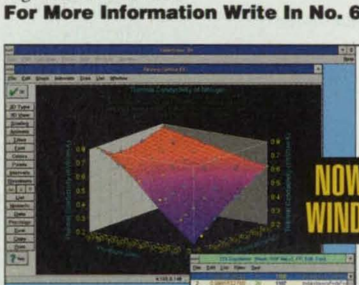

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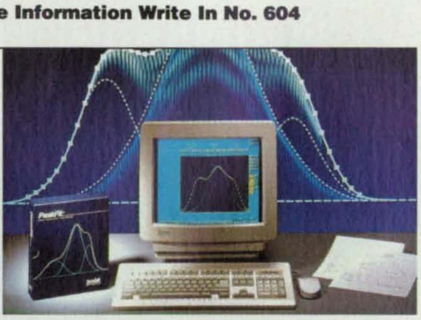

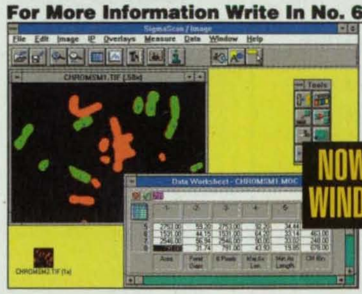

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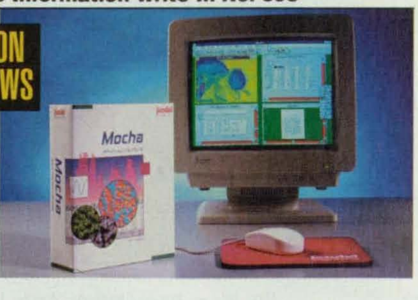


Computing Dynamics of a Robot of 6+*n* Degrees of Freedom

An improved formulation is widely applicable and requires less computation than do prior methods.

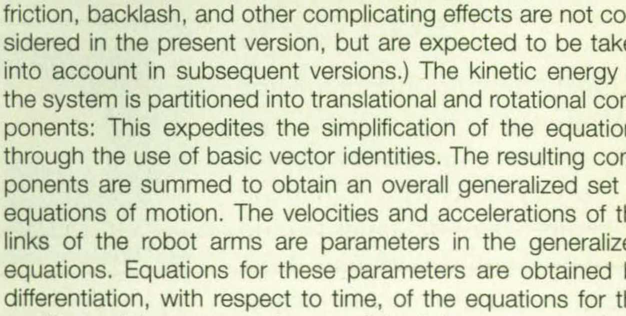
Lyndon B. Johnson Space Center, Houston, Texas

An improved formulation speeds and simplifies the computation of the dynamics of a robot arm of *n* rotational degrees of freedom mounted on a platform that has three translational and three rotational degrees of freedom. This formulation is intended for use in dynamical modeling of robotic manipulators attached to such moving bases as a spacecraft, aircraft, vessel, or land vehicle. Such modeling is an important part of the simulation and control of robotic motions.

Prior formulations have been limited, for the most part, to stationary-base industrial robots that have specific configurations, and have required more computation than could be performed in real time. The new formulation overcomes both limitations, offering the potential for real-time modeling, on typical computer workstations, of the dynamics of both fixed- and moving-base robotic manipulators that have a variety of configurations.

The improved formulation begins with Lagrange's equations of motion for the 6+*n*-degree-of-freedom system. (Gravitation, friction, backlash, and other complicating effects are not considered in the present version, but are expected to be taken into account in subsequent versions.) The kinetic energy of the system is partitioned into translational and rotational components: This expedites the simplification of the equations through the use of basic vector identities. The resulting components are summed to obtain an overall generalized set of equations of motion. The velocities and accelerations of the links of the robot arms are parameters in the generalized equations. Equations for these parameters are obtained by differentiation, with respect to time, of the equations for the positions of the centers of mass of the links.

The generalized equations of motion are put in matrix◊vector form. Intermediate parameters are introduced for simplification. Coriolis, centrifugal, and cross-coupling terms are combined into a generalized forcing-function term, and inertial terms are factored out to form a mass matrix, in which elements are arranged in three block-diagonal groups that represent the translational degrees of freedom of the base, the rotational degrees of freedom of the base, and the rotational degrees of freedom of the joints of the manipulator, respec-



The Computing Time required to conduct a representative dynamical simulation was found to increase only slightly more steeply than linearly with *n*. Typically, in prior formulations, the computing times increase more steeply with *n*, making real-time simulation impractical.

tively. In this form, the forward dynamics problem (given the forces and torques, find the accelerations) can be solved.

The new formulation was tested in representative simulations involving the six degrees of freedom of the platform and various *n* from 0 to 7. As shown in the figure, the computation time increased slightly more steeply than a simple linear dependence on *n*, but much less steeply than a quadratic dependence on *n*.

This work was done by Leslie J. Quiocho of **Johnson Space Center** *and Robert W. Bailey of Lincom Corp. For further information,* ***write in 158*** *on the TSP Request Card. MSC-21751*

Improved Program for Calculation of Heat-Load Multiplier

Repetitive calculations are accelerated and partly automated.

Marshall Space Flight Center, Alabama

The PRM1940 computer program computes a heat-load multiplier for use in the Power Balance Model (PBM) computer program. PBM calculates hundreds of operating parameters of the main engine of the space shuttle from relatively few measurement data. PRM1940 is a stand-alone program which incorporates only those PBM calculations necessary to compute the heat-load multiplier. PRM1940 was developed to accelerate and partly automate the calculation of the heat-load multiplier; previously, the heat-load multiplier was calculated in a time-consuming, labor-intensive procedure that involved multiple runs of PBM. Although these programs are specific to the space shuttle application, they may be of interest to engineers concerned with monitoring of conditions in turbines, chemical-processing plants, and other high-temperature flow machinery.

One of the parameters that PBM calculates is the rate of coolant flow in the main combustion chamber of the engine. It determines this rate in an iterative fashion by varying the rate until two independent methods of calculating the rise in enthalpy of the main-combustion-chamber coolant yield values that agree with each other. One of these enthalpy-rise calculations is based on measured temperatures and pressures. The other is based on a main-combustion-chamber reference heat load, which is scaled by the heat-load multiplier. Previously, the user supplied the heat-load multiplier. The user "tuned" the rate of flow to a desired value by use of this multiplier.

PRM1940 reads files of data specified by the user and performs only those calculations that are necessary for the PBM iterative calculation of the rate of flow. PRM1940 calls an algorithm (known as the Osugi algorithm) that determines the desired rate of flow, then varies the heat-load multiplier until the rate of flow calculated via the PBM methodology matches the Osugi rate of flow.

The resulting heat-load multiplier is written to a file in a format in which it can be incorporated directly into the PBM input file. The user enters this multiplier into PBM, which then calculates a rate of flow matched to the Osugi rate.

This work was done by Mark D'Valentine of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information,* ***write in 102*** *on the TSP Request Card. MFS-30019*

Automated Hardware-Identification System

Compressed symbology will be used to reduce paperwork and coordinate flows of information and hardware.

Marshall Space Flight Center, Alabama

Computer-controlled peening and engraving machines have been used to apply compressed symbology to hardware components made of a variety of metals, as part of a continuing effort to develop "paperless" systems for manufacturing and for tracking inventories. "Compressed symbology" denotes an emerging technology that involves one- and two-dimensional arrays of surface depressions to form optically readable dots. These patterns are more durable and are generally denser than common bar codes are. Like bar codes, they convey identification data in binary form and are read by optoelectric sensors. Computers and the compressed-symbology engraving machines that they control will eventually constitute subsystems of "paperless" hardware-tracking and -identification systems that will coordinate flows of both identifying information and the identified parts themselves, along with ancillary information like work orders.

The computer in an experimental subsystem of this type identifies appropriate marking devices, converts identification data into marking code, and automatically drives the marking operation. The software that controls these functions guides the marking-machine technician through a brief, easy-to-understand question-and-answer session. Future modifications of the software are expected to accelerate marking operations, eliminate the need for trial or practice marking, and reduce the incidence of errors. These modifications will include incorporation of optimum hardware-marking parameters and/or marking-machine-setup information for each major type of material to be marked. In addition, import and export links to the user's host computer are being incorporated to enable verification of serial numbers and other part numbers before marking operations begin. Eventually, the computer will select the marking sequence on the basis of the data on the identity of each part.

Plans for a prototype part-identifying subsystem call for a portable pen computer with symbol-decoding software operating in conjunction with a hand-held charge-coupled-device video camera. A host computer will write the electronic equivalent of work-authorizing documents, which will be downloaded to the portable computer. Using the portable computer, a technician will call up the documents and use them to perform manufacturing operations. By use of the camera, data on identities will be acquired from compressed symbology on parts, employee badges, and menus that reside in the affected work areas. These data will be incorporated into the appropriate places in the electronic documents. Upon completion of manufacturing operations, updated information on the work status of identified parts will be downloaded to the host computer via radio transmission.

This work was done by Harry F. Schramm, Jr., of **Marshall Space Flight Center** *and Donald L. Roxby of Rockwell International Corp. For further information,* ***write in 93*** *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 20]. Refer to MFS-28776.

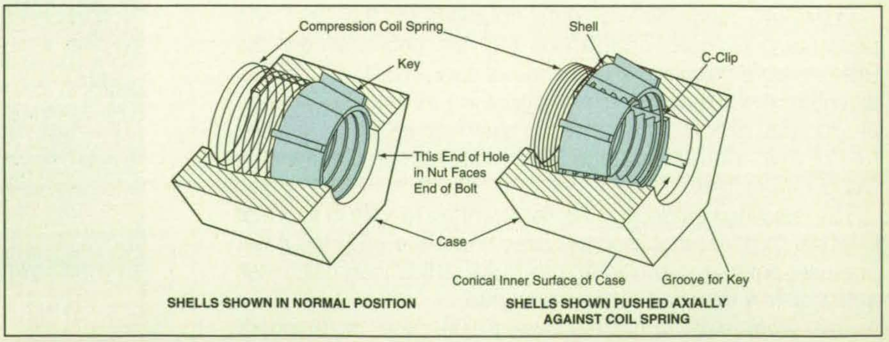
Quick-Connect, Slow-Disconnect Nut

The nut would snap into engagement but would be turned conventionally for removal.

Marshall Space Flight Center, Alabama

The figure illustrates a proposed quick-connect, slow-disconnect nut that would be installed simply by pushing it onto a standard bolt or threaded stud. Once installed, it could be removed only by unscrewing it in the manner of a conventional nut.

The nut would include a hexagonal outer case that would resemble an ordinary nut and would hold several shells in its hole. Each shell would include a key that would protrude radially outward and engage a lengthwise groove in the case: this would prevent rotation of the shell relative to the case. Most of the inner



The Shells Would Be Pushed toward the wide end of the cone during installation, causing the shells to slide over the threads on the bolt. Then the spring would push the shells back toward the narrow end of the cone, causing the threaded inner surfaces of the shells to engage the bolt thread.

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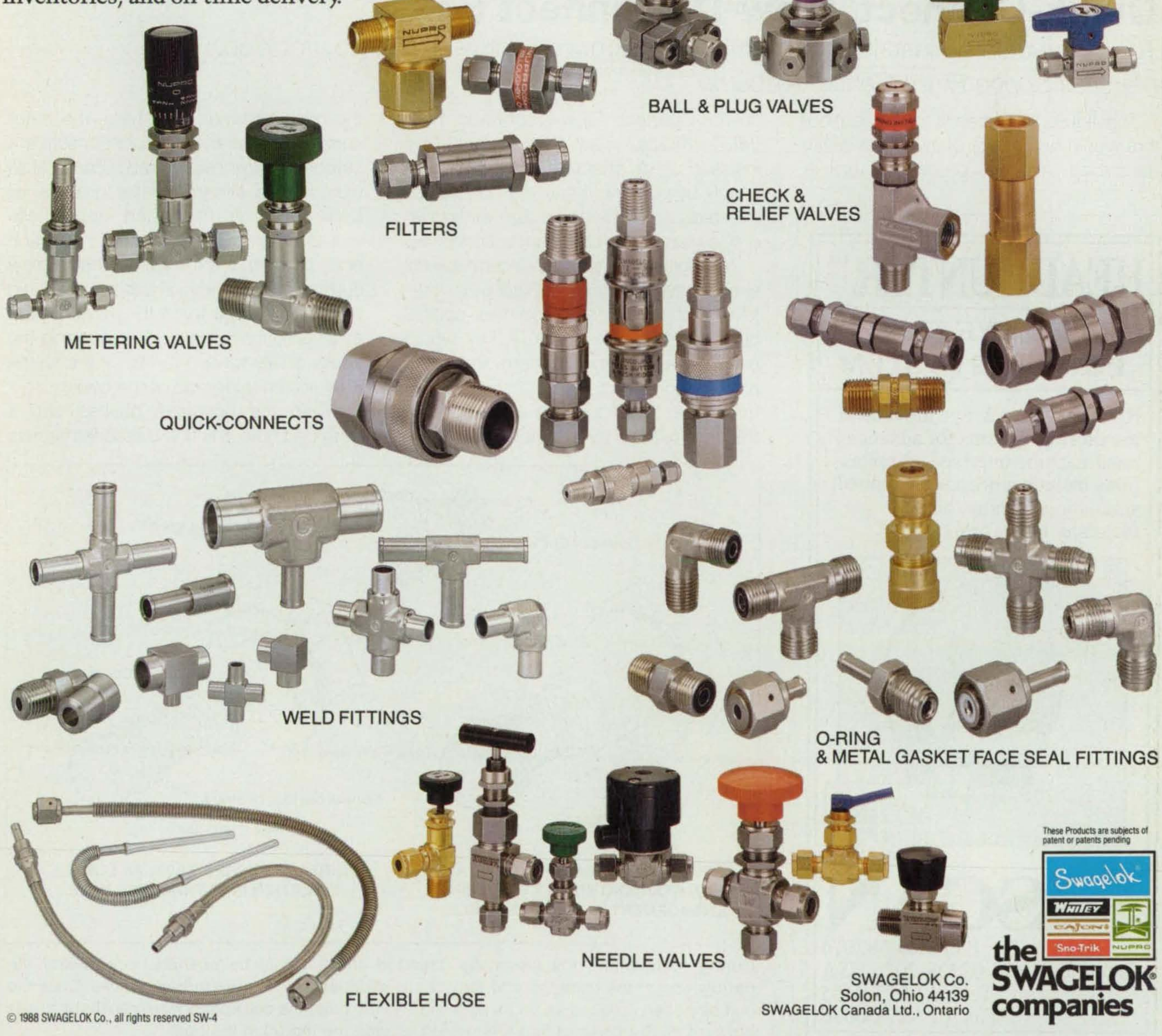

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surface of the hole would be conical, and each shell would have a conical outer surface that would slide axially on the conical inner surface of the hole. Except in the gaps between the shells, the inner surfaces of the shells would collectively constitute a standard threaded surface. Two C-shaped spring clips would be snapped into recesses at the ends of the shells. These clips would push the shells outward against the conical inner surface of the hole, thereby also pushing them axially toward the wide end of the cone. A coil spring would provide sufficient force to overcome the axial force from the C-clips, pushing the shells axially toward the narrow end of the cone, where they would be stopped by a flange.

In preparation for installation of the nut on a bolt, the nut would be oriented with the narrow end of the cone nearest the nut. The nut would then be pushed axially onto the bolt, causing the bolt to push the shells, against the coil spring, toward the wide end of the cone, while the C-clips would push the shells radially outward. The shells would then slip past the external thread on the stud.

Once the nut had been pushed as far as possible onto the bolt, the coil spring would again force the shells toward the narrow end of the cone, causing the shells to move radially inward and engage the bolt thread. Thereafter, the nut would be retained by the bolt; trying to pull the bolt out of the hole would only cause it to engage the nut more securely.

The nut would then be secured further by rotating it clockwise in the usual way. The keys would force the shells to rotate with the outer case. This motion would drive the shells toward the narrow end of the cone until they squeezed radially inward against the bolt thread and/or were stopped by the flange at the narrow end of the cone. In acting as a hard stop, the flange would limit the outward force exerted by the shells on the case, thereby preventing splitting of the case in the tightened condition. To remove the tightened nut, one would simply rotate it counterclockwise in the usual way until it disengaged from the bolt thread.

This work was done by Bruce Weddendorf of **Marshall Space Flight Center**. *For further information,* ***write in 244*** *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, Marshall Space Flight Center [see page 20]. Refer to MFS-28833.

Quick-Connect, Slow-Disconnect Bolt

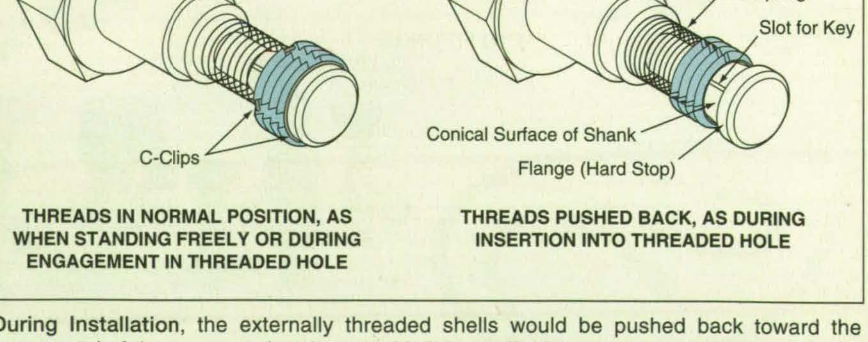
The bolt would be installed by pushing, but removed conventionally by rotation.

Marshall Space Flight Center, Alabama

The figure illustrates a proposed bolt that would function similarly to the device described in the preceding article, "Quick-Connect, Slow-Disconnect Nut" (MFS-28833). The bolt would be installed in a standard threaded hole simply by pushing it into the hole. Once inserted, the bolt could be withdrawn only by turning it in the conventional way.

The bolt would include circumferential shells, each having a conical inner surface that would slide on the conical outer surface of a shank. A key would protrude radially inward from each shell and would engage a lengthwise slot in the shank: this would prevent rotation of the shell relative to the shank. Except in the gaps between the shells, the outer surfaces of the shells would constitute a standard external thread. Each shell would have circumferential grooves at both ends. A C-shaped spring clip would wrap around all shells at each end, holding them against the conical surface of the shank. A coil spring would provide sufficient force to overcome the axial force from the C-clips, pushing the shells axially toward the tip of the shank (toward the wide end of the cone).

When the bolt was pushed into a threaded hole, the first thread in the hole



During Installation, the externally threaded shells would be pushed back toward the narrow end of the cone, so that they would slide readily, into the threaded hole. Once the bolt had been inserted as far as possible into the hole, the coil spring would push the shells outward on the cone so that they would engage the thread in the hole.

would drive the shells back, away from the end of the bolt compressing the coil spring. As the shells moved toward the narrow end of the cone, the C-clips would urge them radially inward. This action would reduce the outside diameter of the shells to less than the minor diameter of the thread in the hole. The shells would thus slip into the hole.

Once the bolt had been pushed as far as possible into the hole, the coil spring would again force the shells toward the wide end of the cone. As the shells moved outward on the cone, they would come into engagement with the thread in the hole. At this point, the bolt would be positively retained in the hole; pulling the bolt would only drive the shells more firmly into the thread in the hole.

Installation would be completed by turning the bolt clockwise to tighten it in the conventional manner: The keys in the shells would force them to rotate with the shank when the bolt head was turned: this motion would drive the shells toward the wide (outer) end of the cone, until they are stopped by the flange at the end of the bolt. This flange serves to carry almost all of the tension load of the bolt, with a small component carried by the conical surface. By increasing the diameter of the conical surface, it can be made to carry more of the tension, which will produce a radial force to lock the fastener if desired. To loosen the bolt, one would simply turn it counterclockwise in the usual way until it disengaged from the threaded hole.

This work was done by Bruce Weddendorf of **Marshall Space Flight Center**. *For further information,* ***write in 243*** *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, Marshall Space Flight Center [see page 20]. Refer to MFS-28829.

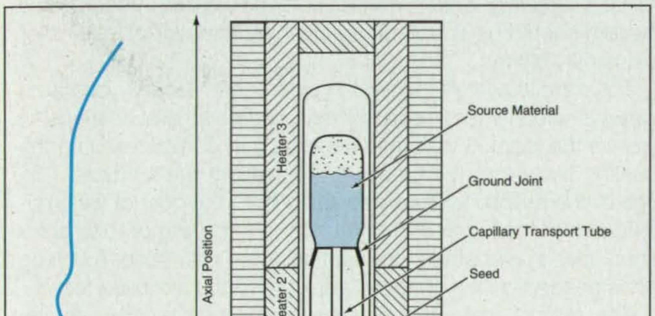
Improved Growth of Cadmium Telluride Crystals From Vapors

High-quality crystals can be grown efficiently.

Lewis Research Center, Cleveland, Ohio

Effusive ampoule physical vapor transport (EAPVT) is an improved technique for growing high-quality crystals from vapors. EAPVT is likely to be used commercially for efficiently growing various semiconductor compounds in the form of single crystals of high structural and compositional uniformity.

Because crystals are grown from vapors at temperatures lower than those used to grow crystals from melts, the crystals grown from vapors are often purer and more nearly structurally perfect. However, growth of crystals from vapors has largely been limited to preparation of layers rather than bulk crystals. This is because most workers in vapor growth have observed slow growth and complex transport behavior. Recent research has shown that these difficulties are not inherent features of crystallization from vapors but are largely consequences of traditional vapor-growth technology, which provides for only limited control of parameters of transport and growth. In particular, fluid-dynamic studies of vapor transport in closed ampoules have shown that the limitations on transport result from accumulations of gaseous impurities around growing crystals.



The **EAPVT Apparatus** is shown here in schematic cross section along with an idealized axial temperature profile.

The development of EAPVT was guided by these insights. In EAPVT (see figure), impurity vapors and excess (incongruent) components of the growth vapor(s) are continuously removed from the vicinity of the growing crystal by effusion through predetermined leaks to a vacuum. Transport under the resulting congruent vapor conditions is so rapid that it is necessary to take measures to limit transport rates to values conducive to a high degree of structural perfection of new growth onto a single-crystal seed plate. Accordingly, transport rates are controlled by use of capillary restrictions between the vapor source and the growing crystal. The EAPVT apparatus also includes an infrared-reflective viewing port for optical *in situ* monitoring of the structure of the growing crystal, thereby enabling the efficient determination of optimal thermal and transport operating conditions.

In an experiment, EAPVT was used to grow cadmium telluride, which is important for making optoelectronic devices. Largely-single-crystal boules 25 mm in diameter and 25 mm long were produced within 48 hours: This demonstrated rates of growth that approach those obtained in melt growth of cadmium telluride. The boules exhibited dislocation (etch-pit) densities as low as 2×10^3 cm^{-2}, low twin densities, and carrier concentrations $\approx 8 \times 10^{15}$ cm^{-3}. Tellurium precipitates were limited to grain and twin boundaries, and optical absorption measurements indicated high purity of the material.

This work was done by Franz Rosenberger and Michael Banish of The University of Alabama in Huntsville and Walter M. B. Duval of **Lewis Research Center**. *Further information may be found in NASA TM-103786 [N92-16158/TB], "Vapor Crystal Growth Technology Development — Application to Cadmium Telluride."*

Copies may be purchased [prepayment required] from the NASA Center for AeroSpace Information, User Services Division, Linthicum Heights, Maryland, Telephone No. (301) 621-0394. Rush orders may be placed for an extra fee by calling the same number. LEW-15737

Enhancement of Water-Jet Stripping of Foam

A robotic water-jet system removes foam only; adjacent areas are spared.

Marshall Space Flight Center, Alabama

An improved robotic high-pressure-water-jet system strips foam insulation from parts without removing adjacent coating materials like paints, primers, and sealants. The robot can even inject water into crevices and blind holes to clean out foam, without harming adjacent areas. Developed for postflight refurbishing of aft skirts of booster rockets, the system includes a six-axis robot that has been provided with a special end effector and specially written control software, called Aftfoam. The system should be adaptable to cleaning and stripping in other industrial settings.

The robotic system is used in place of a manually operated water-jet cleaner that inevitably removed peripheral coatings as well as the foam. It was then necessary to completely strip the coating by walnut-hull blasting, then recoat the surfaces. The use of the robotic system eliminates both the cost of full stripping and recoating and the problem of disposing of toxic solutions used in preparation for coating. Now, only minor touching up is needed on the surfaces adjacent to the removed foam.

The robotic foam-stripping system blends readily into the existing production environment. The special foam-stripping end effector is designed to be highly reliable and requires only normal maintenance. No additional safety procedures are required.

This work was done by Steven A. Cosby, Charles H. Shockney, Keith E. Bates, John P. Shalala, and Larry S. Daniels of United Technologies Corp. for **Marshall Space Flight Center**. *For further information,* ***write in 97*** *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 20]. Refer to MFS-28851.

NEW!

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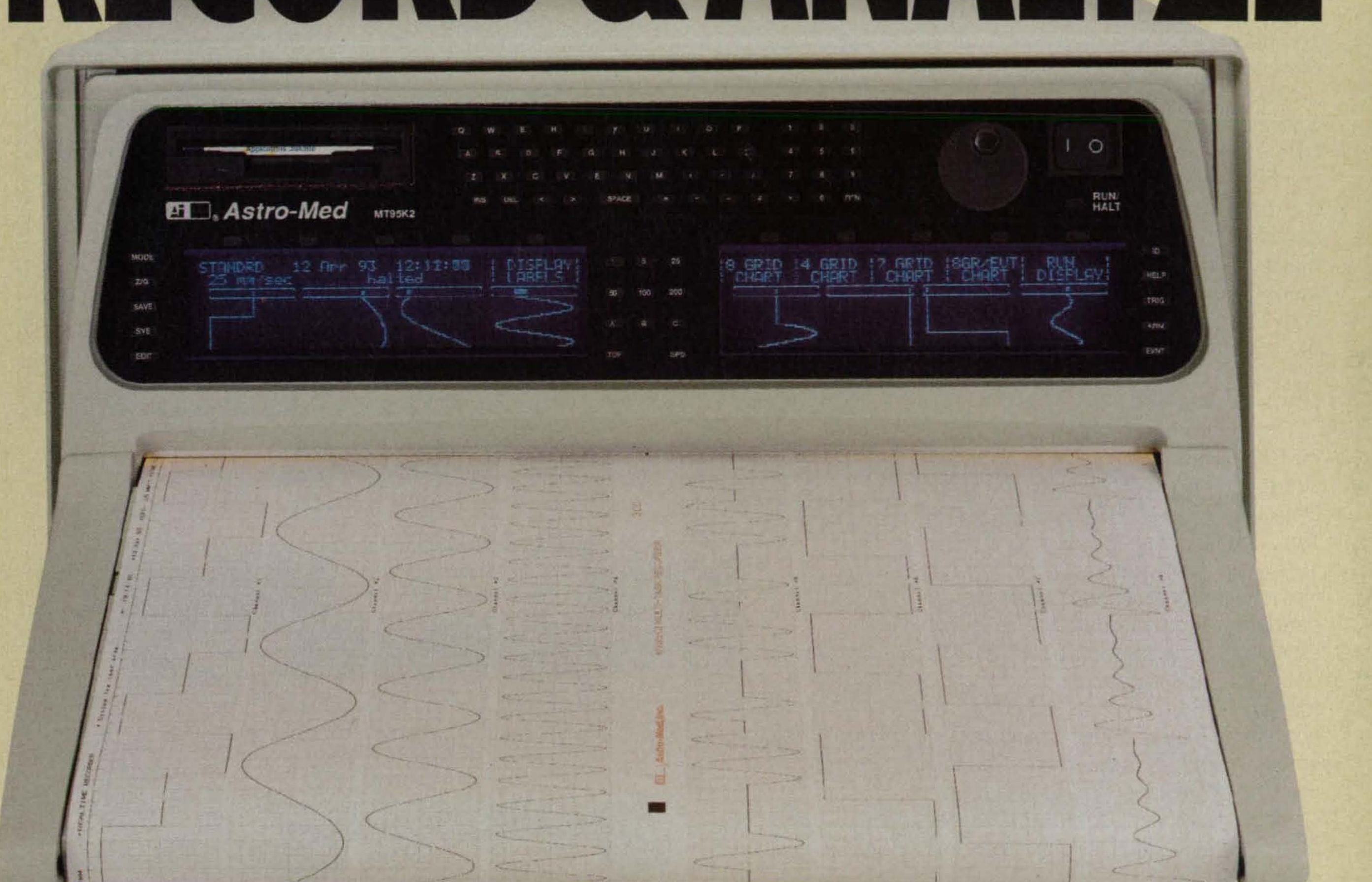

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Detecting Faults by Use of Hidden Markov Models

The frequency of false alarms can be reduced.

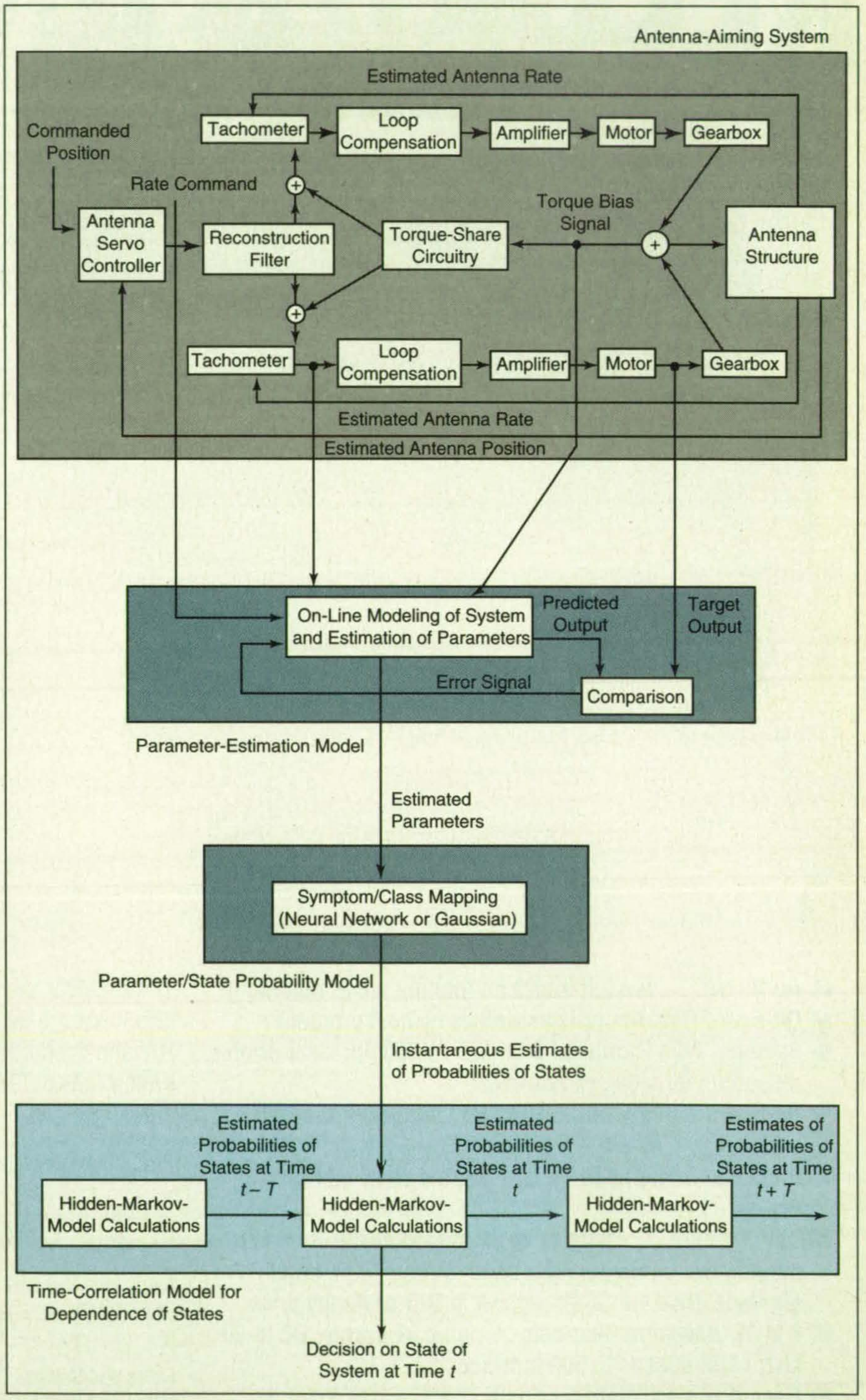
NASA's Jet Propulsion Laboratory, Pasadena, California

Faults in a complicated dynamic system (e.g., an antenna-aiming system as shown in the figure, a telecommunication network, or a human heart) can be detected automatically by a method of automated, continuous monitoring. The basic idea is to obtain time-series data by sampling multiple sensor outputs at discrete intervals of t and to process the data via an algorithm that determines whether the system is in a normal or faulty state. The algorithm implements, among other things, a hidden first-order temporal Markov model of the states of the system. A mathematical model of the dynamics of the system is not needed.

The present method is the "prior" method mentioned in "Improved Hidden-Markov-Model Method of Detecting Faults" (NPO-18982), NASA Tech Briefs, Vol. 18, No. 8 (August 1994), page 44. The monitoring problem can be stated as a data-classification problem: Let there be k sensors, the collective outputs of which constitute a k-dimensional output vector $\mathbf{y}(t)$, where t is time. Given the sequence of $\mathbf{y}(t)$ sampled at discrete intervals of t, infer the current state of the system; that is, assign the data to a class that represents the current state of the system.

In the present method, one assumes that at any given time, the system can be in only one state (the ith state, denoted ω_i), which is a member of a finite set of m states. Only the state ω_1 is deemed normal; the other states (ω_2 through ω_m) are deemed faulty. It is assumed that all faults and their symptoms can be identified in advance by testing, simulation, and/or use of design information, and that a data base called a "fault library" can be generated for both the normal and faulty states: the fault library consists of pairs of symptom vectors and class (state) labels of the form $\{\mathbf{y}_j, \omega_{i(j)}\}$, $1 \leq j \leq N$, where N is the total number of pairs in the library.

The sampled data $\mathbf{y}(t)$ are not used directly but instead are first preprocessed into feature vectors $\theta(t)$ that



The Hidden-Markov-Model Method Was Tested by using it to diagnose faults in the electronic/electromechanical aiming system of a large astronomical antenna. This method yielded fewer incorrect diagnoses of normal or faulty conditions than did other methods.

represent relevant statistical characteristics of the time series and are assumed to be sufficient to characterize the system. For this purpose, consecutive sampling intervals τ are grouped into consecutive blocks of time, each $T = W\tau$ long (where W is an integer), and the feature vector for the block at time t is given by

$$\theta(t) = f\left(y(t), y(t-\tau), \ldots, y(t-T)\right)$$

The state of the system is not directly observable but must be inferred from $\theta(t)$.

The first-order temporal Markov model used in this method involves the assumption that

$$p\left(\omega_i(t)\middle|\omega_j(t-T)\omega_j(t-2T)\ldots, \omega_j(T)\right) = p\left(\omega_i(t)\middle|\omega_j(t-T)\right)$$

where p denotes conditional probability. This equation means that the conditional probability of any current state, given knowledge of all previous states, is the same as the conditional probability of the current state, given knowledge of the state at time $t - T$. Hence, assuming stationarity, to calculate the probability of any state at time t, one need know only $p(\omega_i(t) | \omega_j(t - T))$ plus the initial state probabilities $\pi = p(\omega_1(0), \ldots, \omega_m(0))$, which can be derived from mean times between failures or other gross failure statistics. The $m \times m$ matrix A, given by $\alpha_{ij} = p(\omega_i(t) | \omega_j(t - T))$, is known as the transition matrix and characterizes the Markov model. Given A and π, one can calculate the probability of any state at any time t.

The space available for this article does not allow a detailed description of the use of the hidden Markov model. Briefly, one computes the current posterior probabilities of the states by a recursive algorithm that involves Bayes' rule, the present feature vector, the immediately preceding posterior probabilities, and the transition matrix. The use of the hidden Markov model thus provides for incorporation of the temporal context in conjunction with traditional classification. The Markov-model approach can reduce the false-alarm rate significantly by taking advantage of any time-domain redundancy that may be present.

This work was done by Padhraic J. Smyth of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 122*** *on the TSP Request Card. NPO-18946*

Microfermentation Test for Identification of Yeast

Results can be obtained in days instead of weeks.

Lyndon B. Johnson Space Center, Houston, Texas

A microfermentation test has been developed as a supplementary method for use in identifying yeasts, especially in clinical and environmental studies. In comparison with traditional fermentation tests, the microfermentation test is simpler and easier, and it requires less equipment, material, and laboratory space. The microfermentation test is also faster; it yields a conclusive result within 3 to 5 days, whereas a traditional fermentation can take 3 to 4 weeks. The greater speed of the microfermentation test can sometimes make a great difference in a clinical setting; in the case of a potentially fatal yeast infection, treatment must be started promptly, and the correct treatment depends on the identification of the yeast species.

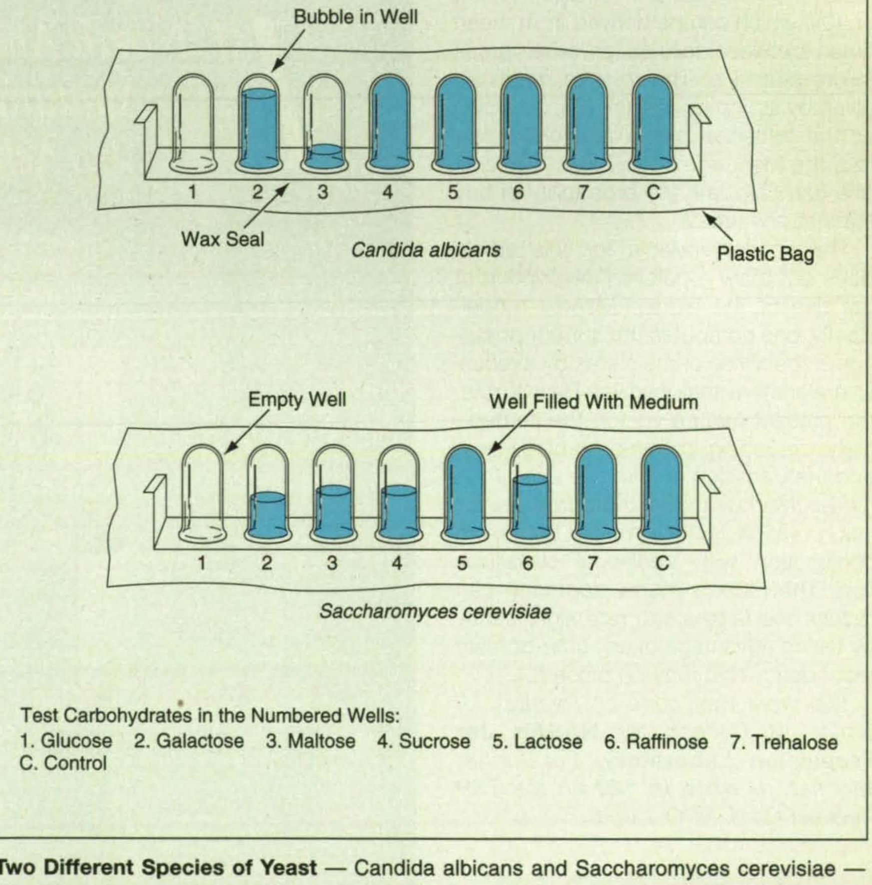
The microfermentation test differs from traditional fermentation tests in the details of implementation, but is based on the same principle. The basic idea is that each species of yeast ferments one or more carbohydrate(s), producing carbon dioxide. Thus, an unknown species of yeast in a suspension of cells can be identified by incubating samples of the suspension in media that contain different carbohydrates and looking for the presence (positive result) or absence (negative result) of carbon dioxide after the incubation period.

The microfermentation test is performed in a microtiter plate, which is essentially a plastic strip or plate dimpled with small wells that are numbered for identification. The volume of each well is a fraction of a milliliter. Usually, the microfermentation test is performed with eight different media; a control medium that contains no carbohydrate, and seven media that are similar except that each contains a different carbohydrate. In preparation for the microfermentation test, a microtiter plate of at least eight wells (one well for each medium) is sterilized with ultraviolet light.

The control medium is a basal medium that consists of distilled water containing peptone at a concentration of 7.5×10^{-3} g/mL and yeast extract at a concentration of 4.5×10^{-3} g/mL. Solutions of the seven carbohydrates are prepared, each solution consisting of one of the carbohydrates at a concentration of 8.5×10^{-2} g/mL in distilled water. A volume of 100 µL of the basal medium is placed in each well. Then to each well except the control well, 50 µL of the carbohydrate solution designated for that well is added. Next, 50 µL of the suspension that contains the unknown yeast cells is added to each of the eight wells. Each well is then sealed by pouring 25 µL of a molten, sterile, soft wax into the well on top of the liquid contents.

After allowing the wax to cool, the microtiter plate is placed with the sealed side down in a sterile Ziploc™ (or equivalent) closable plastic bag in an incubator at a temperature of 30 °C. The wells are observed daily for the production of CO_2 gas. In a well with a positive result, part or all of the medium is forced out by the formation of gas, as indicated by a bubble or by complete emptying of the well (see figure). In the control well and in any other well with a negative result, no gas is formed, as indicated by the fact that the well remains completely filled with its liquid medium.

This work was done by D. L. Pierson of **Johnson Space Center** *and S. K. Mishra and Thomas C. Molina of KRUG Life Sciences. For further information,* ***write in 103*** *on the TSP Request Card.* MSC-22377



Two Different Species of Yeast — Candida albicans and Saccharomyces cerevisiae — yielded positive results in different carbohydrate media in a microfermentation test.

Slow-Release Fertilizers for Plants

Pellets provide all of the micronutrients needed by plants of a given species.

Lyndon B. Johnson Space Center, Houston, Texas

A synthetic mineral provides growing plants with nutrients, including micronutrients (those consumed in trace quantities). The mineral dissolves slowly in moist soil or in a hydroponic solution, releasing its constituents.

The mineral is a synthetic apatite (which normally includes calcium phosphate and related compounds) into which the nutrients calcium, phosphorous, iron, manganese, copper, zinc, molybdenum, chlorine, boron, and sulfur are incorporated in the form of various salts. The table lists the starting materials used to synthesize the mineral.

The synthesis begins with the preparation of three stock solutions:

- **Solution A** - Compound 1 (see table) is dissolved in 0.5 L of 20 percent NH_3 in water.
- **Solution B** - Compounds 2 through 7 are dissolved in 0.46 L of deionized water, then 0.04 L of 20 percent NH_3 water is added.
- **Solution C** - Compounds 8 through 11 are dissolved in 20 mL of deionized water.

Solution B is stirred vigorously into solution A, then solution C is added and the mixture is stirred for another 5 min. The mixture is allowed to stand for 18 h, during which time the precipitate settles to the bottom. The supernatant liquid is then decanted and the precipitate is washed several times in deionized water. The washed precipitate is baked for 2 h at a temperature of 200 °C, then 2 h at 400 °C. The dry precipitate cake is crushed and pressed into pellets with 2.5 percent by weight lignosulfonate as a binder.

Each pellet has a homogeneous inorganic composition. The composition can readily be adjusted to meet the precise needs of a plant.

This work was done by Douglas W. Ming of **Johnson Space Center** *and D. C. Golden of the National Research Council. For further information,* ***write in 159*** *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 20]. Refer to MSC-21953.

	Chemical	Number of Moles in Solution
1	$Ca(NO_3)_2 \cdot 4H_2O$	0.7272
2	$(NH_4)_2HPO_4$	0.328
3	Na_2CO_3	0.2
4	NH_4Cl	0.2
5	$Na_2B_4O_7$	0.003
6	$(NH_4)_6Mo_7O_{24} \cdot 4H_2O$	9×10^{-7}
7	$(NH_4)_2SO_4$	0.02
8	$Fe(NO_3)_2 \cdot 6H_2O$	0.01
9	$MnCl_2$	0.006
10	$Zn(NO_3)_2$	0.002
11	$Cu(NO_3)_2$	6.3×10^{-6}

Synthetic Apatite Is Prepared from solutions of a variety of chemicals. The concentrations reflect the needs of a plant for various nutrients.

Books & Reports

These reports, studies, and handbooks are available from NASA as Technical Support Packages (TSPs) when a Request Card number is cited; otherwise they are available from the NASA Center for Aerospace Information.

Mechanics

Stresses in and Near a Bend in a Thin-Walled Duct

A report describes a computational study of distributions of stresses in and near a 90° bend in a thin-walled duct subject to various applied loads. The purpose of this study was to help satisfy the need for more accurate knowledge of local concentrations of stresses caused by the loads: such knowledge would make it possible to design light-weight ducts to survive reasonably fore-seeable operating conditions with some degree of reliability. Such knowledge could also guide the selection of locations for mounting strain gauges to measure local stresses for comparison with computed values, thereby contributing to refinement of theoretical concepts and computational techniques.

This work was done by J. B. Min and P. K. Aggarwal of **Marshall Space Flight Center**. *To obtain a copy of the report "Effect of Type of Load on Stress Analysis of Thin-Walled Ducts,"* ***write in 55*** *on the TSP Request Card. MFS-28863*

Mathematics & Information Sciences

Reliability-Engineering Manual

A tutorial book discusses principles and practices of reliability engineering. It begins with a brief historical discussion that illustrates the growing awareness of concepts of reliability and the consequent emergence of reliability engineering as a discipline. It reviews aspects of algebra, calculus, probability theory, and failure physics pertinent to reliability calculations. Mathematical models of reliability based on exponential distributions are explained. Examples of prediction using rates of failure are presented, along with a technique for allocating rates of failure to elements of a system. A discussion of the probability-density and cumulative probability functions [with emphasis on the normal (Gaussian) distribution] provides the basis for analysis of tolerance and wearout failure. Methods of testing for reliability are discussed. Mathematical models of the reliability of software are presented. Types of software, defects in software, and the concept of software quality are presented, followed by a discussion of how software quality is implemented. The final chapter discusses what is involved in setting up a reliability-management program and organization.

This book was compiled by Vincent R. Lalli of **Lewis Research Center**, *and Henry A. Malec of Digital Equipment Corp. along with a team of contributors. Further information may be found in NASA RP-1253 [N92-32456/TB] "Reliability Training."*

Copies may be purchased [prepayment required] from the NASA Center for AeroSpace Information, User Services Division, Linthicum Heights, Maryland, Telephone No. (301) 621-0394. Rush orders may be placed for an extra fee by calling the same number. LEW-15857

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continued from Mission Accomplished, page 14

fed Formulaid are comparable to levels in breast-fed babies. Last year, Formulaid was incorporated into pre-term infant formula and launched in Belgium and, recently, the British Nutrition Foundation recommended that infant milk formulas should include DHA and ARA at levels normally found in human milk.

Martek also produces a series of algae-derived stable isotope biochemicals for use as laboratory reagents to support discovery and design of new drugs. One of the company's patented growth media, known as Celtone M, is formulated to improve researchers' ability to determine the three-dimensional structure of human proteins through nuclear magnetic resonance (NMR) spectroscopy.

Celtone M is a mixture of amino acids in which each atom is labeled with a stable isotope, for example, carbon-13 or nitrogen-15. "Our algae are very good at incorporating stable isotopes. We bubble up carbon-13 dioxide and feed them potassium nitrate made entirely with nitrogen-15 atoms. The algae take these inorganic salts and make amino acids, which we separate and feed to mammalian cells," explained Linsert. "So, now, when the cells express a protein, each atom provides a signal that can be picked up using NMR. You can locate each carbon-13 and nitrogen-15 atom geographically. Therefore, you can know the protein's structure."

The new growth medium could prove a boon to researchers conducting structure-based drug design. In this discipline, drugs are developed by solving the 3D structure of target receptors, the sites on cells to which the drugs will bind. Celtone M labeled with carbon-13, nitrogen-15, and deuterium may enable the structural determination of proteins more than twice the size of those studied to date using NMR techniques. In 1994, Martek entered into agreements with Columbia University and the Genetics Institute for using the medium to determine human protein structures.

Further, Martek is developing minimally-invasive diagnostic products for detection of gastrointestinal disorders, such as small intestine bacterial overgrowth, fat malabsorption, liver malfunction, and lactose intolerance. The tests involve ingestion of a capsule containing a specific carbon-13 labeled compound, after which breath samples are collected periodically and analyzed for their carbon-13 content. The breath tests have the potential to replace invasive and expensive procedures such as endoscopies and biopsies for certain conditions.

Martek also has initiated a search for microalgae-derived pharmaceutical drugs. Today's drugs are derived mainly from bacteria, plants, and fungi. The plant-derived pharmaceuticals, for instance, currently account for 25 percent of all drugs, yet come from just 40 species. The tens of thousands of algal species hold the same potential but have never been exploited due to problems of large-scale monoculturing—problems Martek has solved.

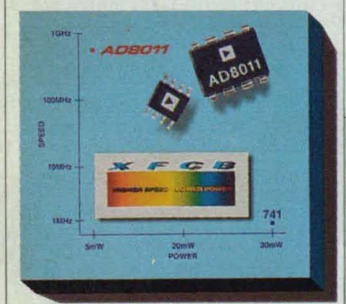
The company has accumulated the world's largest commercial living library of microalgal species, more than 1800 species, and developed the only known computerized database comprising all of the organisms in their library. Currently, Martek is screening the library for active compounds that may have pharmaceutical potential for the treatment of antibiotic-resistant bacteria or be effective against infectious fungi. Martek is collaborating with Merck & Co. and other pharmaceutical companies in this screening effort.

For more information about the technology described in this article, contact: Martek Biosciences Corp., 6480 Dobbin Road, Columbia, MD 21045. Tel: 410-740-0081; Fax: 410-740-2985.

New on the Market

Marketech International, Pittburgh, PA, has unveiled a new class of **ultrafine nanophase ceramic powders** having a typical diameter of 20 nm and a surface area of 109 m^2/g. The materials include silicon nitride (Si_3N_4), silicon carbide (SiC), a composite of silicon/nitride/carbide, silicon dioxide (SiO_2), and boron carbide (B_4C). Just a few thousand atoms in diameter, these materials have unique forming characteristics for plastic deformation and, because of their large surface area, are highly reactive.

For More Information Write In No. 718



Analog Devices, Norwood, MA, is offering the AD8011 **operational amplifier** with a 300-MHz bandwidth on a maximum of 1 mA supply current, consuming up to 5 mW from one +5 V supply. The device uses a two-stage circuit architecture and is priced at $1.95 in lots of 1000. For processing high-speed video signals, it offers 0.1 dB gain flatness to 25 MHz, 0.02% differential gain, and 0.06° differential phase error.

For More Information Write In No. 707

Targa Electronics Systems Inc., San Ramon, CA, has announced a 500 MB SCSI **solid-state disk** that has no moving parts, thereby eliminating data loss due to mechanical failure. The FLASH Memory architecture allows hard disk read-write compatibility requiring no additional software drivers. Designed for environments too severe for rotating media, the disks can operate under vibration (10 g, 5-2,000 Hz), shock (50 g), high altitude (50,000 ft), and temperature extremes (-40 to +85 °C).

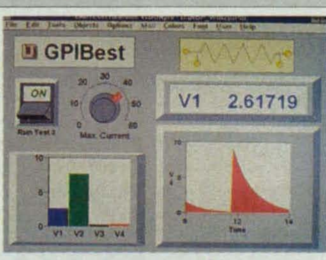
For More Information Write In No. 714

The computer-controlled and fully integrated AWS-150 **orbital arc welding system** from Weldlogic Inc., Chatsworth, CA, increases weld control while lowering the skill level required for operation. A full line of orbital tube weldheads accommodates circular tubes from 0.093- to 4.0-inch diameters. Front panel dial versions also are available.

For More Information Write In No. 715

Pressensor **pressure sensitive film** from Inteque Resources Corp., Fort Lee, NJ, provides a lasting visual record of pressure and pressure distribution across an entire area of contact between surfaces. When sandwiched between parts, the film immediately produces an image of the contact area in shades of red. It is available in 9.5" × 10.5" sheets.

For More Information Write In No. 719



DataLab Solution, a **data acquisition package** released by Laboratory Technologies Corp., Wilmington, MA, incorporates an 8-channel analog input board and a matched version of Notebook data acquisition software. Priced at $199 and designed to broaden the availability of computerized data acquisition beyond major research facilities, the package provides eight 12-bit single-ended analog input channels, eight bits of digital input, and eight bits of digital output.

For More Information Write In No. 717

The Oce 9575-S, an innovative **plotter/copier/scanner** from Oce-Bruning, Chicago, IL, incorporates LED electrophotographic technology to address both input and output of paper and digital documents in CAN and EDMS environments. A scan-to-file option allows the user to copy, scan, store, retrieve, view, edit, print, and finish documents in one multifunction system, at 400 dpi and up to 2 "E"-size documents per minute.

For More Information Write In No. 716

New on the Market

The MathWorks Inc., Natick, MA, is offering a **fuzzy logic software tool** that integrates with and extends the company's MATLAB technical computing and SIMULINK graphical simulation environments to streamline development of intelligently-controlled processes. The Fuzzy Logic ToolBox 1.0 makes fuzzy technology accessible for all phases of product development, from research and design to simulation and implementation of real-time systems. Features include five GUI-driven editors for each phase of fuzzy logic design and support for state-of-the-art fuzzy logic algorithms.

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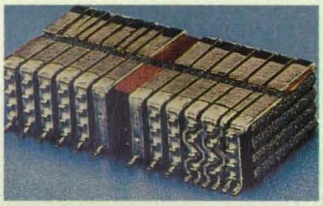
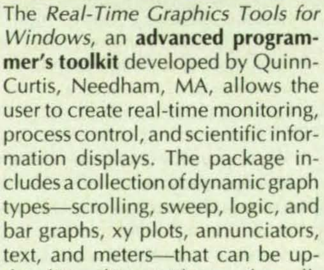


Staktek Corp., Austin, TX, has announced the Uniframe Stakpak™ **memory modules**, a stacked standard TSOP design that offers density improvements of two to four times that of standard, single-chip packaging with similar electrical and thermal performance. Available in stacks of 2 through 8, each module has a memory capacity of 64-256 MB for FLASH, 2-32 MB for SRAM, and 32-128 MB for DRAM. Also available are SIMM solutions with up to 128 MB in a 72-pin SIMM format.

For More Information Write In No. 711



The *Real-Time Graphics Tools for Windows*, an **advanced programmer's toolkit** developed by Quinn-Curtis, Needham, MA, allows the user to create real-time monitoring, process control, and scientific information displays. The package includes a collection of dynamic graph types—scrolling, sweep, logic, and bar graphs, xy plots, annunciators, text, and meters—that can be updated in real time with smooth scrolling and a minimum of redrawing and flicker. A variety of static chart types also is supported and LED indicators, buttons, scroll bars, and check boxes can be added to any graphics window.

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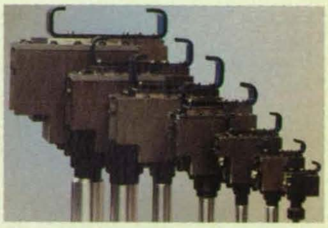
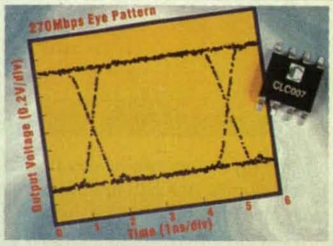


Mono-Grippers, a new line of **grippers** from ZAYTRAN, Inc., Elyria, OH, having one stationary and one moveable jaw, were developed for fixed automation systems that handle single-sized parts and do not need a centering gripper's flexibility. Engineered to go 10,000,000 cycles, the gripper bodies are hardcoated to maintain position repeatability to within 0.00", while the cylinder bores are treated to improve seal life and minimize friction.

For More Information Write In No. 710



Comlinear Corp., Fort Collins, CO, has unveiled two 400 Mbit/sec **serial digital cable drivers** designed to conform to the SMPTE 259M standard for the transmission of serial digital video signals. The drivers accept single-ended or differential ECL input signals (-0.8 V/-1.6 V) and drive single-ended ECL levels ($800mV_{pp}$) over AC-coupled back-matched 75Ω video loads.

For More Information Write In No. 704

Lubralloy®, a chemically deposited, hard nickel-alloy **plating process** from Microfin Corp., Providence, RI, produces a uniform, smooth, and wear-resistant coating on complex shapes. Conferring low-friction advantages to moving parts, the plating works optimally with aluminum, titanium, stainless steel, high nickel alloys, and copper. Abrasion- and corrosion-resistant, the coating can extend wear life up to four times.

For More Information Write In No. 702

AbTech Corp., Charlottesville, VA, has announced a Windows version of AIM™ (Abductive Information Modeler), a **modeling tool** that automatically models parameters such as prices, expert judgments, probabilities, fuzzy values, costs, sensor readings, and control settings. AIM often can produce more accurate and robust models than neural networks and regression techniques.

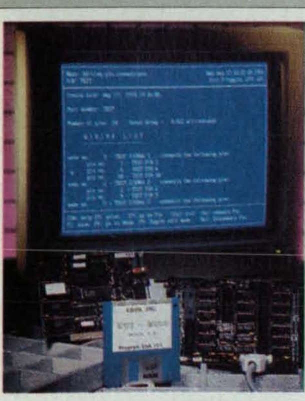
For More Information Write In No. 705

New on the Market

A portable SCSI **target tester** has been introduced by Ancot Corp., Menlo Park, CA, for stress testing of direct-access, CD-ROM, optical memory, and other devices. Running as a stand-alone unit or under the control of a PC, all results are saved in non-volatile memory. The device measures SCSI command timings with 100-nsec resolution, automatically scans the SCSI bus for up to 15 testable targets, and supports the new SCAM protocol.
For More Information Write In No. 703

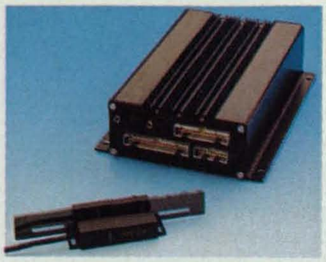
E-A-R Specialty Composites, Indianapolis, IN, has formulated ISOLOSS® HD **polyurethane elastomer**, a proprietary damping and isolation material that controls unwanted mechanical energy in applications ranging from shock control in miniature disk drives to noise and vibration reduction in industrial assembly equipment. The material can be applied to gasketing, sealing, constrained-layer damping, and vibration isolation.
For More Information Write In No. 712

Scantek Inc., Silver Spring, MD has announced Distiller™, **data management software** that combines signal processing and graphics with relational database architecture to derive select information from masses of raw data in complex data analyses. For example, in finding the largest magnitude signal from 15-channel recordings of 40 different operating modes, Distiller can reduce analysis time by a factor of 25. The package includes modules for statistics, analysis of complex vibration signals, and computation of frequency response.
For More Information Write In No. 701



The Zero Path Encoder, ZPE-100, from Opti-Cal, Los Osos, CA, is a **holographic linear encoder** system with resolutions from 3 to 200 nm. The highly stable unit features quartz scales combined with a read head just 0.5" high, and overall repeatability of <0.01 micron. It includes quadrature and up/down outputs.
For More Information Write In No. 708

Vertex Technologies, Cincinnati, OH, has introduced the Automatic Supply Depot, a **computerized dispensing system** from which workers can obtain or return small tools, maintenance supplies, and other industrial items. The computer automatically updates inventory, accounting, and purchasing records of items dispensed and returned.
For More Information Write In No. 709



MicroStation Modeler ™, a tightly integrated, ACIS-based **solids modeling environment,** has been released by Bentley Systems Inc., Exton, PA. It enables users to combine solids, surfaces, and wireframes to describe complex parts, while selecting from parametric, explicit, or feature-based design. Featuring thin shelling and assembly management, it provides a full set of standards.
For More Information Write In No. 720

Computer Systems Technical Support, Anaheim, CA is offering the UCT-2000 **universal continuity tester**, a PC-based system for testing and certifying cables, wire harnesses, and other wiring devices as well as backplane and equipment racks. The drop-in system offers distributed switching capability, using a 15-pin cable that begins at the controller and daisy-chains through the expansion units as necessary. The maximum number of test points is 28,000, in increments of up to 512 points per expansion unit.
For More Information Write In No. 706

For More Information Write in No. 447

For More Information Write in No. 448

New Literature

An eight-page RULON® M 2000 design guide from FURON, Bristol, RI, describes the five grades of this **high-performance material**, lists technical characteristics of each, and describes critical applications in which it has replaced metals, ceramics, and plastics. RULON® M 2000 features a wide operating temperature range, high strength and rigidity, and inherent lubricity and can be formed or injection molded into various shapes and machined to extremely close tolerances.
For More Information Write In No. 721

A 71-page processing brochure for Victrex® PEEK, a **high-temperature thermoplastic**, is available from Victrex USA Inc., West Chester, PA. The literature details the steps necessary to provide proper care during handling, drying, and rework. A series of graphs illustrates the effects of melt temperature on viscosity at a range of shear rates for the various PEEK grades. Also included are graphs illustrating the flow length that can be achieved at different section thicknesses under various molding conditions.
For More Information Write In No. 733

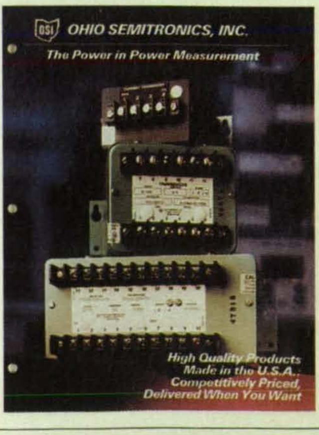
An 81-page product guide from Compac Engineering Inc., Paradise, CA, describes the company's **flow, liquid level, and temperature switch sensors**. The Series 5 liquid/gas flow sensing switches offer five flow trip point settings and detect in a range of .008 to 1.0 GPM. The Series 10 liquid level sensing switches can sense or control almost any liquid, mount up or down, and perform open or closed switch functions.
For More Information Write In No. 729

Edmund Scientific Co., Barrington, NJ, has published a 236-page technical reference and catalog of its custom **optical solutions for current CCD cameras**, which may require more than a standard C-mount lens. The reference offers solutions to tighter packaging requirements and non-traditional configurations.
For More Information Write In No. 732

Danfoss Electronic Drives, Rockford, IL, has introduced its 1995 product catalog and engineering guide to **adjustable speed drives for AC and DC motor control**. The 224-page catalog describes the 25 models in the VLT® 2000 and 3000 series of AC drives, spanning a horsepower range of 1/2 to 300 hp; the Cycletrol Series DC controls; and the VariSpeed DC and R400 regenerative DC adjustable speed controls.
For More Information Write In No. 730

A new line of **rotary actuators** is highlighted in a catalog from PHD, Inc., Fort Wayne, IN. Series RA actuators feature a high-strength steel alloy rack, one-piece pinion shaft, and free floating pistons that provide breakaway pressures less than 5 psi for low friction. Oversize sealed ball bearings and large pinion shafts permit shaft stability under heavy loading and high load-stopping ability.
For More Information Write In No. 725

New lines of **transducers, test instrumentation, and accessory equipment** are introduced in a brochure from Ohio Semitronics Inc., Hilliard, OH. The company offers more than 35 standard models of AC and DC watt, var, current, and voltage transducers as well as transformers, relays, signal converters, and demand meters.
For More Information Write In No. 722



New Literature

Total Power International Inc., Lowell, MA, has released a 24-page catalog describing **linear and switching power supplies** from 10 W to 1500 W and DC/DC converters from 1 W to 150 W. Open frame, box, PCB, VME rack mount, and encapsulated styles are available.
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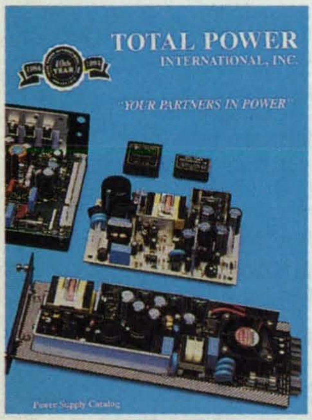

The latest edition of the *PC/104 Resource Guide* from the PC/104 Consortium, Mountain View, CA, provides an overview of the PC/104 standard and a cross-reference of products and functions. Product listings from 125 of the consortium's member companies include PC/104 modules and other PC/104-related boards, peripherals, and software. The PC/104 modules' small size (3.6 x 3.8 in.) and low power requirements (typically 1-2 W per module) make them well-suited to embedded control applications.
For More Information Write In No. 731

Spring-Fast® **composite grommet edging** is described in a brochure from Device Technologies Inc., Marlborough, MA. The easy-to-install edging protects wires and cables from abrasion due to sharp corners and rough surfaces. A polymer coating provides a durable, smooth, and non-conductive surface.
For More Information Write In No. 726

Copyright Your Software, published by Nolo Press, Berkeley, CA, provides details on how to maximize **copyright protection for software**. The book is intended to enable anyone involved in software development—programmers, publishers, contractors, or developers—to register a copyright without a lawyer.
For More Information Write In No. 724

De-Sta-Co, Troy, MI, has released a 100-page handbook of **clamping solutions**, which provides extensive technical information on manual and power clamping devices. Chapters address toggle clamps, the universal workholder, workholder design principles, hold-down action clamps, squeeze action clamps, and straight-line action clamps.
For More Information Write In No. 728

The 32-page *Automation Components Application Guide, H903* from Techno-Sommer Automatic, New Hyde Park, NY, offers application and selection guidelines for more than 2300 off-the-shelf **automation components**. The guide spotlights a wide variety of robotic grippers, including friction types such as pivoting arm, parallel, remote control, mini finger, tube, wide jaw, collet, needle, and toggle tongs. Also described are applications for pneumatic tool changers, swivel units, linear cylinders, and suction cups.
For More Information Write In No. 727

A catalog of **modular pulse-processing electronics and semiconductor radiation detectors** is available from EG&G Ortec, Oak Ridge, TN. It contains tutorial information, applications advice, and instrument selection charts for research scientists in a variety of disciplines. Featured new products include nuclear spectroscopy, multichannel scaling, mass spectrometry, LIDAR, fluorescence lifetime, single-photon counting, picosecond timing, and gamma-ray or alpha-particle spectroscopy.
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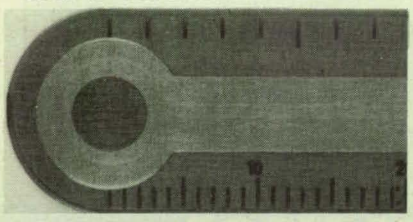

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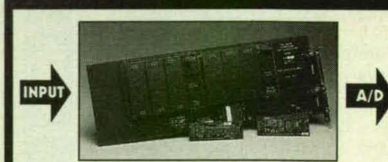

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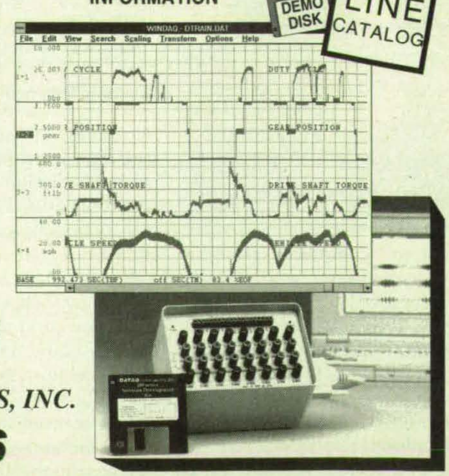

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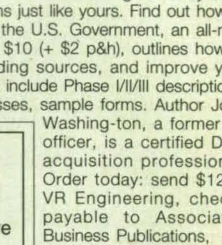

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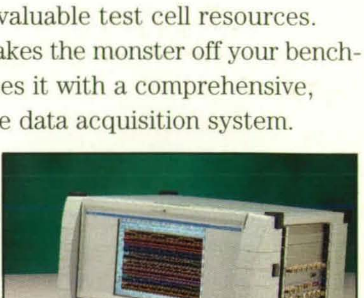

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