NASA Tech Briefs

National Aeronautics and
Space Administration

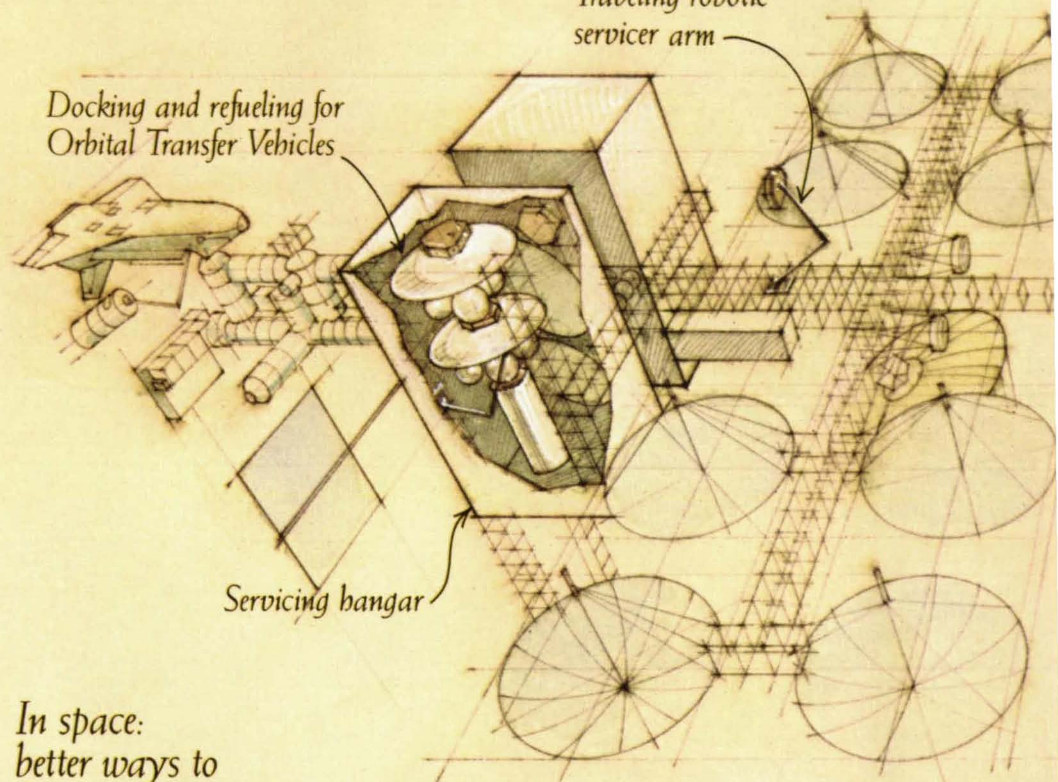
November/December 1986
Volume 10 Number 6

NASA Spinoff Technology:

Using glow discharge techniques to improve sunglasses

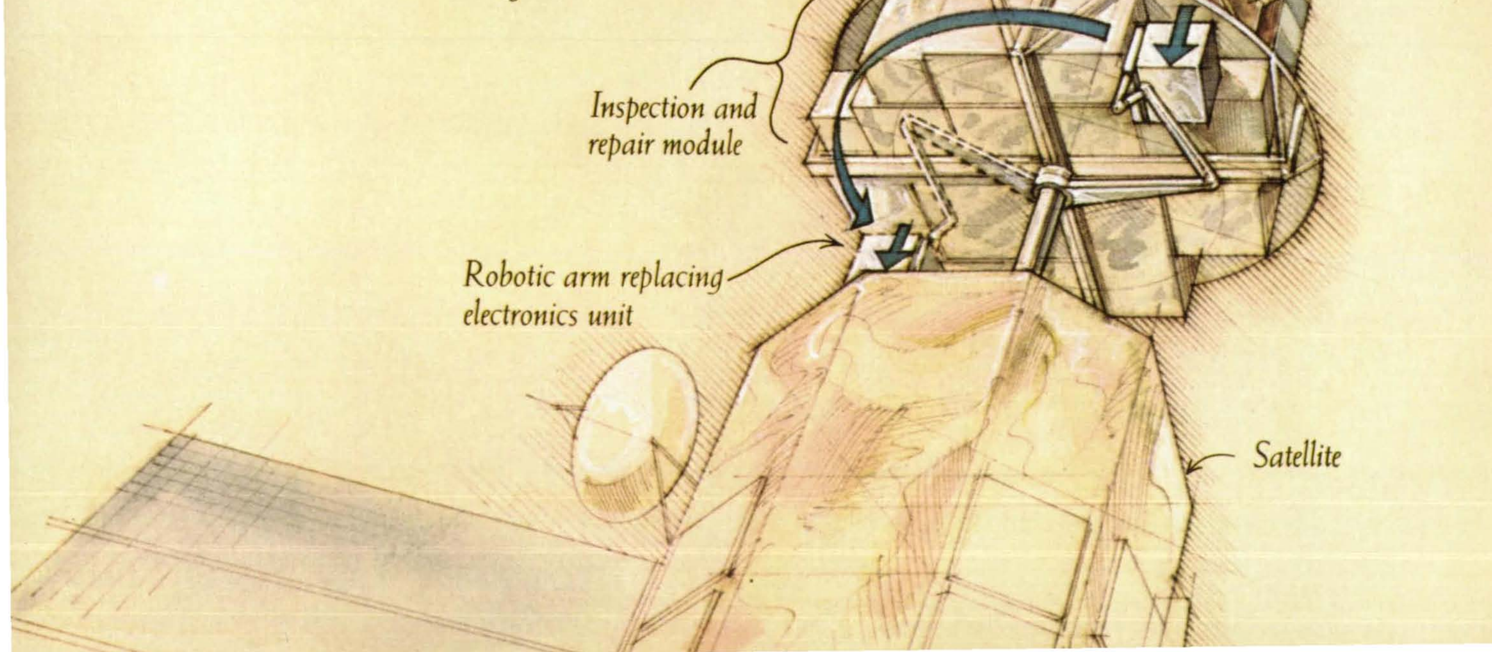
Artificial intelligence and robotics: giving machines the ability to sense, reason and act.

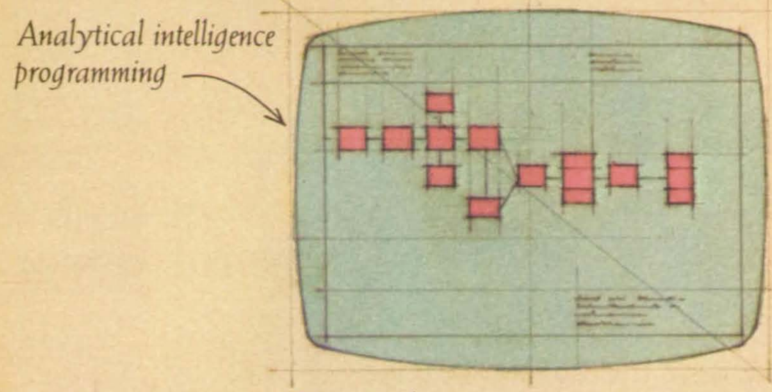
Much as it may hurt to think so, many things might be done better by independently functioning machines than by humans. Certain tasks may require superhuman precision or speed, or need to be done where humans can't go. Martin Marietta is creating systems that combine the ability to sense, reason and take action—to function autonomously and intelligently. And we are exploring ways to put them to work on a variety of tasks.

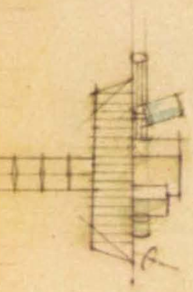


In space: better ways to do servicing.

NASA's manned space station and orbiting satellites will require the use of many robotic devices driven by artificial intelligence.







On earth: faster manufacturing and inspections.

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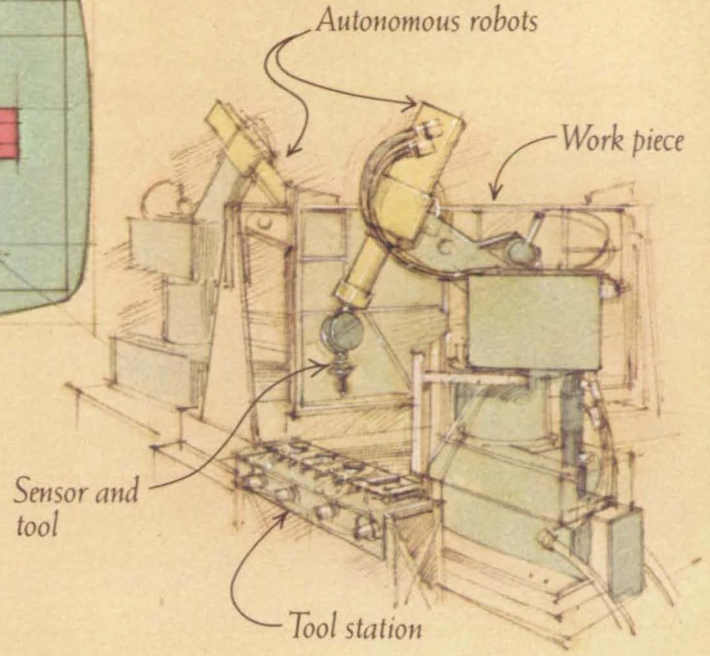
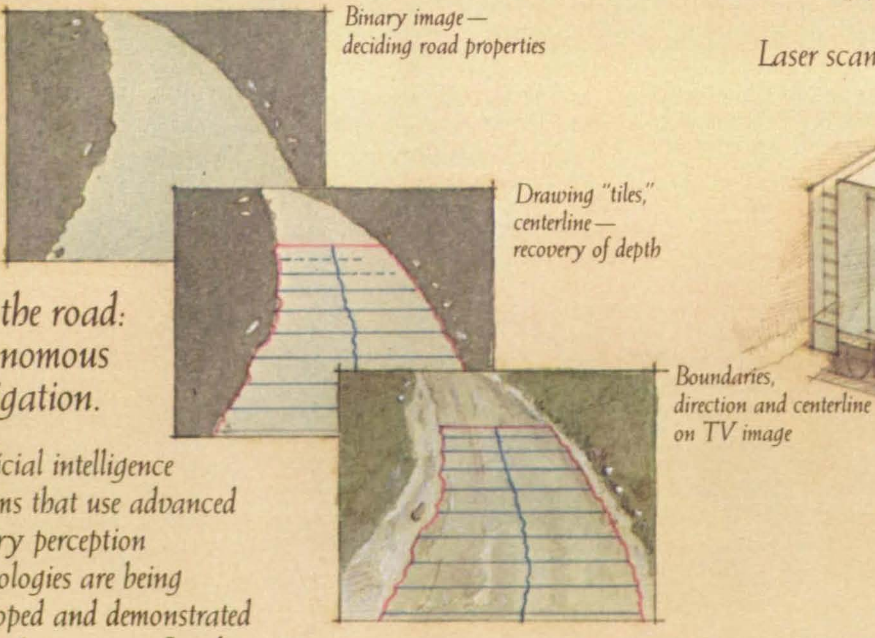
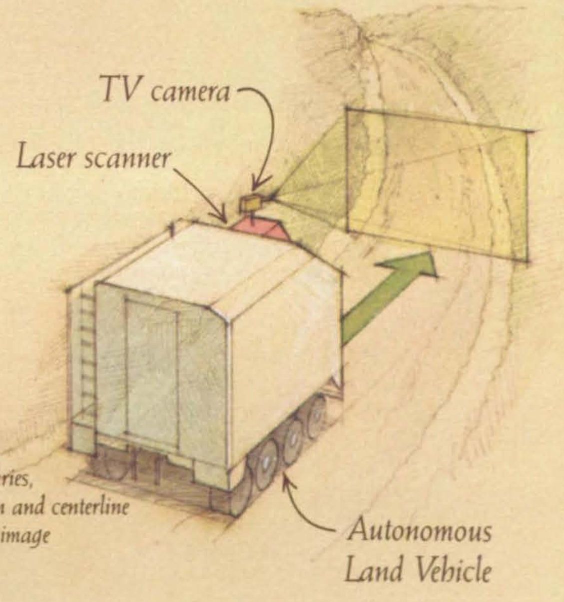




On the road: autonomous navigation.

Artificial intelligence systems that use advanced sensory perception technologies are being developed and demonstrated in the Autonomous Land Vehicle. Already able to follow roads, this mobile test bed will eventually be able to plan its route, avoid obstacles and even thread its way across country.



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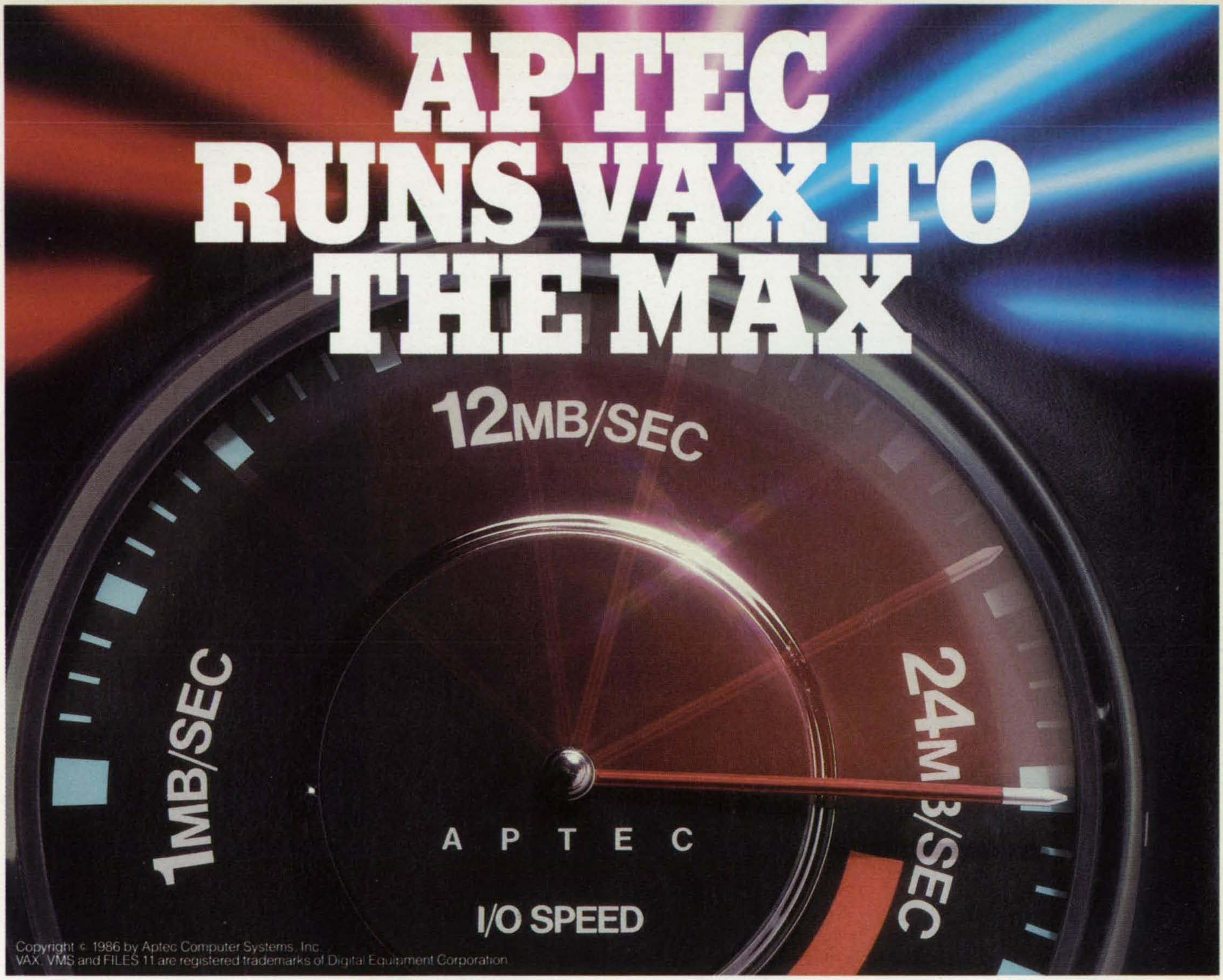

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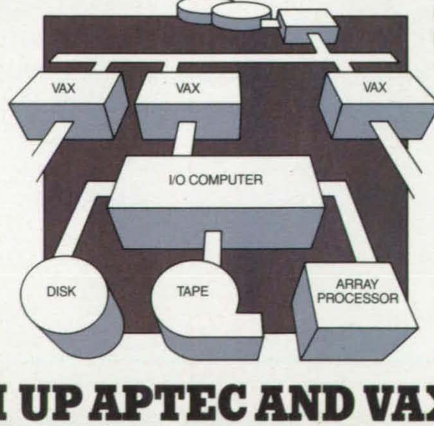

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NASA Tech Briefs

National Aeronautics and
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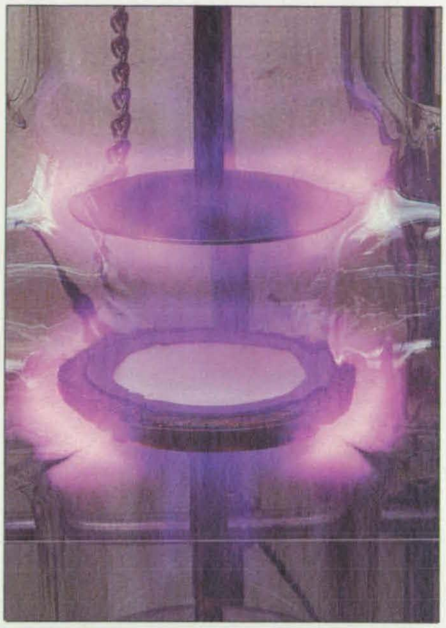

On The Cover: While improving purification filters for spacecraft water reclamation, an Ames research scientist developed a method of depositing a thin plastic coating upon another plastic sheet. This process has since been used on over five million pairs of sunglasses sold by Foster Grant company. See Mission Accomplished, page 99, for details.

This color composite image of Florida from Lake Okeechobee (top center) to Whitewater Bay was taken by a NASA Landsat satellite. Analyzing enhanced photos such as these is one of the services offered by the Technology Application Center, one of NASA's Industrial Application Centers (IAC). A review of the IAC network begins on page 10.

Technical Section Thumb Index

Thumb Index Technical Section

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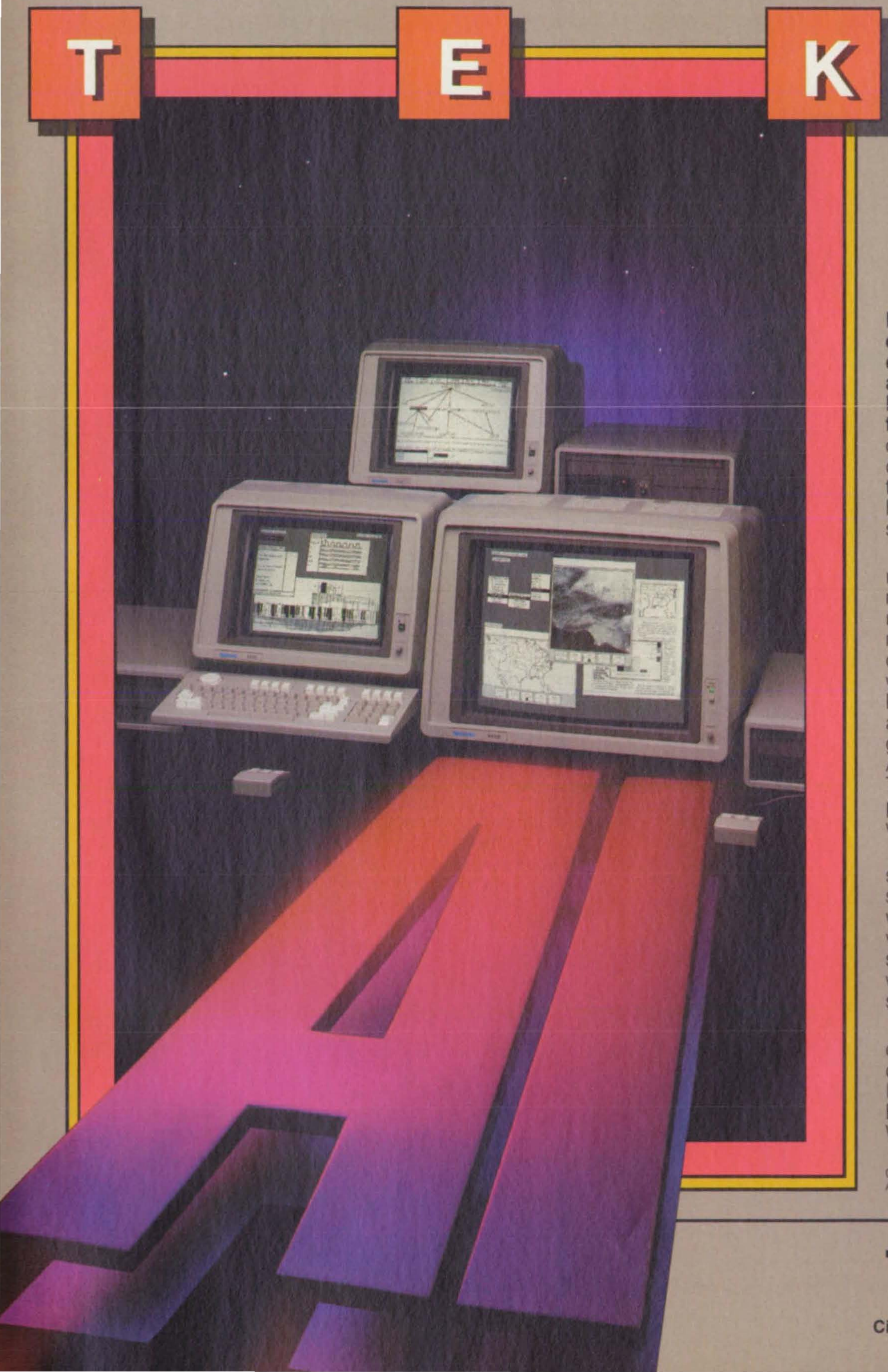

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Editorial Notebook

I was recently delighted to notice that in a single issue of the *New York Times Magazine* NASA-derived technology was credited in two totally different and unrelated stories: the first piece on efforts being made to regain the Americas Cup, and the second on cosmetics testing. We'd known about the Americas Cup effort before through a feedback card, but it is encouraging to see these successful transfers of NASA technology acknowledged in the press.

In this issue, we're rashly attempting to describe one of NASA's methods of such technology transfer: the Industrial Applications Centers. I say "rashly" because the organizations themselves have historically had a tough time advertising themselves. We've tried to help out a few with ad copy but, to date, our efforts haven't won any advertising awards, either.

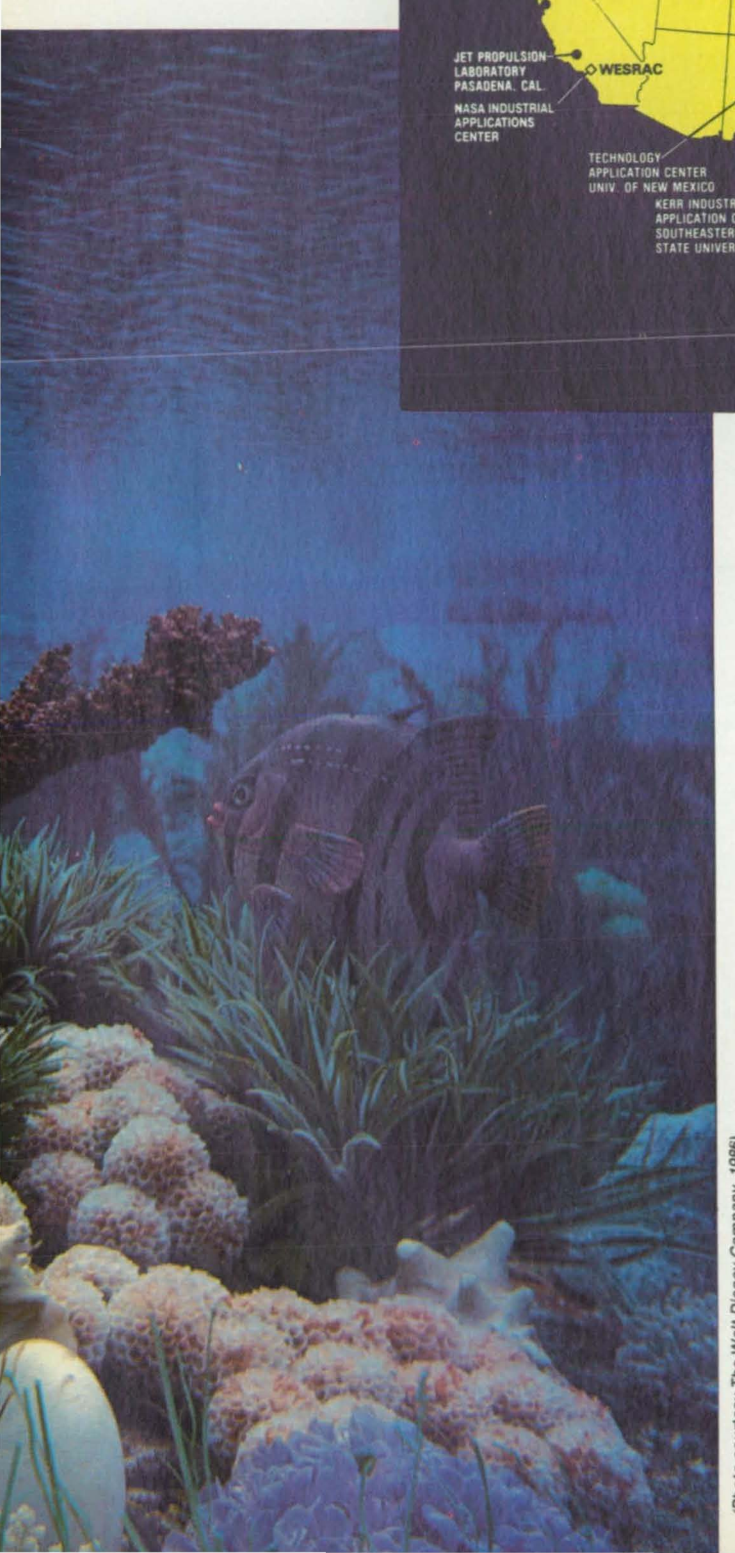
That's one of the reasons we're devoting a feature article to the Industrial Applications Centers. When you offer as wide a range of services as the IACs do, it's close to impossible to describe succinctly what you do, let alone what you are capable of doing. And while they're all part of the technology utilization family, each IAC has a different lineage, with the single common bond being NASA.

As I mentioned to Len Ault, NASA's NTB Publications Manager, the project is a little like trying to dress an elephant. Even with a cooperative elephant, it's hard to get everything on, let alone coordinate the wardrobe.

I don't want to take the analogy so far out that we can't close the loop, but I hope you'll enjoy our tip of the editorial hat to NASA's Industrial Applications Centers; the story begins on page 10. Technology transfer is still in its infancy, more art than science—and these IACS are among the leading alchemists of our time, pushing the envelope of technology transfer.

Doing our bit to transfer vital information, we'd like to point out that the 1981 NASA Tech Brief Index is now available from NASA for ten dollars; send in the coupon on page 97. The index to 1982 will be ready in early January, and succeeding years through 1986 will follow about every two months. □

INSIDE THE IACS
High Technology on Tap



(Photo courtesy The Walt Disney Company, 1986)

Credit Congress with foreseeing down-to-earth applicability in the technological and scientific innovations that NASA and its contractors would create as they led the push into the last frontier; written right into NASA's founding charter is the mandate to spread new technologies throughout the American economy. From its inception, NASA rose to meet this challenge, organizing what today has evolved into the Technology Utilization Division of the Office of Commercial Programs.

In the scant 28 years since NASA was born, thousands of aerospace-based technologies have been spun off into the country's private and public sectors through this technology transfer network, leading to breakthroughs in business and industry. The network has several components, including one you're holding right now —*NASA Tech Briefs*. Although each part has its function, the Industrial Applications Centers—perhaps the least known, least publicized members of the team—are an underutilized resource representing a wealth of opportunities.

The nine IACs, as they are acronymically known, exist to help American industry sharpen its leading edge by providing access to a vast computerized storehouse of technical knowledge. Located at academic institutions around the country, their ability to draw on millions of documents and more than 400 databases worldwide is important in itself. But the real value-added services offered by the IACs go beyond information retrieval to specific problem-solving assistance and regular contact with laboratory R&D scientists employed by NASA, ►

On the left is a scene from the Submarine Voyage through Disneyland's underwater lagoon. Because the chlorine in the water degrades their paint, the figures have to be removed, cleaned, spray painted and repositioned every three months. The NASA Industrial Applications Center at the University of Southern California came up with a photopolymer originally designed to protect lenses in space. Coating the figures with the polymer should reduce the maintenance by a factor of three. The map shows NASA's Industrial Application and Field Centers.

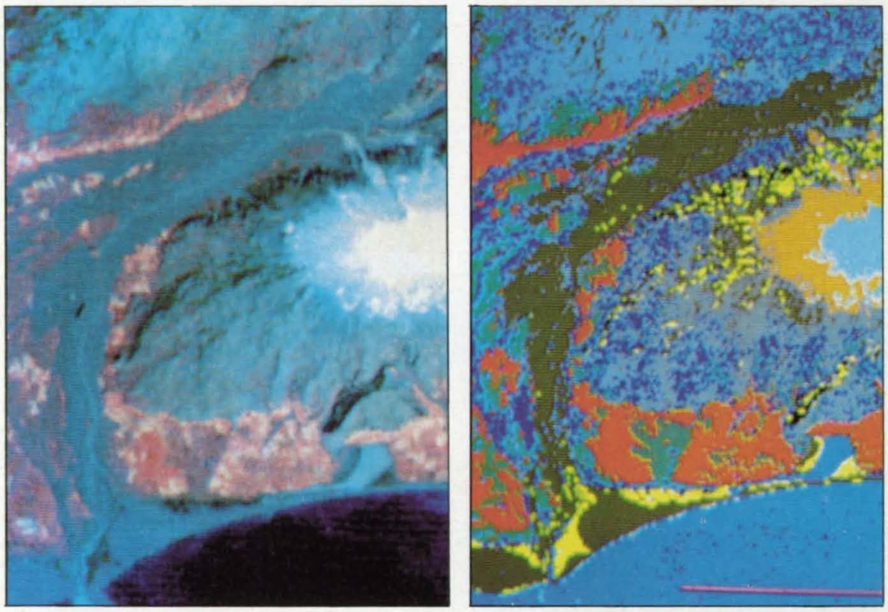
other government agencies, and universities.

Because typical IAC funding comes from multiple sources—NASA, the sponsoring institution, state subsidies and IAC users—the centers are able to provide their services at remarkably modest fees. They provide free estimates, often based on a verbal statement of a client's needs. And because the IACs' very reason for being is to share NASA-developed technologies, personnel actively welcome inquiring minds; the matter doesn't have to be highly technical—they're interested in answering questions and finding solutions to even the most earthbound problems.

The Big Search

While each Industrial Application Center has a particular forte, the basic assistance pattern is fairly constant, and all centers have access to the massive RECON database, where results of all NASA research are stored. A potential client contacts the nearest center, describing a problem or information need. In consultation with an IAC information specialist, details of the problem are specified and the databases appropriate for the search are considered. From the resulting list of relevant titles, authors, organizations, document sources and abstracts, the client can order complete texts of particularly interesting articles; the IAC can also provide the names of prominent researchers doing work in the subject area.

Several types of search services are available, depending on the client's needs. One highly effective method, the **Interactive Search**, requires a personal visit to the IAC. While a database specialist reviews databases on line, the client can watch search progress on his own terminal. This method integrates the skills of the IAC's database expert with the client's own detailed knowledge of his problems and interests. The **Remote Interactive Search** obtains the same results from any location; all that's needed is a personal computer, telephone, modem, and two phone lines. The p.c. is linked to the IAC's search station through one line, and the client is linked to the database expert on the second. In a **Selected Search** (following a standard one), an IAC staff member who's expert in the given field reviews preliminary reports and selects the most germane material. If necessary, an expert from the university associated with the center can be tapped for assistance. Finally, the **Current Awareness Search** can track specific technologies on as many databases as necessary, with updates on the available literature issued to the client on his chosen schedule.



To the left is a false color composite image of a coastal area of Iceland composed of three channels from Landsat multispectral scanner satellite data. Near the middle of the photo is a snowcapped mountain encircled by a river valley that runs into the sea. The photo to the right is a computer classification of the same image. Each color relates to a cover type identified by the computer. Both photos are typical of the services performed by the Technology Applications Center at the University of New Mexico.

An Inside Look

Though every Industrial Application Center works at technology transfer, each has unique characteristics.

The Aerospace Research Applications Center (ARAC), associated with the Indianapolis Center for Advanced Research, Inc., was the original IAC, developed in 1963. As director F. Timothy Janis explains, ARAC emphasizes an engineering approach to problem solving. "Our purpose is not only to look at transferring technology to the private sector; because there is probably a solution to your problem, we ought to be able to arrive at that solution through adaptive engineering, be it analytical or be it real."

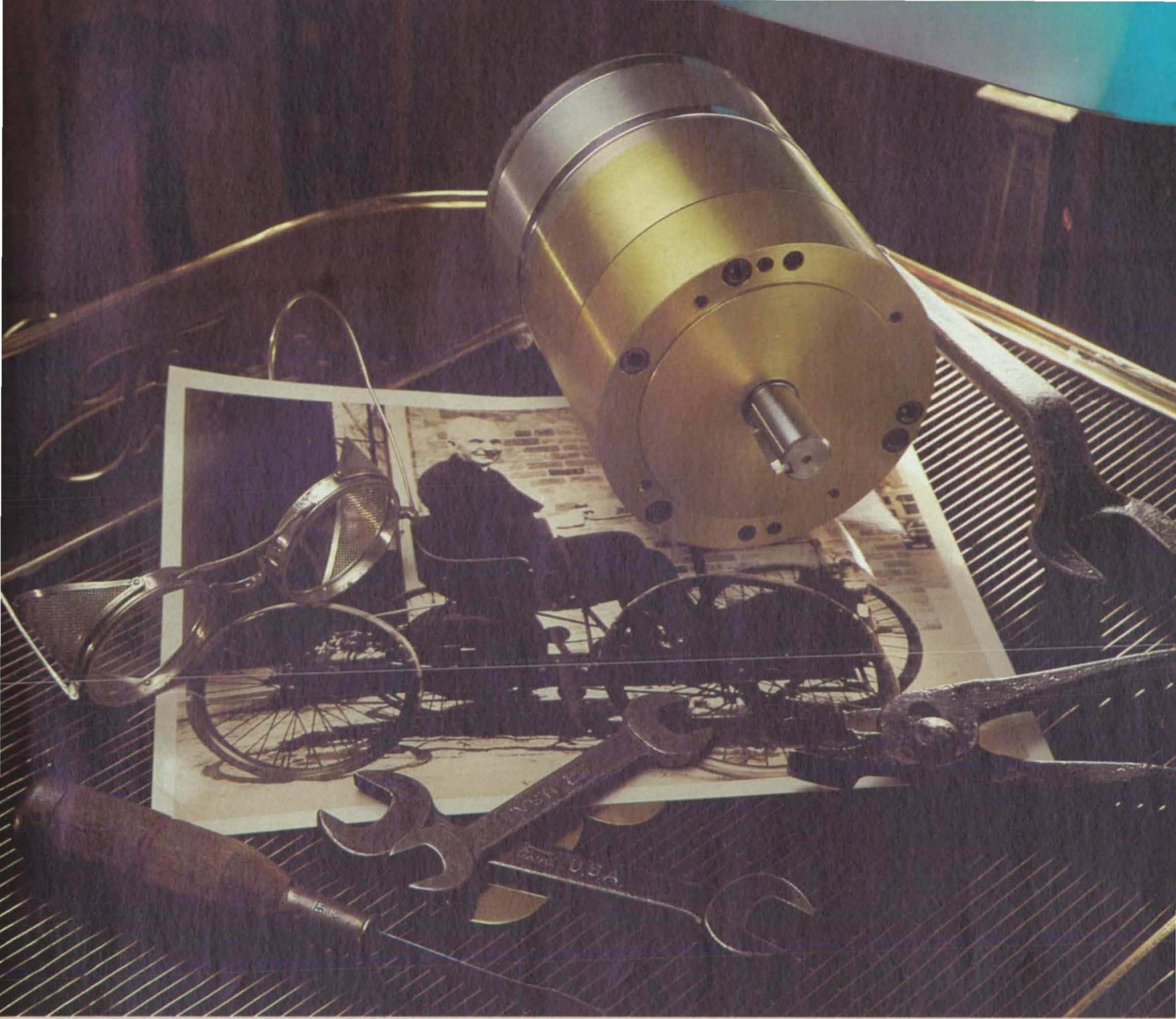
ARAC, with 14 engineers on staff, specializes in value-added engineering studies for its clients. Each client first states the problem to a sales representative. When the problem is well defined, a project engineer is assigned to the case and sets several relatively independent processes in motion:

- A traditional search is made of the appropriate database(s).
- Simultaneously, the engineer defines the problem for one or more of the 600 technical experts associated with the center.
- A problem statement is sent to the three technology counselors employed by ARAC, who are based at Marshall Space Flight Center in Alabama, the Department of Energy's Argonne Laboratories, and the Department of Defense's Naval Research Laboratory. The counselors contact the appropriate people at their locations, and relay information and suggestions back to the project engineer at ARAC.

The project engineer is responsible for integrating all of the resulting information, whether derived from the searches or from expert reports. Contact with participating experts follows, and the engineer uses what he has learned to present a number of possible solutions to the client. The engineer's objective is not to do the client's design work, but rather to make recommendations based on information gathered and professional judgment. Follow-up assessments are made to assure product quality and to ascertain utility.

The decision to locate the **NASA Industrial Applications Center (NIAC)** at the University of Pittsburgh was originally based on the school's library science emphasis, now generally called "Library Information and Systems," and its concept of information as a distinct product.

The Pittsburgh, PA center has a strong orientation toward business and industry. Paul A. McWilliams, NIAC's executive director, explains one center specialty: "We help companies find new or emerging technologies that will help them regain their competitive edge in the marketplace. Thus, when buggywhips go out of style, we locate technologies that allow the manufacturer to change the product. We look for a product that ►



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has a stronger potential market, but requires minimum possible investment in retraining of the present workforce. At the same time, we seek sophisticated NASA technologies that can't be reproduced in someone's garage next year, which could force a client out of the marketplace."

NIAC also emphasizes space commercialization and has expertise in custom database construction. The center is currently expanding its technology transfer efforts by developing satellite institutions to assist industry in nearby states. Says McWilliams: "What we have is a mechanism to heighten awareness of NASA technology through the universities and colleges within a state. These institutions have access to the state's business and industry, and know them far better than we could. They'd be able to talk about the problems within an industry or among companies they know well, and then we'd take the next step and recommend how to resolve the problems."

NASA's **Southern Technology Application Center (STAC)** serves the private sector in the Southeast, and puts a special emphasis on researching patent potential for small companies. Headquartered at the University of Florida in Gainesville since 1977, STAC can access more than 1,200 databases containing over 500 million records. Using NASA's RECON database as a starting point, the STAC staff works with clients in the field to insure full utilization of its services, and makes access to experts easy by profiling several thousand in a database.

Recognizing that small, high-tech companies and innovators are often frustrated by the intricate procedures and major expense involved in patent application, STAC offers product potentiality studies to shortcut the process. They search for pertinent existing patents and make "prior art" and "state-of-the-art" assessments. From search results they determine if an idea can be patented. An innovator must still consult an attorney, but much of the work has already been done—and at a fraction of the usual cost.

Founded in 1964, the **Kerr Industrial Applications Center (KIAC)** at Southeastern Oklahoma State University in Durant deals primarily with small businesses. Director Tom McRorey says, "Through the state Department of Economic Development and Small Business Development Center networks, we're able to provide technical assistance to people who don't know what to ask for and can't pay large sums to have it provided. Most of this information can't be obtained anywhere else.

"When you deal with small businesses," he notes, "you deal with every kind of company. We do quite a bit on the oil and gas industry, and work with several small metal fabrication companies. We also do frequent searches in corrosion resistance and heat-resistive coatings."

KIAC caters to larger companies, too. According to McRory, in some companies "the engineering and operational people don't talk to each other very much. So even though a major company might have the capacity to do essentially what we do, and might be doing it, not everyone in the company knows about it. Or it's easier to pay KIAC than it is to go through the bureaucracy."

Associated with the University of Kentucky, the **NASA/UK Technology Applications Center** directs much of its attention toward non-commercial technology transfer. Center director Bill Strong says that "NASA/UK is primarily oriented towards providing science and technological information to the public sector, i.e. local and state governments, as opposed to industry and business. We interact with the Council of State Governments, the Kentucky Municipal League and other public-sector organizations."

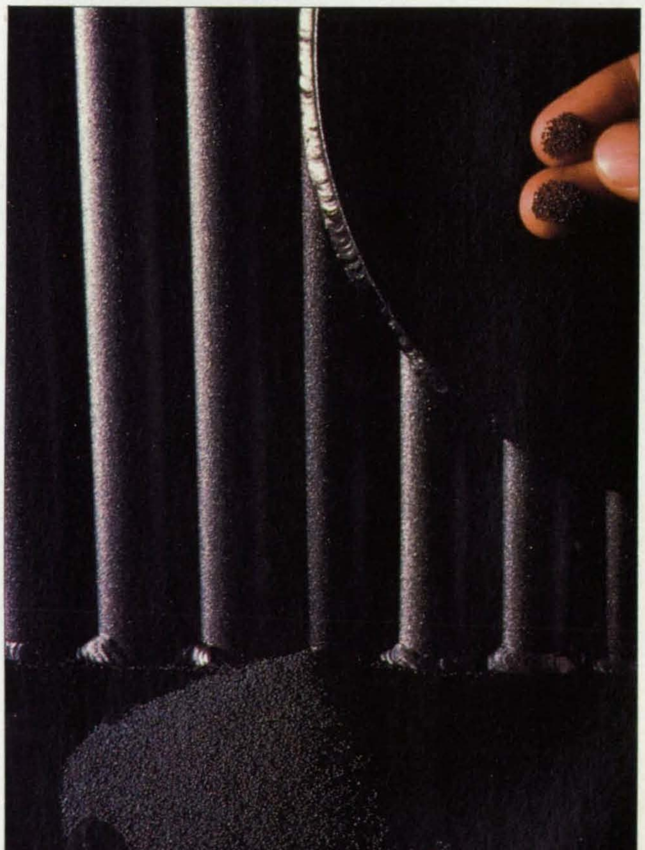
Located in Lexington, the Council performs research studies for the 50 states; since 1977 NASA/UK has been answering its technical questions, which range from economic development to environmental problems and industrial expansion. Says Strong, "Our solutions are applied, not academically oriented. We take academic, scientific and technical results and solve day-to-day problems that confront a mayor. If he's got water pollution or asbestos in his water purification plant, we'll find a solution."

The **IAC at the University of Southern California (WESRAC)** was one of the first centers to emphasize use of Remote Interactive Search Systems (RISS), which the staff sees as highly beneficial to clients. Says Herb Asbury, manager of program development, "Very often the first definition of a question is not vividly painted. When you get the clients on line, the real questions start to come into focus."

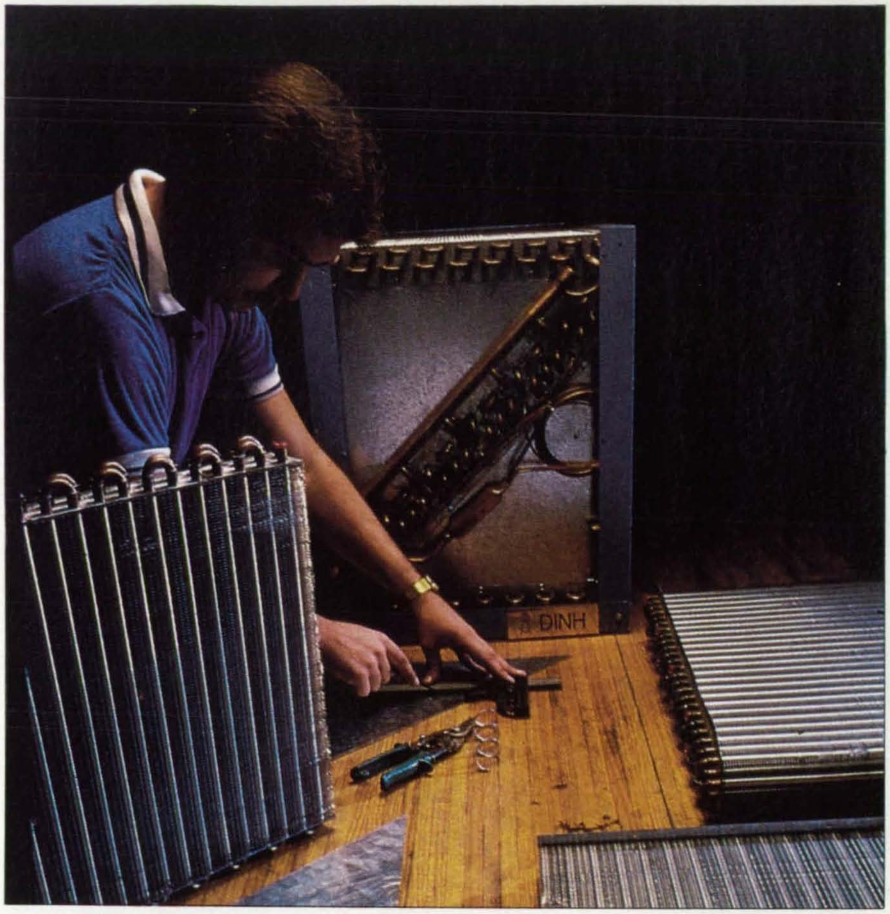
He adds, "WESRAC is hooking up with and assisting Small Business Assistance Centers in a number of states. They'll become what we're calling 'NASA Satellite Technical Information Centers,' and will act as remote marketing agents. We'll provide the search services." Asbury expects the "satellites," already in the works in Colorado, Washington, Iowa, Nebraska and Idaho, to be able to generate more demand for their services in their home states.

The **Technology Application Center (TAC)** at the University of New Mexico, in gear since 1963, specializes in remote sensing analysis for natural resources. "We focus on imaging technology for natural resources, the processing and manipulation of multiple channel digital data," says Mike Inglis, the center's associate director.

Much of the information TAC analyzes comes via satellite, commonly the Landsat series, which generates data extending across a wide spectral range. TAC specialists ►



The North Carolina Science and Technology Research Center was asked to recommend a way to decrease metal fatigue in fabric looms. The IAC came up with a process that involves shot peening to introduce a residual compressive stress in the metal making up the looms. The actual shot is shown here. The vertical bars have already been shot peened, hence their silvery appearance as contrasted with the darker horizontal bars.



The Dinh Company, Alachua, FL, developed a heat pipe dehumidification system that can double the moisture removal capacity of any air conditioner. NASA's Southern Technology Applications Center assisted with the research necessary to develop the system, whose components are shown here.

process that data using NASA-developed Earth Resources Laboratory Applications Software (ELAS). Results are often used as a basis for on-site follow-up research.

Inglis says, "When a client comes to us with an initial question about remote sensing, we try to introduce him to the value of image-processed digital data and additional remote sensing and image processing applications. We work with him to develop a methodology customized to his needs."

The TAC is also looking at other aspects of imaging technology, especially adaptation of imaging analysis techniques to the field of medicine.

Dan Wilde, director of **NERAC, Inc.**, based in Storrs, CT, likes to think of the center as "50 million solutions waiting for a problem." Clients join for a year, and can call the center whenever they have a problem. Explains Wilde, "It's like a WATS line; when you have it, you use it a lot more than when you have to pay for each call. Our users pay for a year's service, enabling all the people in their company to contact us. This is important, because the more a company uses us, the greater chance they'll have of asking us a question we can really help them with." NERAC's own computer is available anytime a user has a problem, and the center can access any number of databases in hopes of finding the best solution.

"It's hard for us to predict in advance what questions we can answer," says Wilde. "So we say to people, 'For a year you can ask us anything. We'll do our best to help you. If we succeed, great. Come back and ask us another question. If we fail, we're sorry. But come back and try again.'

"It's the companies that keep coming back that get the best help," Wilde notes. He says it's not difficult for a company to save the typical NERAC subscription fee of $5,100, and adds that some subscribers use the center at a volume of $200,000 per year.

"If you've got a problem, all you do is pick up the phone and call your contact at NERAC. Your contact will help you define your problem. Once that is done, you go back to work and your contact goes to work for you. You don't have to know anything at all about computers or databases."

The **North Carolina Science and Technology Research Center (NC/STRC)**, located in Research Triangle Park, serves textile and furniture manufacturers as well as other local industries. Says J. Graves Vann, Jr., the center's acting director, "We go to extra lengths in consulting with our clients to understand and assist them in the precise definition of their problem or question."

There are several reasons for the close consultation, according to Vann. "It enables us to formulate an overall strategy to identify the appropriate resources to bear on the problem, and it allows us to custom-fit the services to economically meet the client's specific needs." Both the state government of North Carolina and NASA provide support for this center, keeping research costs low.

The **Technology Application Team (TAT)**, located near NC/STRC in the Research Triangle, plays a very specific role within the technology transfer network. Says TAT director Doris Rouse, "Rather than disseminate information from databases, we act as a matchmaker between industry's needs and the NASA technology that can provide the answers. We work with national industry associations to identify the industry's needs. We then consult with the Technical Utilization Officers to find the matching NASA technology. The TUOs also help us locate the NASA people who will work side by side with industry representatives." Additionally, the TAT works with other federal agencies to obtain resources for technology transfer projects. "It takes resources to do the necessary adaptive engineering," explains Rouse. "NASA doesn't have all the money to do that, and usually industry doesn't either. What we do is go to another federal agency that has an interest in that area, for example to DOD. We obtain their cofunding and technical expertise in the project."

• • •

With high-tech experts involving themselves in industrial problems as ordinary (and as crucial) as developing a new product line that won't be obsolete next year, the IACs should have clients beating down their doors. Through their phenomenal information access and farflung network of contacts in government, research and academia, the IACs can easily, effectively and inexpensively answer a multitude of technical questions—even about problems that might not seem technical at first glance. Because it's their specialty, the IACs can often provide more economical problem solving than a company's own in-house computer operations. They not only have the data on hand, they're trained to ask for it. □

For complete contact information on IACs nationwide, see page 28.

Wyle at work.

Helping make Space Station a reality.

Wyle Laboratories is playing an important role in the development of the Space Station. As a team member with Martin Marietta, we are responsible for payload accommodations analysis and mission modeling for the U.S. Laboratory.

We are defining requirements and developing conceptual designs for experiment apparatus and production-scale materials processing facilities. We're also developing materials processing furnaces to support Microgravity Science research.

Wyle has in-depth experience in defining and assessing user requirements and developing functional hardware and systems to meet user needs. Our translation of research objectives into workable integrated systems represents a valuable asset in the successful development of the Space Station.

For over 20 years, Wyle has been working with NASA and prime contractors on virtually every major space system development program.

Wyle is also contributing Mission Support for National Transonic Wind Tunnel and JPL Environmental Testing Facilities. For more information, call collect: Don McAvin in Huntsville, AL, (205) 837-4411.

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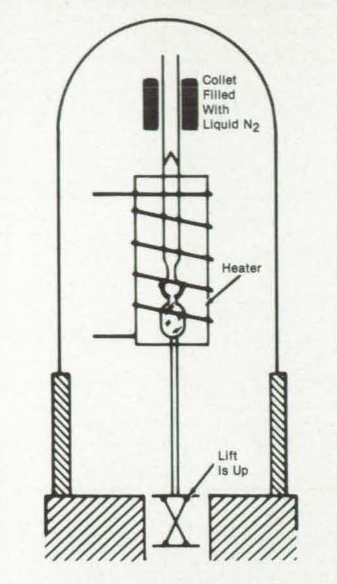
Hampton, VA
Houston, TX

Circle Reader Action No. 396

New Product Ideas

New Product Ideas **are just a few of the many innovations described in this issue of *NASA Tech Briefs* and having promising commercial applications. Each is discussed further on the referenced page in the appropriate section in this issue. If you are interested in developing a product from these or other NASA innovations, you can receive further technical information by requesting the TSP referenced at the end of the full-length article or by writing the Technology Utilization Office of the sponsoring NASA center (see page 27). NASA's patent-licensing program to encourage commercial development is described on page 27.**



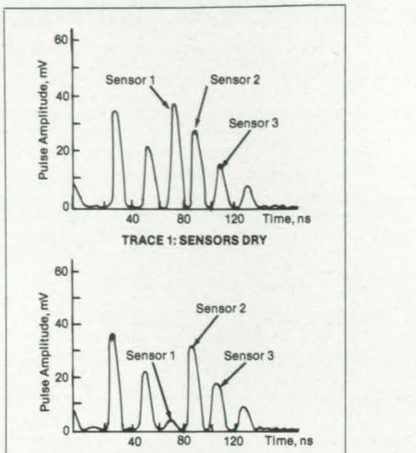
THIRD PHASE: CHARGE DISTILLATION

Two-Step Vapor/Liquid/Solid Purification

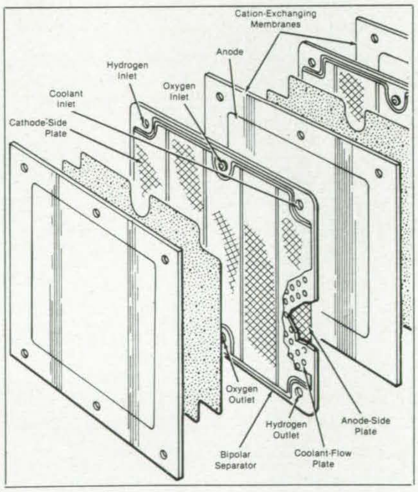
A vertical distillation system (see figure) combines in a single operation the advantages of multiple zone refining with those of distillation. Developed specifically to load Bridgman-Stockbarger (vertical-solidification) growth ampoules with ultrapure tellurium and cadmium, this system, with suitable modifications, could serve as a material refiner. Because the crystal grows down from the top of the ampoule into the heater until it passes the melting-point isotherm, the bottom end of solid material always has a drop of melt, held by surface tension. There is a segregation of impurities as the molten raw material is distilled to this drop and a second segregation as the material in the drop is solidified. Upon reaching a certain size, the growing drop falls back into the evaporator, carrying with it impurities rejected in the solidification process. (See page 51.)

Laser-Pulse/Fiber-Optic Liquid-Leak Detector

Fluid systems can be monitored quickly for leaks in remote, hazardous, or inaccessible locations by a system of compact, lightweight, fiber-optic leak sensors that are presently undergoing development. The sensors would be installed at such potential leak sites as joints, couplings, and fittings. A sensor is read by sending a laser pulse along the fiber, then noting the presence or relative amplitude of the return pulse (see figure). (The inten-



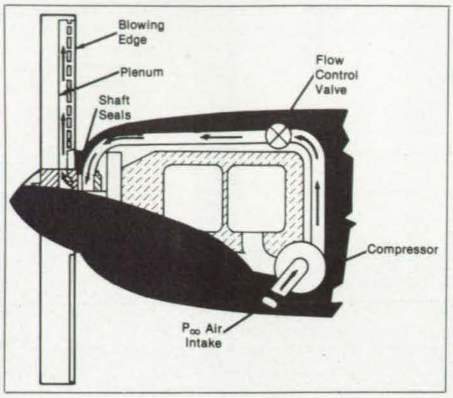
sity of the reflected laser pulse is determined in part by the index of refraction of the medium surrounding a sensor, through its effect on the electromagnetic modes in the fiber core and cladding.) This leak-monitoring technique should be applicable to a wide range of fluid systems and would minimize human exposure to toxic or dangerous fluids. (See page 38.)



Fuel-Cell Structure Prevents Membrane Drying

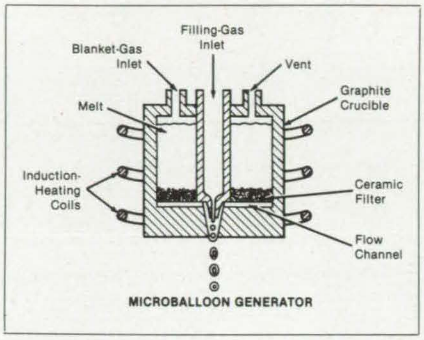
A membrane-type fuel-cell battery in which embossed plates direct flows of reactants and coolant has improved reactant flow and heat removal. The compact, lightweight battery can produce high current and power without drying of its membranes. The battery consists of a series of fuel cells (see figure), each of which contains a cation-exchanging membrane between internally cooled bipolar separators. The coolant-path design maintains the anode side of the cell membrane at a lower temperature than that of the cathode side. The resulting temperature differential causes water to diffuse from

the cathode to the anode, offsetting the opposite transport of water by migrating hydrogen ions (produced by the oxidation of hydrogen) and thereby preventing the drying of the hydrogen side of the membrane. (See page 32.)



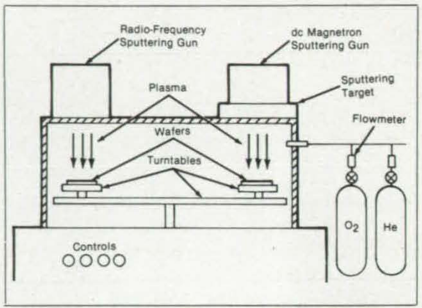
Circulation-Control Variable-Pitch Propeller

A variable-pitch propeller based on the circulation-control airfoil concept has no moving parts other than those needed for propeller rotation. The new propeller (see figure) involves blowing a tangential stream of air from a thin upper-surface slot over the airfoil rounded trailing edge. The jet sheet remains attached to and turns around the trailing edge, thus controlling the circulation around the airfoil. This principle controls the effective pitch of the propeller. With the circulation-control variable-pitch propeller, the effective pitch of the propeller could be varied over a wide range, simply by controlling the flow of air to the blowing slot. In small aircraft, it would improve takeoff performance and increase fuel economy at little or no additional cost. (See page 74.)



Producing Refractory Microballoons

An apparatus produces tiny spherical shells, or microballoons, from refractory metals, ceramics, and glasses. The microballoons are generated at rates of 400 per second or higher with uniform shape and size. The size is selected from a wide range of diameters, ranging from 800 μm to less than 150 μm. The microballoons can be used, for example, in fluidized-bed heat exchangers; as containers for hazardous materials, catalysts in chemical and pharmaceutical processes, and solid fuel for rockets; as fuel containers for fusion power experiments; as shock-wave dampers; and as starting materials for high-strength, low-density sintered alloys and ceramics. (See page 83.)

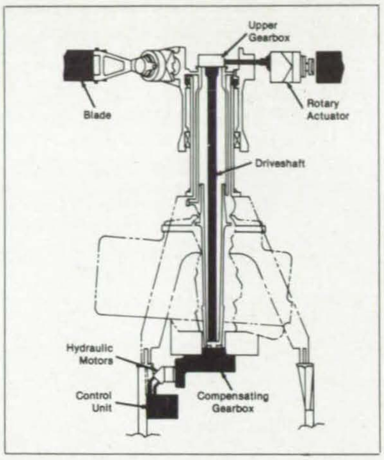


Multifunction Vacuum Chamber for IC Metallization

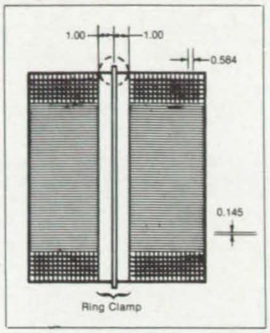
A vacuum-system chamber for processing multilayer metallization on in-

tegrated circuits (IC's) performs four operations ordinarily done in separate equipment: the chamber etches holes, removes photoresist, cleans by sputter etching, and deposits the final layer of metal. Costing less than the separate equipment performing the same functions, the chamber avoids exposing the integrated circuits to room air and, consequently, to oxidation and dust between steps. It also eliminates the time spent in transferring the circuits from one apparatus to the next. The chamber (see figure) contains turntables that continuously turn silicon integrated-circuit wafers to ensure uniform processing of several wafers at a time. Unlike the conventional process, the multifunction process does not use liquid acids and reducing agents for hole etching and photoresist removal. The cost of disposing of these hazardous materials is therefore avoided. (See page 86.)

Pitch Control for Helicopter Rotors



A pitch controller for helicopter rotors uses hub-mounted actuators located symmetrically between rotor blades. The new controller is designed for X-wing rotors that require collective pitch control; that is, the pitch of all blades must be changed by the same amount. The collective control allows the rotor to be trimmed during a variety of flight regimes, in particular during hovering and fixed-wing flight. The new controller has a short load path and is therefore stiff without excess weight. Its linkage permits large lead/lag motion of the blade without changing the blade pitch; the linkage also restrains vertical shear forces on the blade. Moreover, all linkages and drives are redundant: a single failure cannot cause catastrophic loss of control. (See page 76.)



Lightweight, Nesting Struts

Tapered for stiffness and for compact nesting for transportation but nevertheless fabricated with a constant load-bearing cross section, struts made of graphite-fiber-reinforced epoxy resin may be useful in small structures where great strength is not required. Each strut is 9 m long and 0.305 m in diameter at its large end, tapering to 0.025 m in diameter at its small end. A pair of struts is joined by a ring clamp at the large-diameter end (see figure). The end fittings are bonded to the struts during manufacture so that the double-strut assembly can be easily inserted in the truss as a structural member. A completed pair of struts with its fittings has a mass of 5.7 kg. (See page 82.)

Tufoil® THE TRANSISTOR OF LUBRICATION

How to make your machinery use less power, start and run smoother, quieter, with lower wear

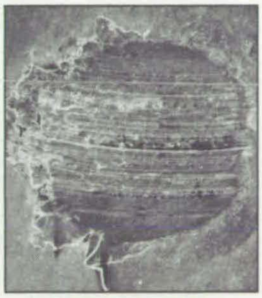
Lab tests show our patented technology produces the lowest friction and wear of any known lubricant . . . not just a little bit better, but better by a wide margin (orders of magnitude in some cases). Four-ball tests at the U.S. National Bureau of Standards show the friction for our product, TUFOIL, as low as .029 with very low wear. Confirmation is coming in from labs all over the world.

TUFOIL LIGHTNING GREASE (a jelled version of TUFOIL) works where all others fail. Field tests show that the life of crucial machine parts is greatly extended.

SCANNING ELECTRON MICROSCOPE PHOTOS 50X MAGNIFICATION

HEATS FAST
Molybdenum Disulfide Grease
(Test "C" below)

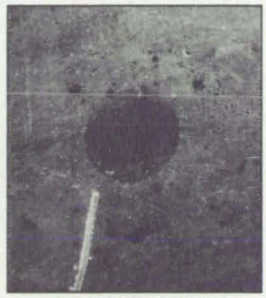
ROTOR BALL



STATOR BALL

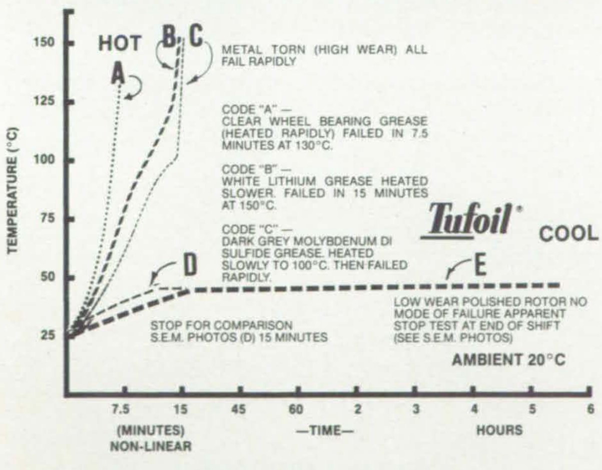
STAYS COOL
Tufoil Lightning Grease
(Test "D" & "E" below)

ROTOR BALL



STATOR BALL

4 BALL TEST OF GREASES
80 KG LOAD — 1700 RPM — .375 DIA. STEEL BALLS



The Tufoil lubricants have been under development for 15 years. They all contain Teflon™ or Fluon™
Teflon is Reg. TM of DuPont. Fluon is Reg. TM of ICI Americas, Inc. TUFOIL is Reg. TM of Fluoramics, Inc., U.S. Patents No. 3,933,565, 4,127,491 and 4,224,173. Other U.S. and International Patents issued and pending.

OEMs all over the world are using TUFOIL products to make machines run better, smoother and last longer.

Ground support vehicles start easier on cold mornings . . . turn table spindles have less rumble . . . automatic inserting machines run smoother . . . servos and steppers are more accurate . . . computer print heads are more accurate.

TUFOIL for Engines; TUFOIL Lubit-8; TUFOIL Gun-Coat; TUFOIL Compu-lube; TUFOIL Lightning Grease; all fill different needs . . . all use our patented dispersion technology!

TUFOIL LIGHTNING GREASE STAYS COOL AND SHOWS LESS WEAR

Scanning electron microscope photos of the rotor and stator ball scars from "C" (moly disulfide grease) show a great deal of wear and metal distress. "A" and "B" were similar.

The newly developed TUFOIL LIGHTNING GREASE was tested for 15 minutes. The test was stopped at "D" so that S.E.M. photos of the balls could be made for comparison purposes. Both the rotor and stator marks appear polished and smooth. A great deal of super fine PTFE debris (teflon or fluon) can be seen at the bottom of the rotor photos. It is loosely bonded to the metal surface. Solvent rinsing will not easily remove it.

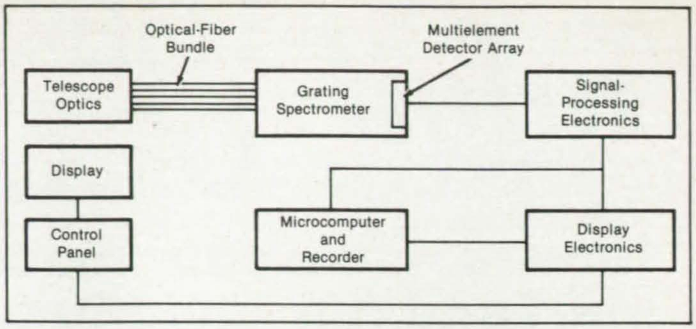
The wear areas on the stator were calculated, showing the spot on the control was 7.7 times larger than for TUFOIL grease (7.7 times the wear). Another test was set up with fresh balls ("E") and run for a full shift of 6 hours. The temperature stabilized at 50°C. The test was terminated with no mode of failure apparent. S.E.M. photos show highly polished surfaces with scar marks only slightly larger than those for "D" (the 15 minute sample).

We then life tested for 7 days (7 hours per day) . . . no failure and less wear than the moly disulfide produced in 15 minutes.

Call for prices and information!

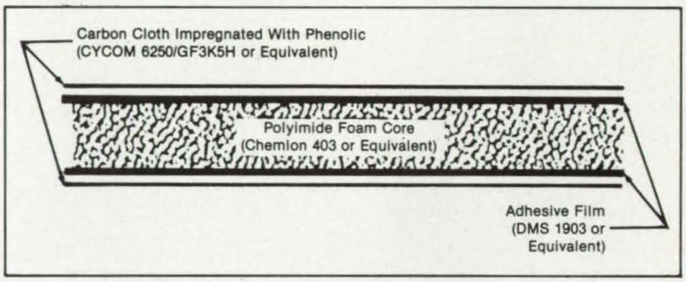
Fluoramics Inc.
103 PLEASANT AVENUE,
UPPER SADDLE RIVER, NJ 07458
201-825-8110

Circle Reader Action No. 455



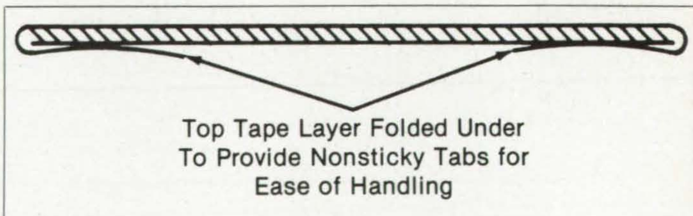
Improved Spectrometer for Field Use

A proposed portable spectrometer for analyzing minerals in the field would generate spectral images like a camera and process the spectral data for real-time identification of materials. To identify an unknown mineral, the user would locate significant peaks in the displayed spectrum and match them to a spectrum in a portfolio of reference spectra. Alternatively, the user would call up a display of prerecorded spectra in the same wavelength region for comparison or allow the spectrometer to determine the best match automatically. In principle, the new instrument would accommodate a wide variety of minerals. (See page 36.)



Fire-Resistant Aircraft Ceilings

A ceiling panel for airplane cabins is more fire resistant than conventional panels. The new panel incorporates a core of polyimide foam as a fire shield. The core significantly delays burn-through by flames and thus offers passengers greater protection. Biwoven carbon cloth impregnated with precured phenolic resin is glued to both faces of the polyimide core for reinforcement (see figure). (See page 48.)



TYPICAL APPLICATION

Strong Adhesive Tape for Cold Environments

An improved tape devised for repairs in space may also find use on Earth in polar regions and in superconducting applications. The tape retains its adherence and strength at extreme temperatures, where conventional tapes would fail. The improved tape (see figure) consists of two layers of Kapton (or equivalent) polyimide tape, which is adequately adhesive at extremely cold temperatures, with a reinforcing layer of thin, open-weave Kevlar (or equivalent) aromatic polyamid. Other mesh materials may also be suitable. (See page 52.)

HOW YOU CAN BENEFIT FROM NASA's TECHNOLOGY UTILIZATION SERVICES

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

On the following pages, we've outlined NASA's TU Network—named the participants, described their services, and listed the individuals you can contact for more information relating to your specific needs. We encourage you to make use of the information, access, and applications services offered by NASA's Technology Utilization Network. You can save time and money by doing so.

HOW YOU CAN UTILIZE NASA'S

Industrial Applications Centers

A nationwide network offering a broad range of technical services, including computerized access to over 100 million documents worldwide.

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

You can obtain more information about these services by calling or writing the nearest IAC. User fees are charged for IAC information services.

Aerospace Research Applications Center (ARAC)
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Indianapolis, IN 46204
Dr. F. Timothy Janis, Director
(317) 262-5003

Kerr Industrial Applications Center (KIAC)
Southeastern Oklahoma State University
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Durant, OK 74701
Tom J. McRorey, Director
(405) 924-6822

NASA Industrial Applications Center
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University of Pittsburgh
Pittsburgh, PA 15260
Paul A. McWilliams, Executive Director
(412) 648-7000

NASA/Southern Technology Applications Center
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Gainesville, FL 32611
J. Ronald Thornton, Director
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NASA Industrial Applications Center (WESRAC)
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Radford G. King, Acting Director
(213) 743-6132
(800) 642-2872 (CA only)
(800) 872-7477 (toll-free US)

If you represent a public sector organization with a particular need, you can contact NASA's Application Team for technology matching and problem solving assistance. Staffed by professional engineers from a variety of disciplines, the Application Team works with public sector organizations to identify and solve critical problems with existing NASA technology.

Technology Application Team
Research Triangle Institute
P.O. Box 12194
Research Triangle Park, NC 27709
Doris Rouse, Director
(919) 541-6980

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HOW YOU CAN ACCESS TECHNOLOGY TRANSFER SERVICES AT NASA FIELD CENTERS:

Technology Utilization Officers & Patent Counsels

Each NASA Field Center has designated a Technology Utilization Officer and a Patent Counsel to facilitate technology transfer between NASA and the private sector.

If you need further information about new technologies presented in NASA Tech Briefs, you should request the Technical Support Package (TSP) that accompanies the brief. In the event that a TSP is not available, you can contact the Technology Utilization Officer at the NASA Field Center that sponsored the research. He can arrange for expert assistance in applying the technology by putting you in touch with the people who developed it.

If you want additional information about the patent status of a particular technology or are interested in licensing a NASA invention, contact the Patent Counsel at the NASA Field Center that sponsored the research. Be sure to refer to the NASA reference number at the end of the tech brief.

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IF YOU HAVE A QUESTION...

NASA Scientific & Technical Information Facility

If you have a general or specific question about NASA's Technology Utilization Network or its services and documents, you can contact the STI facility for assistance. The STI staff can answer your questions, supply documents and provide referrals to meet your needs. You can use the feedback card in this issue to contact STI directly.

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BWI Airport, MD 21240
Walter M. Heiland, Manager
(301) 859-5300, Ext. 242, 243

Electronic Components & Circuits

Hardware, Techniques, and Processes

Designing dc Inductors With Airgaps

Optimal parameters are obtained by designing near the saturation point.

NASA's Jet Propulsion Laboratory, Pasadena, California

An iterative procedure aids the design of dc inductors with airgaps in the cores (see figure). For a given core area and length, the technique gives a design having the specified inductance and the peak flux density in the core, using the minimum required copper weight. The new technique is superior to the previous trial-and-error technique, which often resulted in cores larger than necessary or in less inductance than could be obtained from a core of given size. Typical applications include lightweight inductors for aircraft electronics.

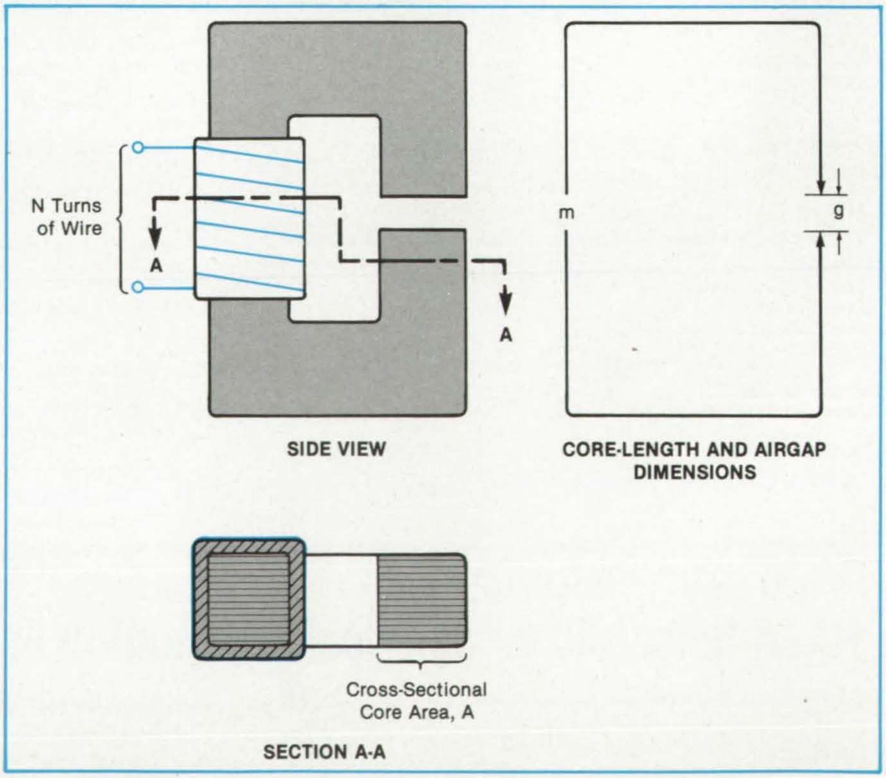
The new approach is based on the full use of the core: The inductor is designed to operate at the saturation flux density of the core material (or at another maximum flux density related to the saturation value). Subject to this constraint, the airgap length, g, and the number of turns, N, are selected to give the required inductance, L. Because there is only one combination of g and N that will satisfy the inductance and saturation criteria for a given core, the procedure quickly leads to an optimal design.

The procedure depends on the fact that N/g is nearly constant, regardless of variations in L, for practical inductor dimensions and core materials. At first, the designer knows the maximum coil current, I; the cross-sectional core area, A; the incremental relative permeability, μ_s, of the core material at the operating point; the maximum flux density, B; the core length, m; and the dc relative permeability, U_s, at the operating point.

The first step is to select a trial airgap, g_1. (Typical gap sizes lie between 0.01 and 0.25 cm.) The designer calculates the initial value, F_1, of the fringing-flux factor, F: This factor depends on g_1 and the other core dimensions. The initial number of turns is then determined from

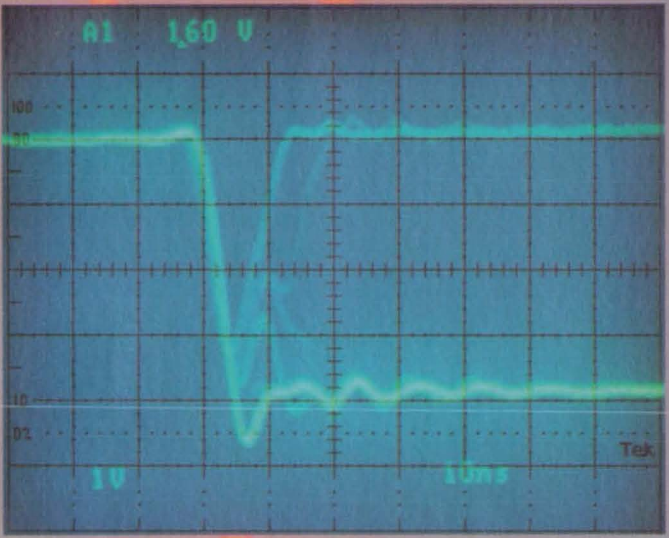
$$N = \frac{B(g_1 + m/U_s)}{(0.4\pi I)(F_1)}$$

Next, the designer calculates the initial inductance from

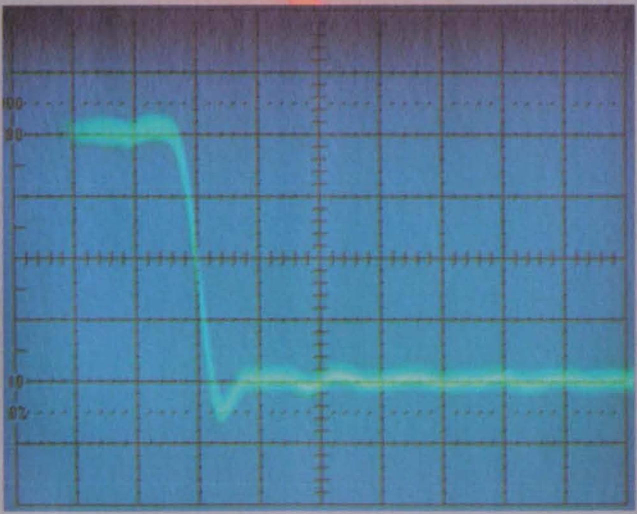


This **Inductor With a C-Shaped Core** is an example of the types that can be designed with the iterative procedure.

IN A MATTER OF SECONDS, THE NEW TEK 2467 CAN SAVE WEEKS OF TROUBLESHOOTING.



Now. See what you've always needed to see with a portable scope. (Above) Tek's new 2467 Transient Intensifying Oscilloscope, with its exclusive micro-channel-plate CRT, highlights the infrequent metastability of a flip-flop output. (Below) The same metastability is invisible on a conventional high-speed scope.



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Discover marginal conditions you don't even know exist. Now designers and test engineers can quickly identify circuit or system faults caused by infrequent metastability, asynchronous noise, crosstalk or erratic timing-margin violations—even if they occur only once in a million normal operations.

Not only can you shorten time to market, you can deliver more reliable new products.

To see the Tek 2467 in action, or to order, contact your Tek Sales Engineer. Or call the Tek National Marketing Center, 1-800-426-2200. In Oregon, call collect, (503) 627-9000.

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Circle Reader Action No. 359

$$L_1 = \frac{0.4\pi(N_1)^2(AF_1)}{g_1 + m/\mu_s}$$

If L_1 differs from L by more than the tolerance, then a second airgap length is estimated from $g_2 = g_1 L/L_1$. The preceding sequence of calculations is then repeated to find F_2, N_2, and L_2. These iterations are continued until the computed inductance is sufficiently close to L. Most designs require one to three iterations to bring the inductance within 1 percent of L. The procedure can be executed rapidly on a programmable, hand-held calculator.

This work was done by Albert P. Wagner of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 74 on the TSP Request Card.* *NPO-16739*

Circuit for Lifetime and Surface-Recombination Measurements

A test circuit for silicon solar cells suppresses spurious effects.

NASA's Jet Propulsion Laboratory, Pasadena, California

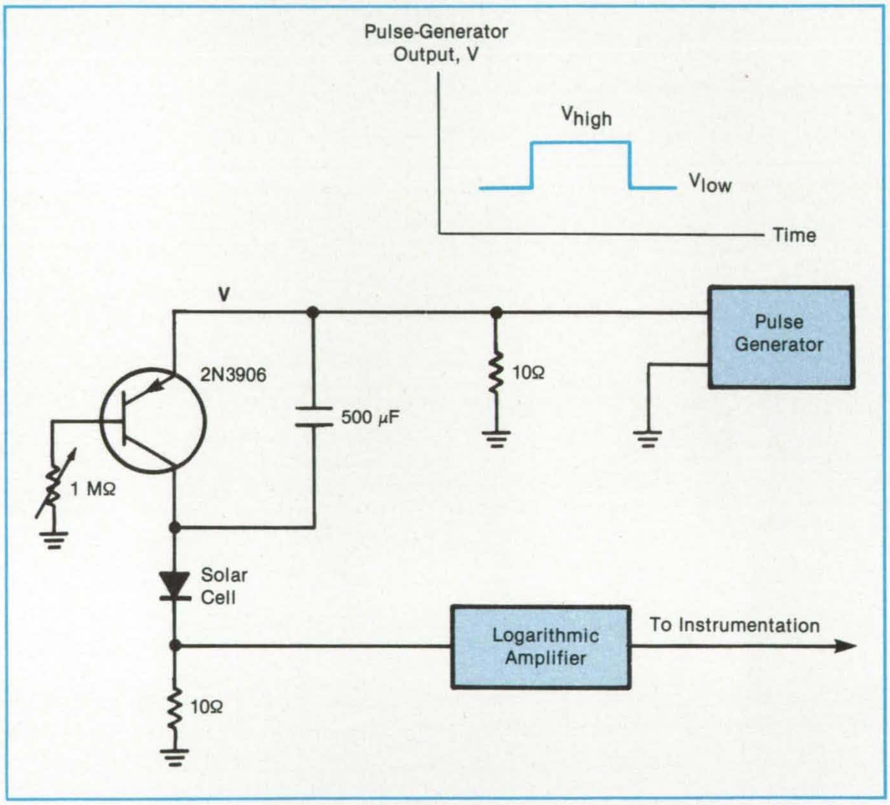
A new circuit increases the accuracy of measurements of the recombination lifetime and the effective surface recombination velocity in a silicon solar cell. Essentially a fast electronic switch, the circuit grounds a forward-biased cell so rapidly that the transient voltage to be measured is not affected significantly.

Previously, the method of open-circuit voltage decay or of junction-current recovery was used. The solar cell was maintained initially under forward voltage and current. Then a reverse current was applied suddenly, and the voltage across the cell was measured as a function of time. For the open-circuit voltage-decay method, the applied reverse voltage was zero; for the junction-current recovery method, the reverse voltage was finite.

In either method, the transient voltage across the solar cell was interpreted by an idealized theory that neglected the effects of mobile holes and electrons in the space-charge region of the cell. This theory is acceptable for germanium devices, which have a low energy gap and a low proportion of mobile holes and electrons. In silicon devices, however, mobile holes and electrons play a prominent role in establishing the voltage transients, and their presence creates errors in the interpretation of the measurements.

The new circuit avoids the problem by placing a short circuit across the solar-cell terminals. The short circuit removes mobile holes and electrons from the space-charge region, within about one nanosecond.

As before, the solar cell is first subjected to forward current. At the designated switching time, a metal-oxide/semiconductor transistor is switched on to create the short circuit (see figure). The recombination lifetime and the time for mobile holes and electrons to cross the base region so that effective recombination can begin is more than 1,000 times greater than the 1-nanosecond discharge time for the space-charge region. Therefore, mobile holes and electrons in the space-charge region have negligible influence on the measurement of the recombination lifetime and surface recombination velocity.



The **Switching Transistor** initially applies a forward current to the solar cell during the interval when the pulse-generator output is high. At the transition from V_{high} back to V_{low}, the solar-cell anode is effectively shorted to ground within a nanosecond. The cathode-to-ground voltage is measured and recorded as it changes with time.

The short-circuit method is accurate for solar cells in which the diffusion length is about the same as the base thickness and in which the base doping is uniform. This method can still be used for such graded-base devices as the drift-field solar cell or the extended back-surface-field solar cell, provided that the effects of the nonuniform dopant concentration are taken into account.

This work was done by Frederik A. Lindholm, Arnost Neugroschel, and Tae Won Jung of the University of Florida for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 45 on the TSP Request Card.* *NPO-16752*

Circle Reader Action No. 313

Fuel-Cell Structure Prevents Membrane Drying

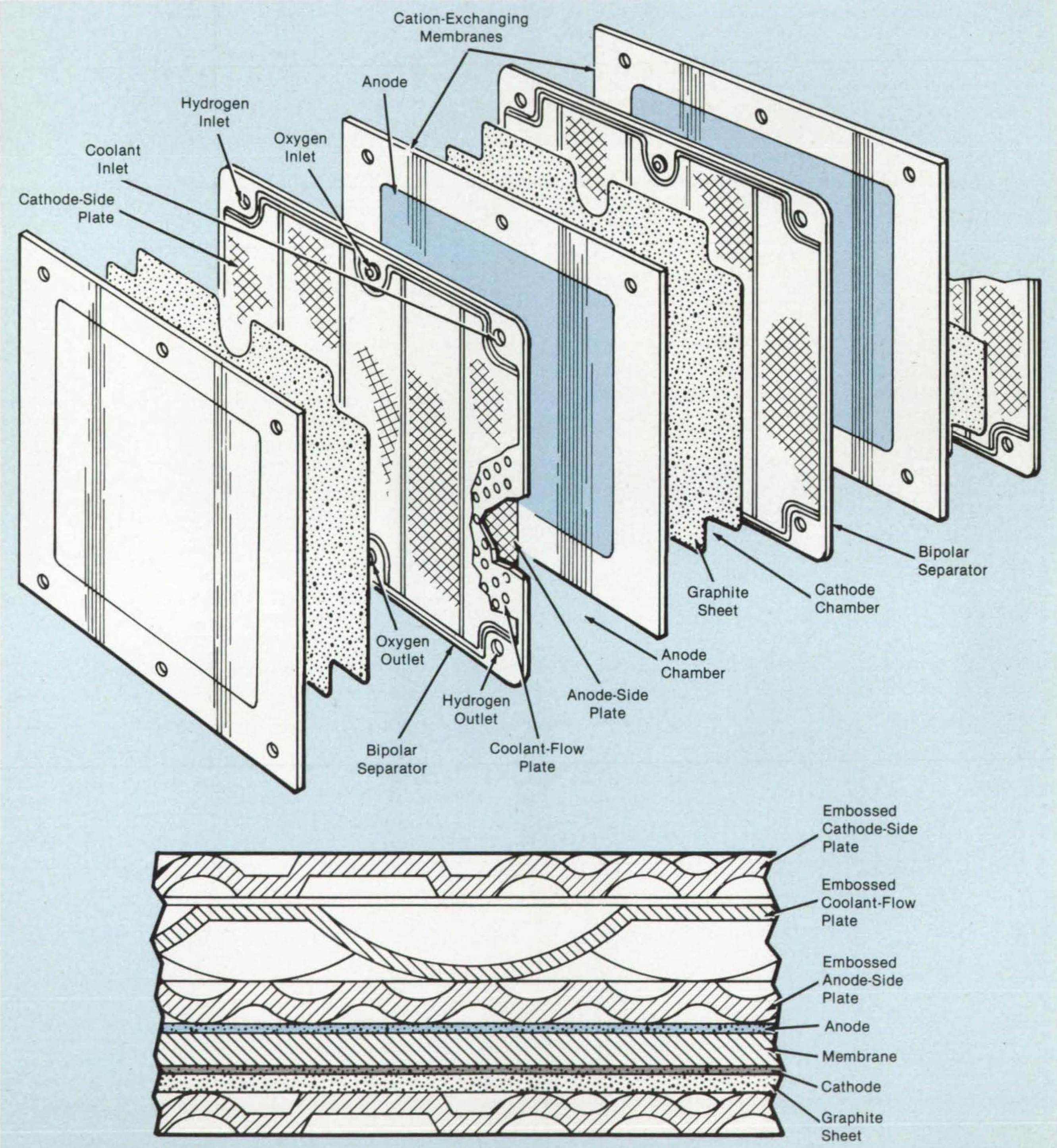
Embossed plates direct flows of reactants and coolant.

Lyndon B. Johnson Space Center, Houston, Texas

A membrane-type fuel-cell battery has improved reactant flow and heat removal. The compact, lightweight battery can produce high current and power without drying of its membranes.

The battery consists of a series of fuel cells (see figure), each of which contains a cation-exchanging membrane between internally cooled bipolar separators. An anode is attached to one side of a membrane; the anode is an aggregate of liquid- and gas-pervious catalytic particles in a polymeric binder. A pervious cathode is bonded to the other side of a membrane; it too is composed of catalytic and binder particles.

The bipolar separators on opposite sides of a membrane form an anode



The **Fuel-Cell Battery** includes a series of membranes and separators. The anode graphite sheets, which support the cell membrane, do not appear in this view. The bottom part of the figure shows the internal structure of a separator in cross section.

chamber and a cathode chamber. Hydrogen gas is oxidized at the anode, releasing electrons to an external load circuit. The hydrogen ions thus created pass through the membrane to the cathode, where oxygen and electrons react with the hydrogen ions to form water. The water product collects at the bottom of the cell, where it drains away through the oxygen-outlet manifold. (Fuel/ oxidizer combinations other than hydrogen/oxygen may be used. The reactants may be hydrogen/chlorine or hydrogen/bromine, for example.)

Oxygen enters the cathode chamber through an inlet at the top of the bipolar separator. Hydrogen enters the anode chamber through an inlet at a corner of the separator. In the new fuel-cell configuration, the separator contains embossed plates on its opposite faces to guide the flowing gases— hydrogen on the anode side and oxygen on the cathode side. The plates distribute the gases uniformly for efficient reaction.

A coolant plate between the anode-side and cathode-side plates forms two adjacent chambers through which coolant flows. The cathode-side plate is made of niobium, 5 mils (0.13 mm) thick. The anode-side plate is made of zirconium, which is resistant to embrittlement by the hydrogen flowing over it. The coolant plate is made of titanium. The three plates are held together by the frame of the separator. The concave bumps embossed in the coolant plate on the cathode side tend to collect coolant, so that flow there is slower and removes less heat than does the flow along the anode side. The anode side of the cell membrane is therefore maintained at a temperature lower than that of the cathode side.

The effect of this temperature differential is to prevent drying of the hydrogen side of the membrane. Without the differential, as hydrogen is oxidized the resulting hydrogen ions move through the membrane, carrying molecules of membrane water with them. Because each hydrogen ion can carry eight to ten water molecules with it, the water on the fuel side can quickly become depleted. This drying effect, which is aggravated as the battery power output—and hence the cell current density—increases, can limit the maximum power output.

With the temperature differential, however, water diffuses from the warmer cathode to the cooler anode. This reverse diffusion compensates for the loss of water on the fuel side.

This work was done by James McElroy of General Electric Co. for **Johnson Space Center**. *For further information, Circle 111 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Johnson Space Center [see page 27]. Refer to MSC-21031.

Solenoid-Simulation Circuit

Electrical properties of solenoids are imitated for tests of control circuits.

Marshall Space Flight Center, Alabama

A simulation circuit imitates the voltage and current responses of two engine-controlling solenoids. Used in tests of the programs of the digital engine-control circuits, the solenoid-simulation circuit also provides an electronic interface with circuits that imitate the electrical properties of pressure sensors and linear variable-differential transformers (LVDT's).

The solenoid-return voltages in the real engine circuits are measured across sensing resistors placed in the engine-control panel and connected electrically in series with the solenoids. Thus, the solenoid-return voltages are proportional to the solenoid currents. The simulation circuit (see figure) puts out solenoid-return voltages that represent the solenoid pulling and holding currents. For the control-circuit tests, it is necessary to imitate a pulling level of current for a specified duration, followed by a holding level for an indefinite time.

Channels A and B represent the two solenoids. Power resistors R_A and R_B represent the coils of the corresponding solenoids. The time constants for charging the capacitors at the noninverting inputs of amplifiers A_1 and A_3 represent the times required to build up the solenoid current to the pull-in level. When the pull-in level is reached in channel A, amplifier A_1 sends a positive signal to the "set" input of flip-flop A to represent the discrete turn-on of solenoid A. Similar events occur in amplifier A_3 and flip-flop B when the simulated current of solenoid B reaches the pull-in level.

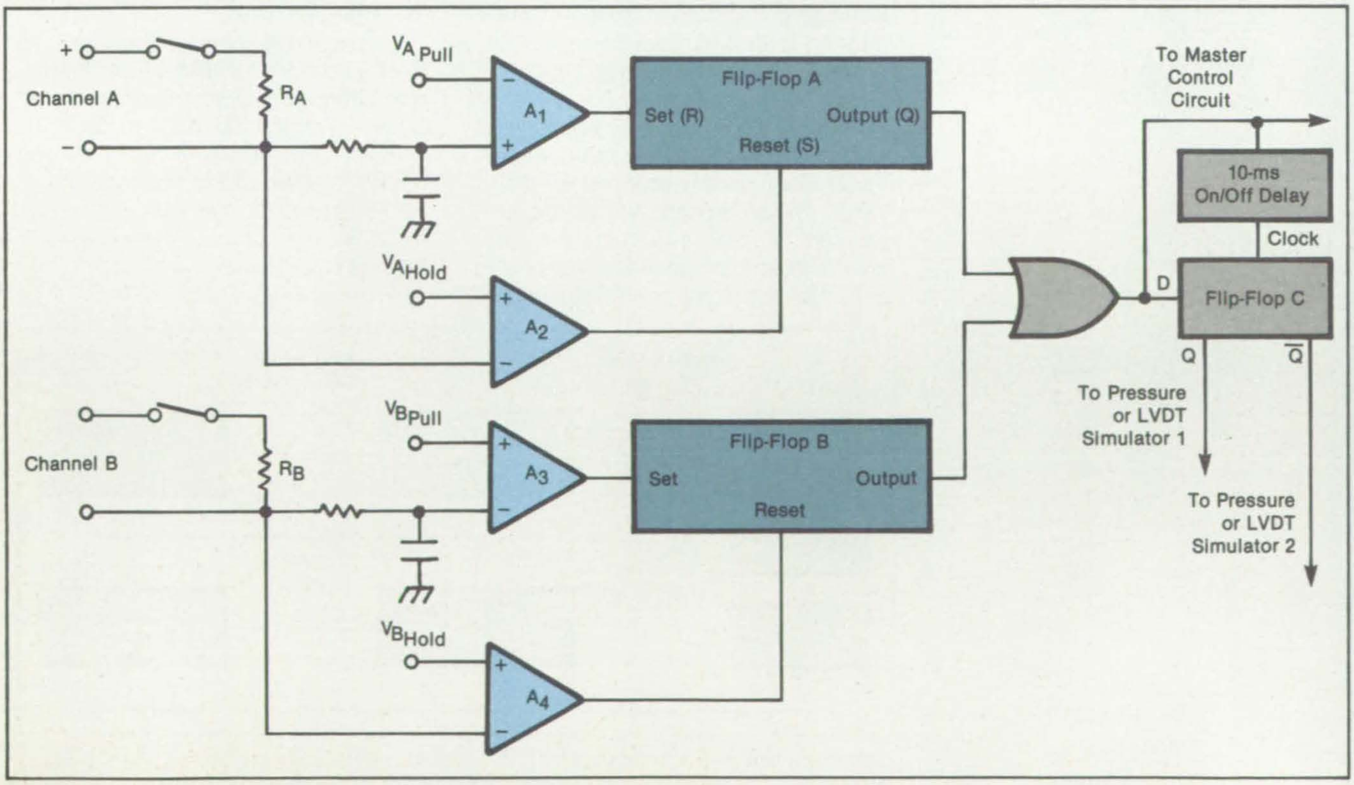
The flip-flop output of each channel continues to indicate that the solenoids are on as long as the simulated solenoid current in that channel equals or exceeds the holding level. When the simulated return voltage falls below the holding level in channel A, amplifier A_2 sends a positive signal to the "reset" input of flip-flop A, causing the flip-flop output to change and thereby indicating the turnoff of solenoid A. Again, similar events in amplifier A_4 and flip-flop B indicate the turnoff of solenoid B.

The "solenoid on" signal of either channel is fed through the OR gate to a master control circuit for use in monitoring the test and protecting the engine-control circuits. Delayed versions of the "solenoid on" signal are used to open and close LVDT simulations and to raise and lower pressure simulations. The delays prevent false triggering from erroneous inputs and simulate the delays encountered in real engine operation.

For each channel, a switch connects either of two sets of voltages representing two different sets of holding and pulling currents. This is to enable the simulation of two different types of solenoid or sensing resistor used in the real engine circuits. The circuit is built on a card with an edge connector, and numerous such identical cards are used in the total engine-simulation circuit. Thus, all the cards are interchangeable, yet each one can be programmed via its edge connector. Edge-connector programming can also include the simulation of faults or the connection of a real solenoid.

This work was done by Richard A. Simon of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information, Circle 140 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 27]. Refer to MFS-29173.



The **Solenoid-Simulation Circuit** produces voltages, currents, delays, and discrete turnon and turnoff signals representing the operation of a solenoid in an engine-control relay. Many such circuits are used in simulating the overall engine circuitry.

Electronic Systems

Hardware, Techniques, and Processes

Books and Reports

Improved Spectrometer for Field Use

Instrument would give answers in the field without waits for lab processing.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed portable spectrometer for analyzing minerals in the field would generate spectral images like a camera and process the spectral data for real-time identification of materials. To identify an unknown mineral, the user would locate significant peaks in the displayed spectrum and match them to a spectrum in a portfolio of reference spectra. Alternatively, the user would call up a display of prerecorded spectra in the same wavelength region for comparison or allow the spectrometer to determine the best match automatically.

The new instrument would make it unnecessary to return the data to a laboratory or an equipment trailer for processing. In principle, it would accommodate a wide variety of minerals. The proposed spectrometer would extend the capabilities of the simpler two-wavelength instrument described in "Portable Radiometer Identifies Minerals in the Field" (NPO-15234), page 419, *NASA Tech Briefs*, Vol. 6, No. 4 (Spring/Summer 1982).

In the proposed instrument, reflected light from the terrain enters a telescope (see figure) and passes along an optical fiber to a grating spectrometer. The grating disperses the light passing through filters onto a linear array of about 1,000 individual photodetectors or a set of charge-coupled-device detectors. The array is electronically scanned so that it yields analog signals, which are processed by gain-adjusting circuits, amplifiers, and demodulators. The analog data from the signal processor are converted to digital form for use by a microprocessor. The microprocessor and a digital recorder provide signals for a liquid-crystal display.

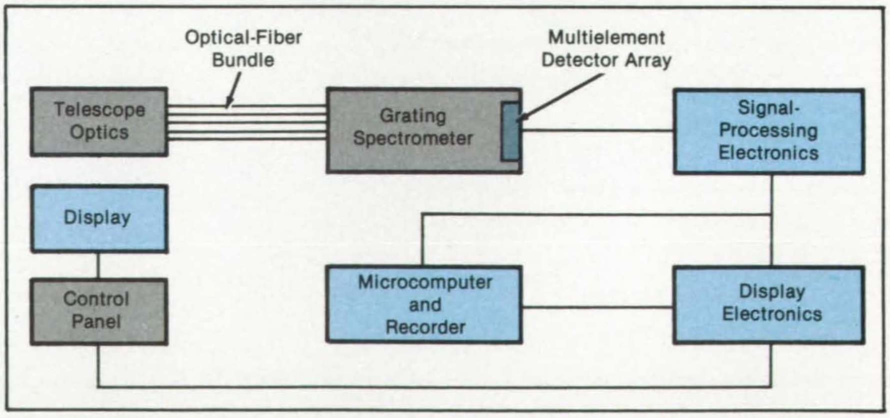
A control pad and spectral display are contained in a separate paddle so that the telescope can be made as light as possible. The user can select a portion of the reflectance spectrum of the surface under examination for real-time display, can expand the reflectance and wavelength display coordinates as desired, and can retain a spectrum for further processing and recording.

An initial calibration is carried out in ambient light, preferably with a target lighted by the Sun. The instrument is pointed at a standard-reflectance calibration target, and the spectrum is recorded.

The instrument is then pointed at the target terrain, and its spectrum, after ratioing with the standard, is displayed on the screen. The spectrum is recorded for future use. For analysis, prerecorded spectra are called up for comparison as a superimposed curve, or else algorithms are applied for automatic identification of the target specimen.

This work was done by Alexander F. H. Goetz of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 117 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 27]. Refer to NPO-15732.



Telescope Optics Are Separated from the display and the control panel so that the instrument is easy for a user to operate. Once a sizeable library of prerecorded reference spectra is accumulated, spectrum-matching algorithm boards can be incorporated into the miroprocessor to evaluate rapidly the components of a target specimen.

Three-Frequency Water-Vapor Radiometer

Measurements increase the accuracies of delay predictions.

NASA's Jet Propulsion Laboratory, Pasadena, California

A three-frequency microwave radiometer measures the quantity of water vapor in the atmosphere, as part of the effort to determine microwave-signal delays due to water vapor. The delay estimates are necessary for the accurate determination of distances in geodesy and such related applications as very-long-baseline interferometry. The water-vapor data are also directly useful in weather research.

The amount of water vapor and the microwave delay caused by the water vapor along a line of sight in the atmosphere are readily estimated from microwave observations along the same line of sight. In prior radiometer systems, the most important measured quantity was the thermal atmospheric emission at a frequency near the 22.237-GHz resonance of the H_2O molecule. In cloudy skies, a second measurement was made away from this resonance to determine the thermal contribution from liquid water. The new radiometer measures the emission at three frequencies, two (20.7 and 22.3 GHz) near the resonance and a third at 31.4 GHz. The three-frequency technique offers a modest improvement in delay estimation over the two-frequency technique.

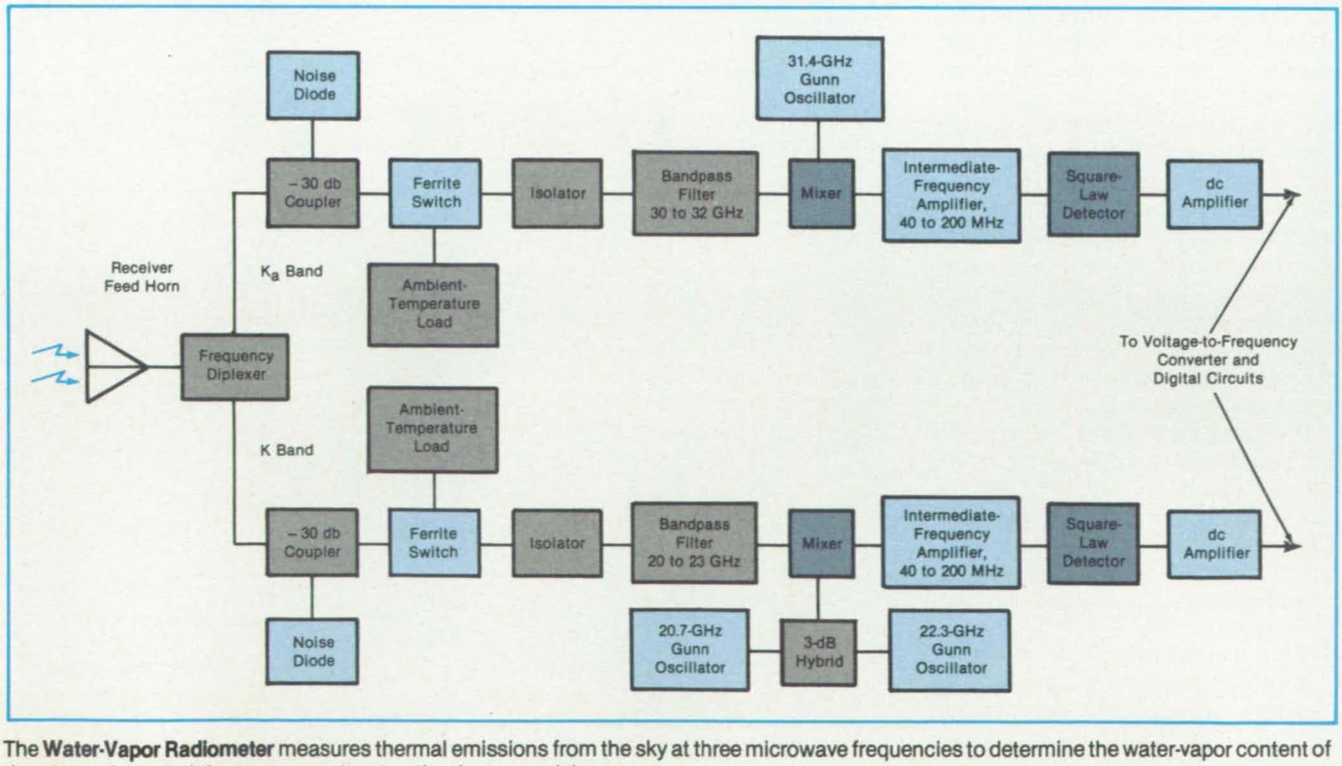
The figure illustrates the microwave portion of the radiometer. The received sky signal is fed through a frequency diplexer, which separates the two lower frequencies from the higher one. The individual receivers are Dicke radiometers, each of which includes a ferrite switch to alternate its input between the received sky signal and an internal ambient-temperature load for temperature calibration and receiver stabilization. A constant white-noise signal from a noise diode is coupled into the sky-signal port of each ferrite switch to provide a gain-calibration reference.

The mixers are of the double-balanced, Schottky-diode type having intermediate-frequency passbands of 40 to 200 MHz. The 20.7- and 22.3-GHz signals are obtained in the lower frequency channel by passively coupling the two Gunn local oscillators into the mixer and alternately turning the oscillators on and off. The bandpass filters suppress the local-oscillator harmonics, that might otherwise cause offsets in the Dicke comparison between the sky- and ambient-temperature reference ports.

All of the radiometer components except the receiving feed horn are configured in a plane and fastened to an aluminum heat sink. The heat sink is thermally isolated from the environment except for a thermoelectric heat pump that maintains it at 35 °C. This temperature control stabilizes the radiometer gain and noise-diode outputs within a small fraction of a percent.

A microprocessor monitors temperatures, power-supply voltages, and the output of a tilt sensor for automatic zenith-angle calibration. It controls the stepping motors that change the line of sight. It also controls the microwave switches. One cycle of the switching sequence takes about 1 s and is comprised of eight integration subcycles of about one-eighth s at each of the eight combinations of switch positions. The radiometer outputs are integrated digitally and processed into sky-brightness temperatures.

This work was done by Michael A. Janssen and Noburu I. Yamane of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 124 on the TSP Request Card.*
NPO-16531



The **Water-Vapor Radiometer** measures thermal emissions from the sky at three microwave frequencies to determine the water-vapor content of the atmosphere and the consequent wet-path microwave delay.

Laser-Pulse/Fiber-Optic Liquid-Leak Detector

Several potential leak sites can be monitored using a single sensing fiber.

John F. Kennedy Space Center, Florida

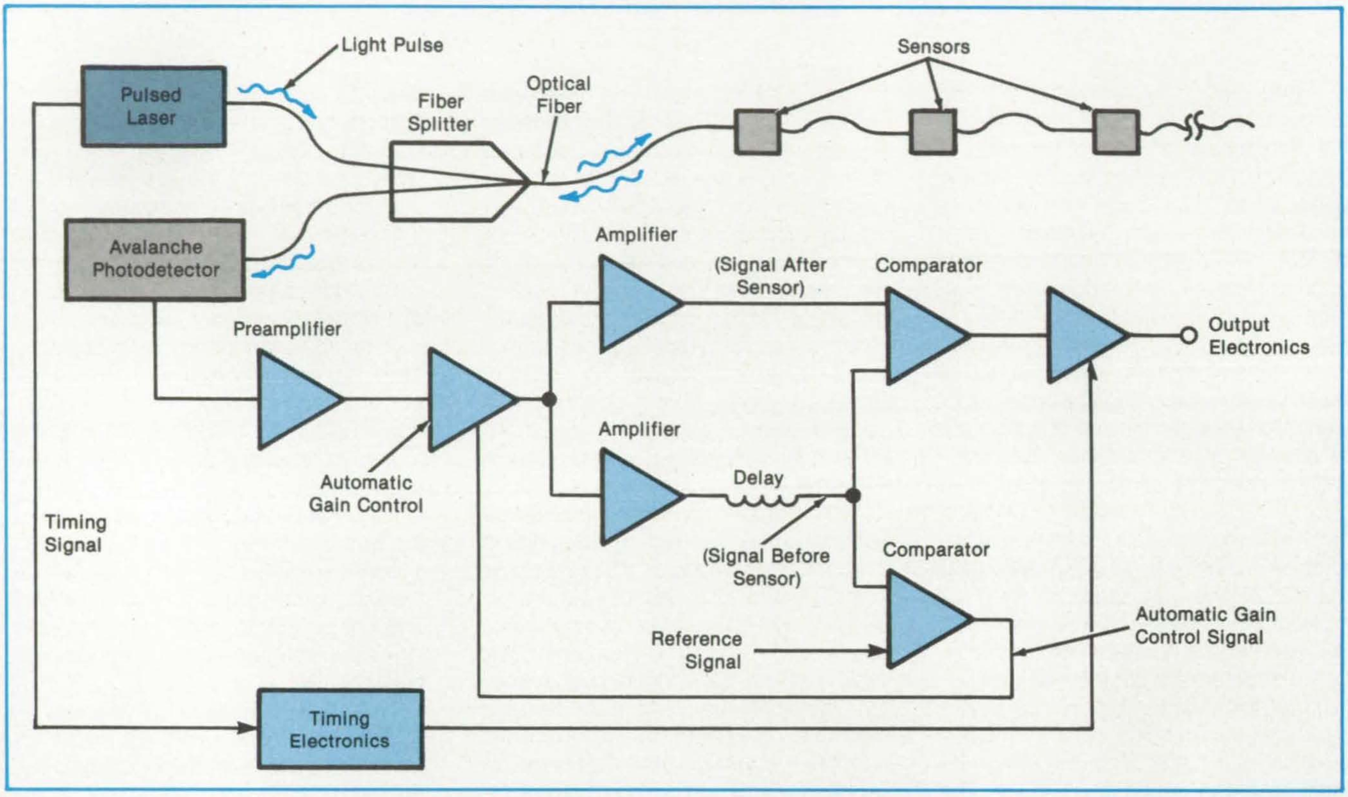


Figure 1. This **Optical Time-Domain Reflectometer** measures pulse travel times to identify the sensor or sensors from which reflected laser pulses originate. A leak is indicated by a change in the amplitude of the pulse reflected from a sensor.

Fluid systems can be monitored quickly for leaks in remote, hazardous, or inaccessible locations by a system of compact, lightweight fiber-optic leak sensors that are presently undergoing development. The sensors would be installed at such potential leak sites as joints, couplings, and fittings. A sensor is read by sending a laser pulse along the fiber, then noting the presence or relative amplitude of the return pulse. This leak-monitoring technique should be applicable to a wide range of fluid systems and would minimize human exposure to toxic or dangerous fluids.

The sensors are optical discontinuities from which light is reflected back along the sensing optical fiber or fibers to a photodetector. The intensity of the reflection is determined in part by the index of refraction of the medium surrounding a sensor, through its effect on the electromagnetic modes in the fiber core and cladding. For example, if leaking oil having an index of refraction near that of the cladding comes into contact with the cladding, a substantial amount of light is coupled out of the core and lost to the en-

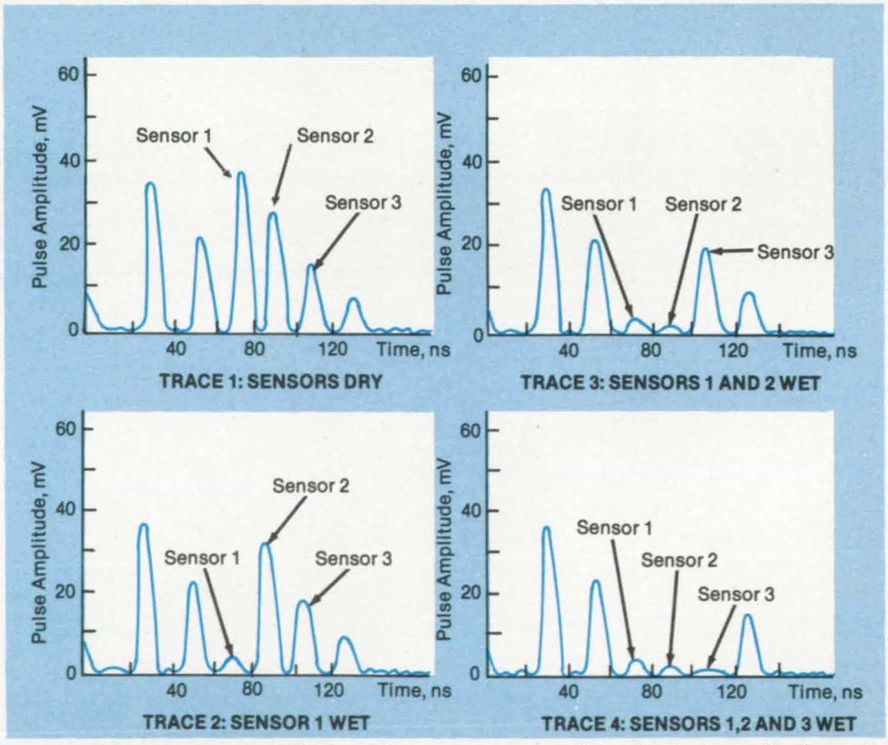


Figure 2. The **Presence of Water at Sensors** connected in series is shown by the reduction of the corresponding reflected laser pulses. The reflections from the dry sensors are indicated by peaks 3 through 5 in the first trace. The subsequent traces show the effects of successively wetting the three sensors.

vironment. In this case, the loss of reflection would indicate a leak.

The types of sensors showing the most promise include tapered constrictions, U-bends, and tilted fiber ends with and without mirrors. An individual fiber could be run to each potential leak site, which would necessitate large amounts of fiber. Alternatively, optical time-domain reflectometry can be used, as shown in Figure 1. There, the sensors are located in series along one fiber. The travel time of an affected pulse indicates the distance along the fiber to the affected sensor, thereby identifying the leak. Calculations indicate that 50 to 100 sensors can be connected along one optical fiber.

Figure 2 shows the signals reflected from a chain containing three experimental sensors in series, approximately 2 m apart. The first two returned pulses are from the connectors between the fiber and sensor chain. The next three pulses are reflections from the three sensors. The last pulse is from the end of the fiber. As can be seen, wetting one sensor increases the signal from subsequent sensors.

This work was done by Michael E. Padgett of **Kennedy Space Center** *and Opto-Electronics, Inc. For further information, Circle 136 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Kennedy Space Center [see page 27]. Refer to KSC-11331.

Books and Reports

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

Understanding Microwave Radiometers

A tutorial document aids in designing these useful instruments.

A report presents the principles of microwave receivers for observing planetary surfaces from space. The report is tutorial in nature and explains the operation of the receivers in enough detail to enable the reader to specify and qualify them for spaceborne operation. It gives many examples to illustrate practical design procedures.

A microwave radiometer is the heart of a radio-astronomy facility. In fact, astronomers have been largely responsible for the major technical refinements in today's radiometric equipment. Commercial users and the military have been slower to accept microwave radiometry, probably because more mature sensors and methods have been available to them. Nevertheless, the remote sensing of the atmosphere and surface of the Earth from space has emerged as a potentially useful but incompletely developed application for microwave radiometry. Ultimately, the disciplines most likely to benefit are glaciology, hydrology, meteorology, and oceanography.

The report discusses the principles of operation of the key components of a receiver. It explains the important differences among receiver types. It develops new definitions as necessary — when concepts have not been defined previously, for example, or when there is no universally accepted definition.

Mathematical expressions are derived for operating performance and sensitivity for both the modulated and total-power receiver configurations. Applied statistics has been rigidly adopted for precision in interpreting derived quantities and in explaining uncertainties. Examples illustrate, from a thermodynamic perspective, the transfer of energy from point to point in the receiver.

This work was done by Joseph M. Stacey of Caltech for **NASA's Jet Propulsion Laboratory.** *To obtain a copy of the report, "Spaceborne Receivers — Basic Principles," Circle 141 on the TSP Request Card.*
NPO-16586

Physical Sciences

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Photocurrent Imaging Detects Solar-Module Defects

A raster-scanned laser beam excites photocurrents in thin-film amorphous silicon devices.

NASA's Jet Propulsion Laboratory, Pasadena, California

Cracks in thin-film amorphous silicon solar modules show up as dark lines on the image from a new solar-cell laser scanner. As a monochromatic laser-beam spot < 1 mm in diameter scans in a raster over a forward-biased solar module, the resulting photocurrent is displayed as brightness on a television monitor (see Figure 1) scanned in the corresponding raster.

While the solar-cell laser scanner will not replace other commonly used test

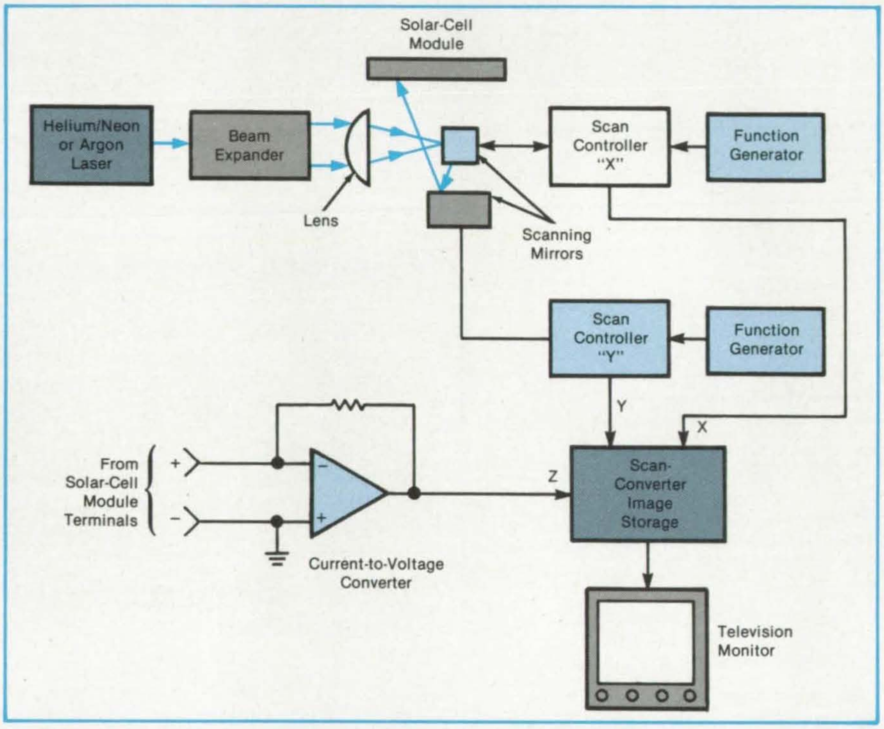


Figure 1. The **Solar-Cell Laser Scanner** uses two galvanometer-driven mirrors to scan a laser-beam spot over the surface of the module or cell under test. Position signals from the scan controllers are used to index the storage of the photocurrent signal data in the scan-converter image memory. The stored image is displayed on a television monitor.

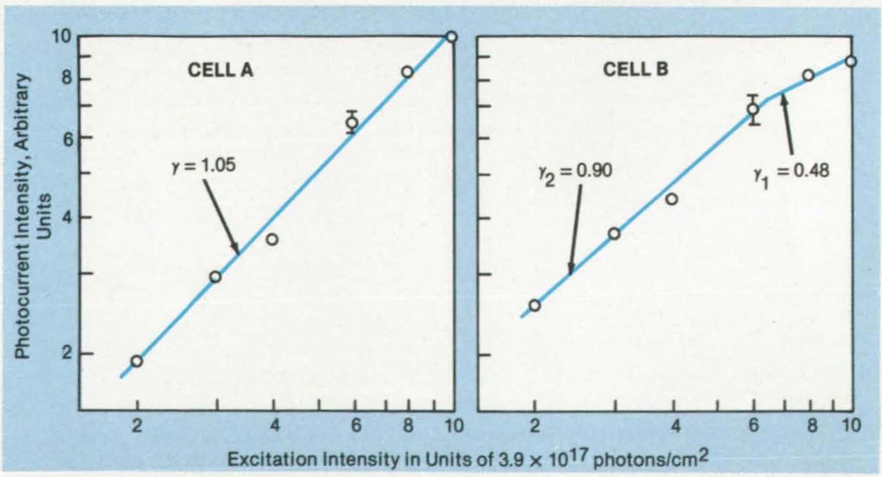
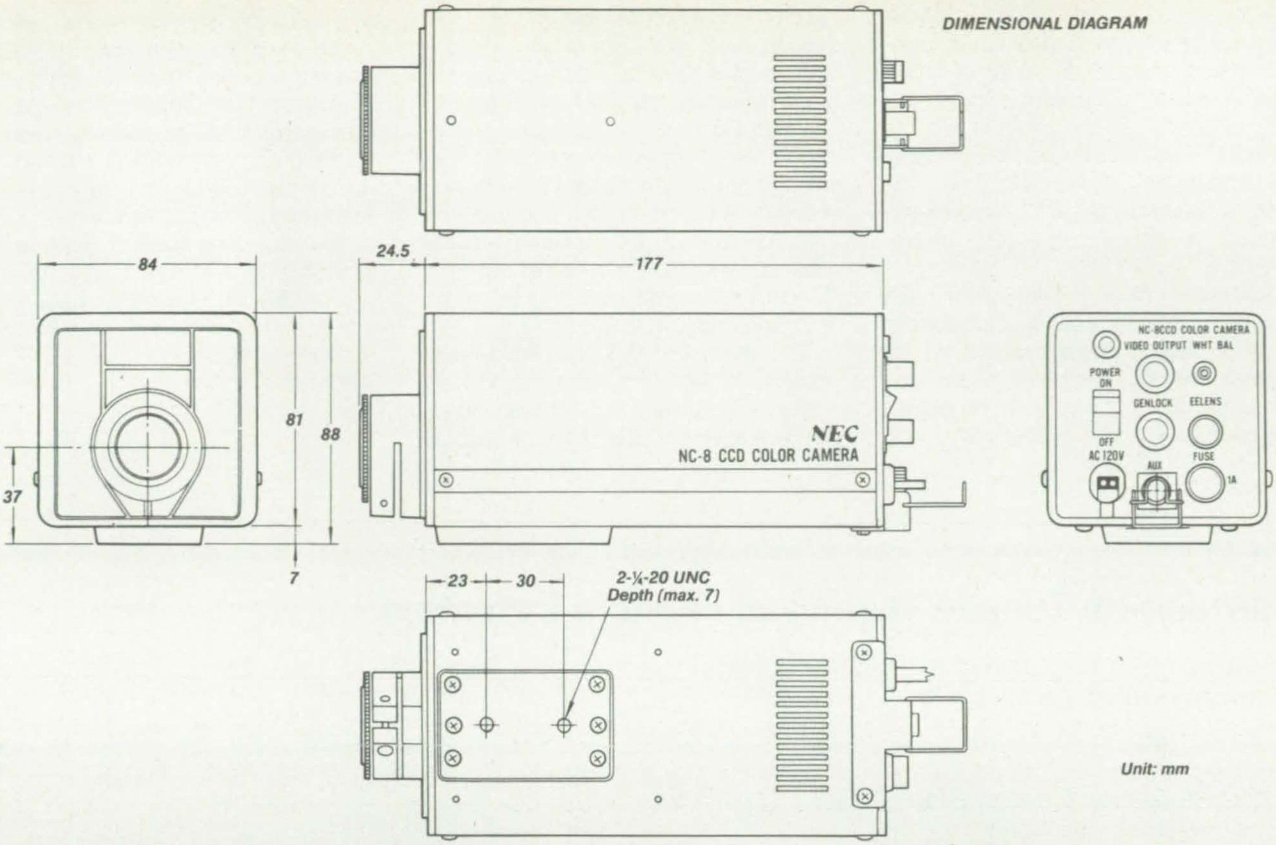


Figure 2. The **Photocurrent Measured at Different Excitation Intensities** can be used to study the physical characteristics of a cell or of a small portion of a cell. Here, two graphs show the independence of the photocurrent on the excitation intensity for two different amorphous-silicon cells in the same array.



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Specifications

Pickup	Interline transfer type CCD x1
Number of picture element	H427xV492
S/N ratio	47dB (illuminance channel, standard recording conditions, AGC: off)
Resolution	Horizontal: 280 lines Vertical: 350 lines
Sensitivity	1,600 Lux F4.0
Minimum illumination	10 Lux F1.4 AGC: ON (20% signal output level)
White balance adjustment	Manual/Remote
Lens mount	C-Mount
Power consumption	Approx. 6.5W (less than 9VA)
Weight	Approx. 1.4kg [3.1 lbs] (excluding lens)

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For more information about the NC-8, TI-22AII, TI-22PII and TI-26A industrial cameras, contact the Industrial Video Group, Broadcast Equipment Division, NEC America, Inc., 1255 Michael Drive, Wood Dale, IL 60191 Toll free 1-800-323-6656. In Illinois phone 312/860-7600.

Circle Reader Action No. 369

and inspection techniques, it should be very useful for the nondestructive evaluation and analysis of failure of entire solar modules or individual cells. No special electrical connections are required: The test uses the normal electrical contacts of the cell. No special environment is needed, and cells can be tested whether or not they have been encapsulated.

Additional characteristics of the cells may be inferred by a study of the effects of the excitation intensity on the photocurrent images. Variations in the dependence of the photocurrent on excitation may be valuable indications of cell quality. For example, the photocurrent responses of two cells of an array are shown in Figure 2. Each cell had a positive/intrinsic/negative structure with the light reaching the optically active intrinsic layer through a transparent conducting SnO_2 layer. Since the excitation intensity in the beam spot was relatively high (5 to 10 Suns), the dependence of the photocurrent, I, on the excitation intensity, F, was fit to an equation from free-carrier transport theory; namely, $I \propto F^{\gamma}$.

The value $\gamma = 1.05$ for cell A may be indicative of uniformly distributed trap states. The values $\gamma = 0.90$ and 0.48 for the two regions of differing slope in cell B are consistent with the recombination kinetics associated with deep gap states and an exponentially distributed band tail of shallow trap centers. These results may indicate that the recombination and trapping characteristics of the two cells are quite different, even though both were fabricated by the same process.

This work was done by Quiesup Kim, Alex Shumka, and James Trask of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 94 on the TSP Request Card.*
NPO-16658

Furnace for Tensile Testing of Flexible Ceramics

Ceramic cloth and thread are tested quickly at temperatures up to 1,250 °C.

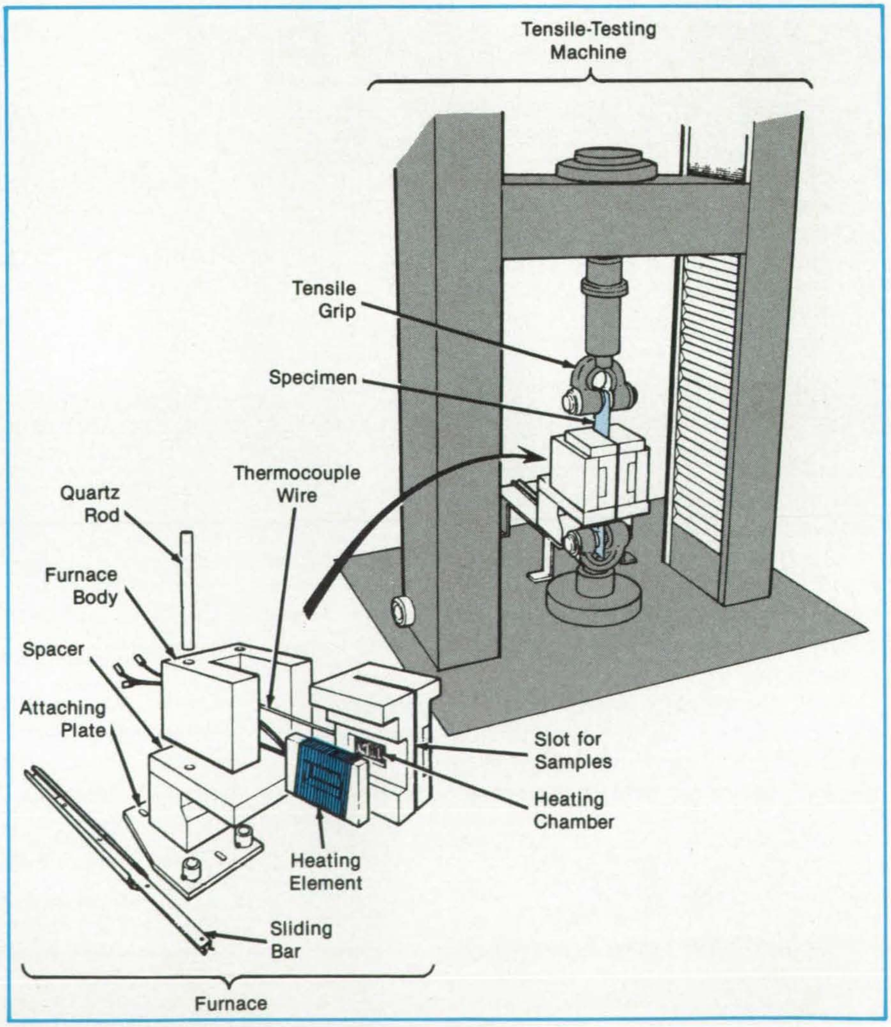
Ames Research Center, Moffett Field, California

Tensile strengths of ceramic cloths and threads can be measured conveniently in a new furnace at specified temperatures up to 1,250 °C, using an ordinary mechanical tester. The samples are heated along part of their lengths in the furnace slots. The interchangeable furnace chambers and the matching heating elements are sized to match the size of the tested ceramic material.

The furnace is made of foamed silica with temperature-controlled embedded resistant-wire heating elements powered by a 110-V, 25-A supply. Designed to heat strips about 1 in. (2.5 cm) wide or threads that are less than 0.06 in. (0.15 cm) thick, the furnace is 4 in. (10.2 cm) wide, 5 in. (12.7 cm) deep, and 3 in. (7.6 cm) high. The furnace test chambers are one-half in. long, one-half in. wide, and 1 in. high (1.27 by 1.27 by 2.54 cm) for thread, and 1-1/2 in. long, one-half in. wide, and 1 in. high (3.81 by 1.27 by 2.54 cm) for cloth.

There are two type "K" thermocouples — one for the temperature control, the other for temperature monitoring — mounted one-eighth in. (3 mm) from the tested material. The small furnace opening — a 1/16-in. (1.6-mm) slot — allows the furnace to be slid into place around, or removed from, the specimen, with insignificant loss of heat at the test temperature.

The tensile-test specimen is mounted in the mechanical tester with a 4-in. (10.2-cm) opening between the tensile grips (see figure). Mounted on a horizontal sliding bar, the preheated furnace is moved forward to enclose the tensile



The **Modular Design of the Furnace** allows the tensile-strength testing of both ceramic thread and cloth.

specimen, the strength of which is then measured in the standard way. After the specimen breaks, the furnace is moved away from the test specimen, a new specimen is mounted in the tensile grips, and the furnace is slid into place for the next test. Because the furnace remains hot and does not enclose the mechanical tester, no time is lost waiting for the furnace to reheat.

This work was done by Marnell Smith, Carlos A. Estrella, and Victor W. Katvala of **Ames Research Center**. *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center [see page 27]. Refer to ARC-11589.

Books and Reports

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

Star-Viewing Scheduler

A strategy and an algorithm produce a well-balanced timetable that accommodates many constraints.

A strategy for scheduling star observations on Space Shuttle astronomy missions ensures the best use of the three future ultraviolet telescopes. The strategy, which is described in a report, takes into account such diverse factors as maneuvers of the Space Shuttle orbiter, interference by the Moon, occultation by the Earth, reflections, unstaffed periods during crew rotation, encounters with the South Atlantic anomaly, and obscuration during the dispersal of ejected water.

On the basis of these factors, the strategy determines observation intervals that are fed to an algorithm, ASTRON. The algorithm determines which of the more than 200 candidate targets will be viewed during each of the intervals and arranges them in an observation sequence. ASTRON determines the observation schedule well in advance of a mission. It takes only 10 minutes of computer time to produce a schedule that is optimized, efficient, error-free, and well balanced.

The algorithm incorporates five criteria, each with a weighting factor chosen by the user: (1) the duration of the specific target interval, (2) the total requested observation time, (3) the total duration of all intervals for the particular target remaining until the end of the mission, (4) the telescope sluing time, and (5) the target priority. In addition to the time for moving the telescope to a target, the sluing time includes the time for instrument settling, acquiring the guide star, and waiting for the target to rise.

The algorithm uses a "Cinderella" logic loop to take advantage of the best viewing conditions, which occur during orbital night. The loop forces night observations to begin at Sunset, thereby keeping the relatively large maneuvers between day and night targets completely in orbital day. This results in high nighttime efficiency and prevents lower priority observations from migrating at random into orbital night.

Thresholds related to instrument sensitivity and observation-program requirements are taken into account. For example, the instruments require at least 500 seconds to obtain usable data. All candidate targets are therefore screened to ensure that they are available for this minimum period. There are also certain observations that require a larger minimum and that cannot be interrupted. The algorithm is designed to accommodate these special cases.

This work was done by Orville T. Guffin of **Marshall Space Flight Center** *and Barney H. Roberts and Phillip L. Williamson of Boeing Computer Support Service. To obtain a copy of the report, "Astronomy Scheduler (ASTRON)," Circle 9 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 27]. Refer to MFS-28089.

Materials

Hardware, Techniques, and Processes

Books and Reports

Hose- and Tube-Cleaning Module

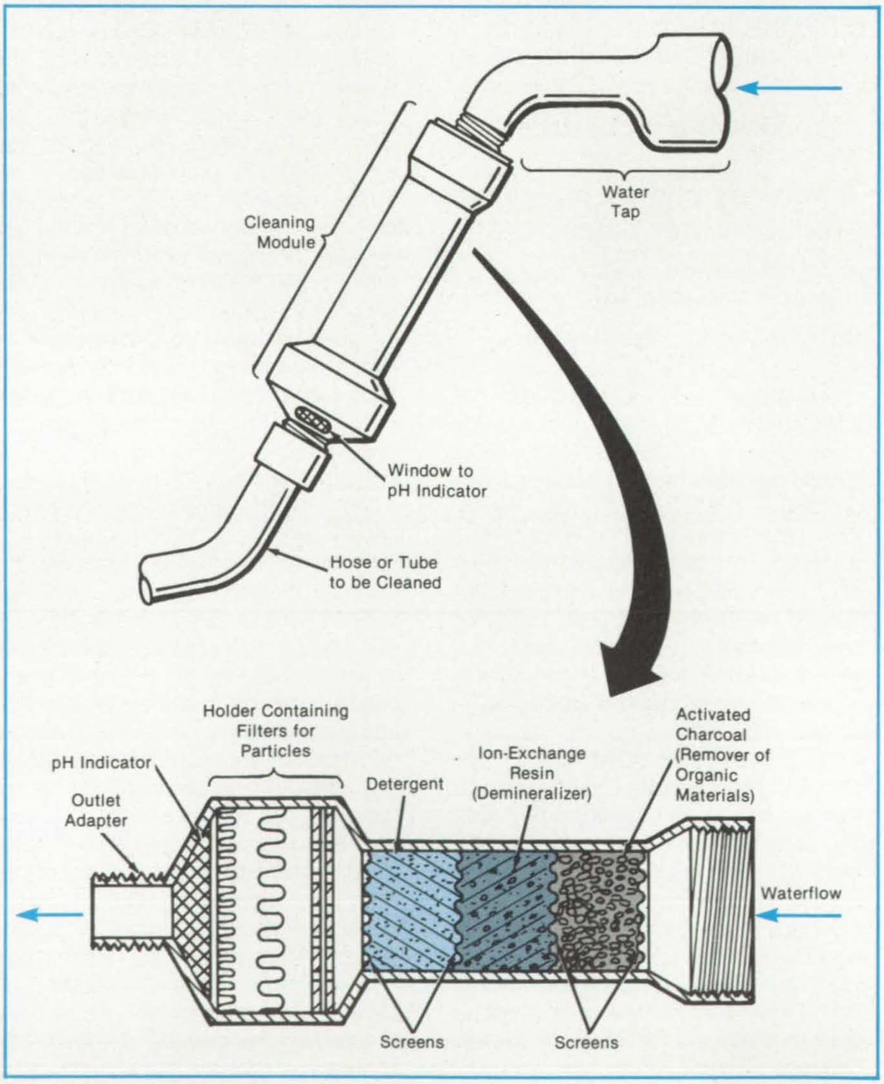
This device enables tubes and hoses to be cleaned easily, without other special equipment.

Lyndon B. Johnson Space Center, Houston, Texas

A self-contained, single-use module would enable a hose or tube to be cleaned thoroughly in the field, in one operation, using water of unknown or questionable quality. Previously, chemicals for flow cleaning had to be mixed, diluted, and pumped through tubes and hoses in many successive steps; moreover, deionizers, water-treatment facilities, and chemical storage were required. With the proposed device the cleaning can be performed safely, without special training. Ready to use, this device could be packaged as a cleaning kit with the tube to be cleaned.

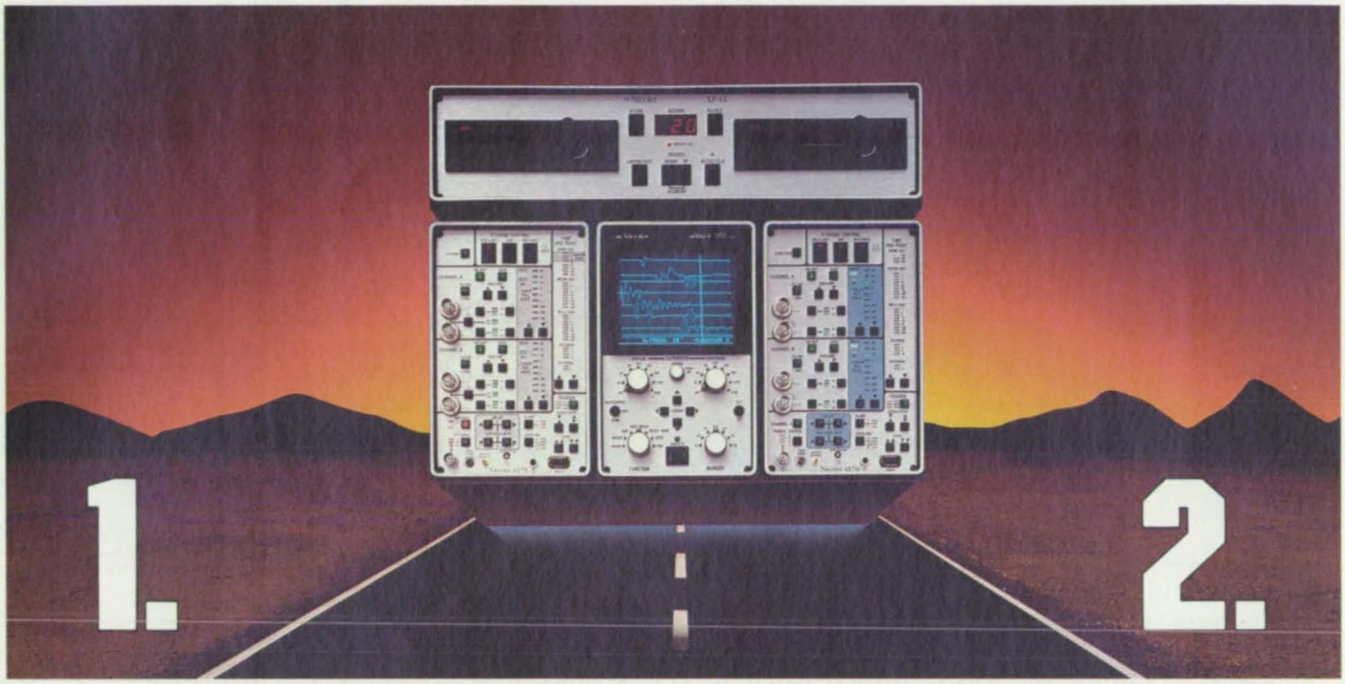
Shown in the figure, the device includes a housing of polyethylene (or other polymer) with an adapter for a water tap at the inlet end and an adapter for the specific application at the outlet end. Beginning at the inlet end, the tube contains a mesh screen to prevent the entry of large particles. The screen also retains a layer of activated carbon particles, which remove organic contaminants in the water flowing into the device.

The activated carbon is followed by another screen and a layer of ion-exchange resin, which removes dissolved minerals. Following the resin is another retaining screen and a layer of water-soluble powdered cleaning compound. Next is a retaining screen followed by a



In this **Cleaning Module,** water entering through the inlet fitting is freed of organic matter by activated charcoal, then demineralized by ion-exchange resin, then laden with detergent, and finally filtered, before flowing to the hose, tube, or other system to be cleaned.

THE FIRST NAME IN DIGITAL SCOPES



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Nicolet

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stack of filters of decreasing size to remove particles from the waterflow.

The filtration zone has a cross section larger than that of the preceding zones to reduce the speed and the pressure drop of the water across the filters. This protects the filters from tearing or breaking and enables them to remove finely divided particles that might remain. The outlet cone of the filter stack contains an embedded litmus or pH chemical indicator to show when the detergent supply is exhausted. The indicator color change is viewed through a window in the filter holder. Alternatively, the housing could be made of transparent or translucent material through which the color change could be viewed.

The device inlet is attached to the water supply. The outlet is attached to the hose or tube to be cleaned. The detergent-laden flow cleans the hose or tube as long as detergent is dissolving in the cleaning device. The flow may be stopped at any time to permit a soaking period. The water is allowed to run until the detergent is depleted, as shown by the change of color in the indicator caused by the decrease of the pH. After this, the water is allowed to flow awhile longer so that the hose or tube is rinsed.

The selection of the materials for the four module zones and the sizes of the zones are based on the contamination expected in the water and on the expected specific cleaning problem. The carbon absorber and the deionizer are made large enough to permit a rinse of sufficient duration or volume following detergent exhaustion. Additional units without detergent could be used for rinsing only, or for partial purification of water for drinking. After use, the module can be discarded; with simple modifications, a reusable device could be constructed.

This work was done by Fred P. Rollins and James S. Glass of Lockheed-EMSCO for **Johnson Space Center**. *For further information, Circle 93 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 27]. Refer to MSC-20857.

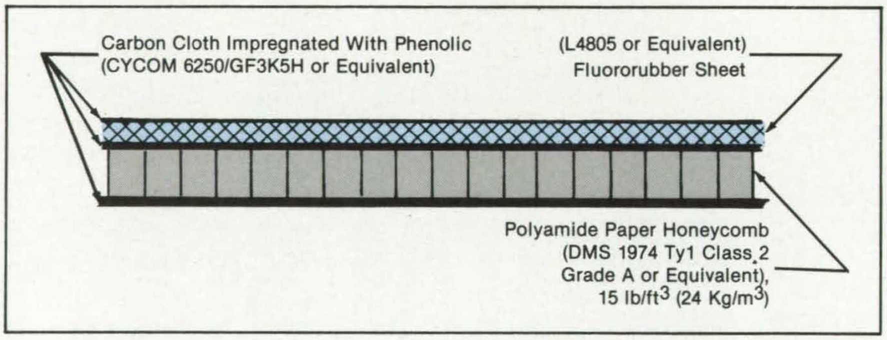
Fire-Resistant Belt Panel for Airplane Windows

The layered structure incorporates materials that generate little smoke.

Lyndon B. Johnson Space Center, Houston, Texas

A window-belt panel for airplanes is fire resistant and generates little smoke when exposed to flames. The panel incorporates a fire-shield layer that adds minimal weight but delays or prevents a fire from burning through.

The structural core of the panel (see figure) is a Nomex (or equivalent) polyamide paper honeycomb. The fire shield, made of fluororubber sheet, is incorporated in a multiple-ply facing bonded to the core. The outer layers of the multiple-ply facing and the back face of the panel consist of biwoven carbon-cloth impregnated with phenolic resin.



The **Multiple-Ply Structure** of the window-belt panel provides strength and fire resistance at low weight. Such standard parts as windows, shade assemblies, and air grills can be attached to the panel.

A conventional belt panel consists of a Nomex (or equivalent) polyamide honeycomb core with a phenolic-resin-impregnated glass-cloth facing and a back-surface ply of epoxy-resin-impregnated glass-cloth reinforcement. The impregnated carbon cloth in the new panel weighs less than the glass cloth and gives off less smoke. The fire-shield layer in the new panel causes only a slight net increase in weight, yet significantly enhances passenger protection by delaying burn-through.

This work was done by Edward L. Trabold and Meade F. Murphy of McDonnell Douglas Corp. for **Johnson Space Center**. *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Johnson Space Center [see page 27]. Refer to MSC-21064.

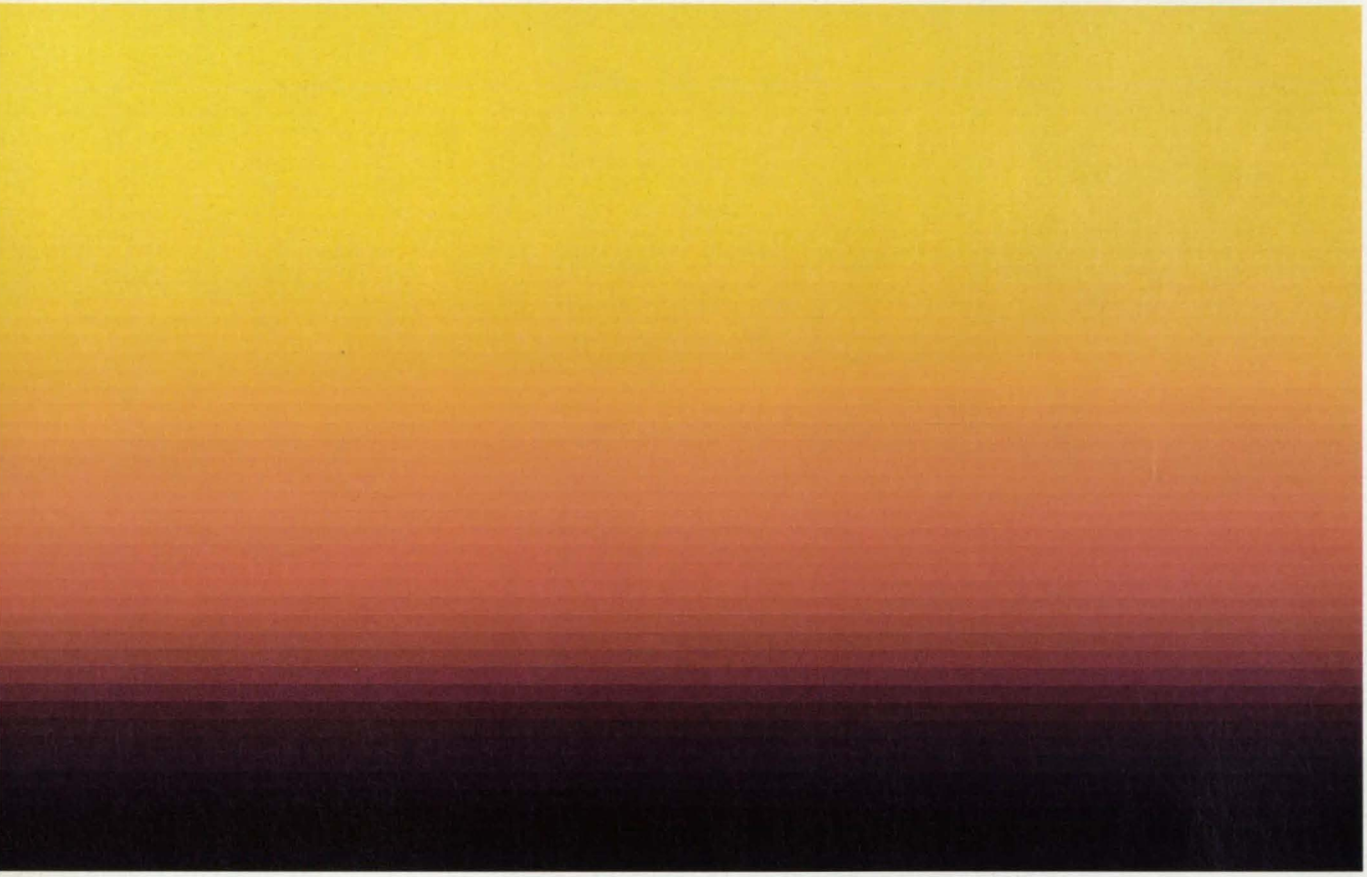
Fire-Resistant Aircraft Ceilings

New materials retard flames but keep panel strong and light.

Lyndon B. Johnson Space Center, Houston, Texas

A ceiling panel for airplane cabins is more fire resistant than conventional panels. The new panel incorporates a core of polyimide foam as a fire shield. The core significantly delays burn-through by flames and thus offers passengers greater protection.

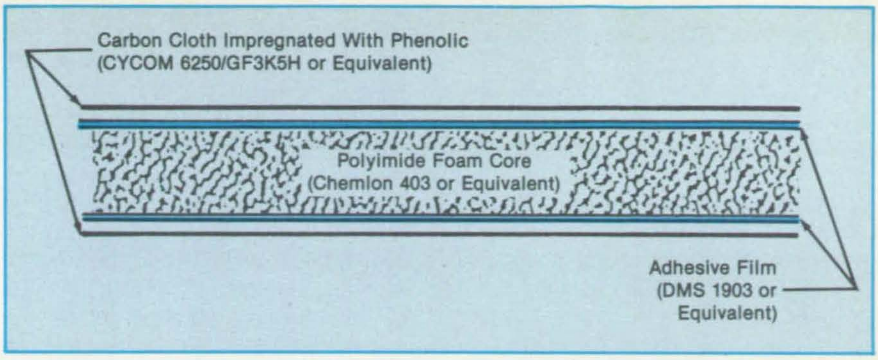
Biwoven carbon cloth impregnated with precured phenolic resin is glued to both faces of the polyimide core for reinforcement (see figure). In a conventional panel, the core is an aramid



paper honeycomb, and the reinforcing layers are phenolic-impregnated glass cloth. Although the new core material weighs more than the old, the new reinforcing layer maintains panel stiffness and weighs less than the old reinforcing material. The net weight gain associated with the greater fire resistance is therefore minimal.

This work was done by Edward A. Trabold and Meade F. Murphy of McDonnell Douglas Corp. for **Johnson Space Center**. *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Johnson Space Center [see page 27]. Refer to MSC-21065.



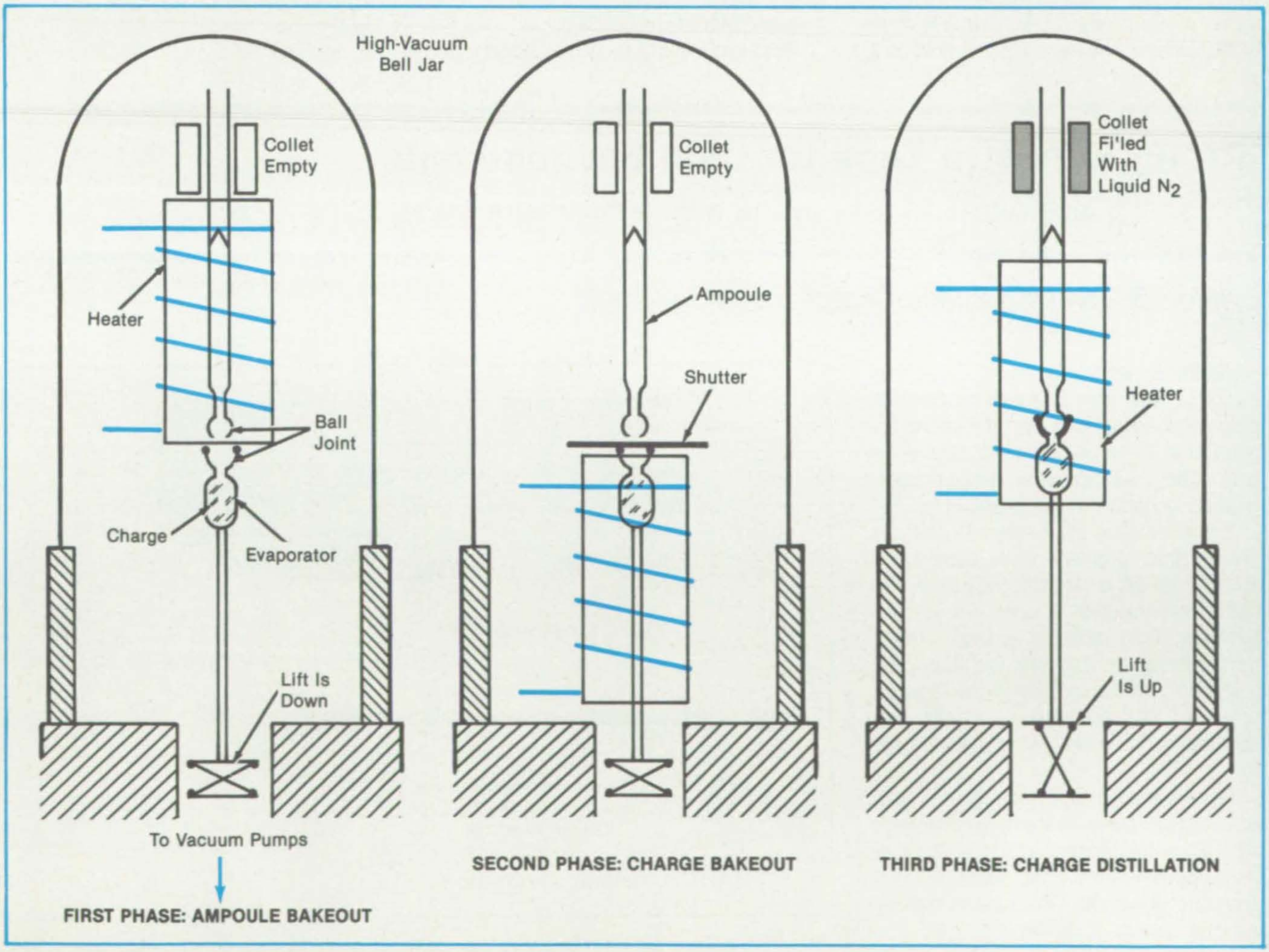
The **Foam Core** of the panel chars instead of burning. Decorative layers, speaker grills, and other details can be attached as on conventional panels.

Two-Step Vapor/Liquid/Solid Purification

One process approaches the theoretical limit of multiple zone refining and distillation.

Marshall Space Flight Center, Alabama

A vertical distillation system combines in a single operation the advantages of multiple zone refining with those of distillation. Developed specifically to load Bridgman-Stockbarger (vertical-solidification) growth ampoules with ultrapure



In the **First Phase of the Purification Process** (left), the ampoule is heated to drive off absorbed volatiles. In the second phase (middle), the evaporator is heated to drive off volatiles in the charge. In the third phase (right), the slowly descending heater causes distillation from the evaporator to the growing crystal in the ampoule.

tellurium and cadmium, this system, with suitable modifications, could serve as a material refiner.

In the new system (see figure), the raw charge is placed in an evaporator, from which it is distilled upward. The ampoule is connected to the evaporator by a dry, ground, vitreous-silica ball joint. The ampoule and evaporator are placed in a high-vacuum bell jar, which is pumped down to a pressure of 10^{-7} torr (10^{-5} N/m^2) or lower.

The evaporator has a long stem supported by a lift system controlled through a ferrofluidic rotary vacuum seal. The crystal-growth ampoule is also supported by a stem — a tube of the same inside and outside diameters as those of the ampoule body, so that it is a smooth continuation of the ampoule body. The stem extracts heat from the ampoule by thermal conduction. The stem is grasped by the spring fingers of a double-walled chuck cooled by liquid nitrogen.

The evaporator and the ampoule are surrounded by a movable heater 14 in. (36 cm) long that has a double winding of platinum wire 0.020 in. (0.05 cm) in diameter, 10 turns/in. (4 turns/cm) on the bottom 2 in. (5 cm) and 5 turns/in. (2 turns/cm) on the upper 12 in. (30 cm), wound on a vitreous-silica tube 1.1 in. (2.8 cm) in inside diameter. The heater is mounted on a recirculating-ball lead screw driven by a stepping motor that gives translation rates from 1 mm/h to 18mm/s, programmed by a preset indexer.

In the first phase of the operation, the evaporator is at its lowest position (with the ball joint open), the heater is positioned to heat only the ampoule, and the cold chuck is not supplied with liquid nitrogen. In this configuration, the ampoule is prebaked to about 400 °C in the vacuum to remove any adsorbed volatiles.

In the second phase, the heater is lowered to cover only the evaporator, and a shutter is placed in the open ball joint to mask off the ampoule. The charge in the evaporator is warmed until its vapor pressure is about 10^{-3} torr (10^{-1} N/m^2), so that moisture and other volatiles are driven off.

The third phase is initiated by removing the shutter, closing the ball joint, and raising the heater so that the top of the free volume in the ampoule is just inside the top of the heater. In this configuration, the charge in the evaporator is melted and heated until the vapor pressure is several torr (several hundred N/m^2), and the distillation process is started. As the distillation proceeds, the heater is moved downward, so that the top of the ampoule cools, thereby causing a crystal of purified material to start growing.

Because the crystal grows down from the top of the ampoule into the heater until it passes the melting-point isotherm, the solid material always has a drop of melt at the bottom end that is held up by surface tension. There is a segregation of impurities as the molten raw material is distilled to this drop and a second segregation as the material in the drop is solidified. When the growing drop reaches a certain size, it falls back into the evaporator, carrying with it impurities rejected in the solidification process. In this way, the solid growth face is constantly washed by fresh molten distillate. Thus the material is effectively purified by multiple zone refining and by distillation.

This work was done by Lawrence R. Holland of the University of Alabama, Huntsville, for **Marshall Space Flight Center**. *For further information, Circle 101 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:

University of Alabama
Huntsville, AL 35899

Refer to MFS-26004, volume and number of this NASA Tech Briefs issue, and the page number.

Strong Adhesive Tape for Cold Environments

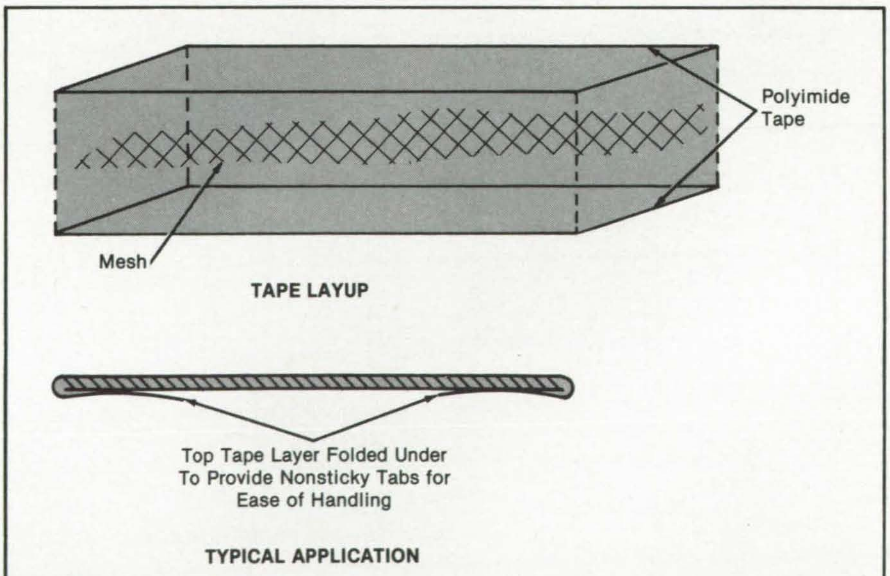
This strong tape remains sticky over a wide temperature range.

Lyndon B. Johnson Space Center, Houston, Texas

An improved tape devised for repairs in space may also find use on Earth in polar regions and in superconducting applications. The tape retains its adherence and strength at extreme temperatures, where conventional tapes would fail.

Experience on the Space Shuttle had shown that ordinary duct tape loses most, if not all, of its stickiness at the orbital temperatures. Kapton (or equivalent) polyimide tape, for example, maintained adequate adhesion but had to be layered for sufficient strength to resist inadvertent tearing by crewmembers. Multiple layers, however, make the tape stiffer.

The improved tape (see figure) consists of two layers of the polyimide tape with a reinforcing intermediate layer of thin, open-weave Kevlar (or equivalent) aromatic polyamid. Other mesh materials may also be suitable.



The **Strong Tape for Low Temperatures** consists of two layers of polyimide tape with a layer of reinforcing mesh.

This work was done by Thomas G. Woods of McDonnell Douglas Corp. for **Johnson Space Center**. *No further documentation is available.* *MSC-20924*

Fuel Manifold Resists Embrittlement by Hydrogen

A completely-cast hydrogen-compatible alloy is preferable to protective plating.

Marshall Space Flight Center, Alabama

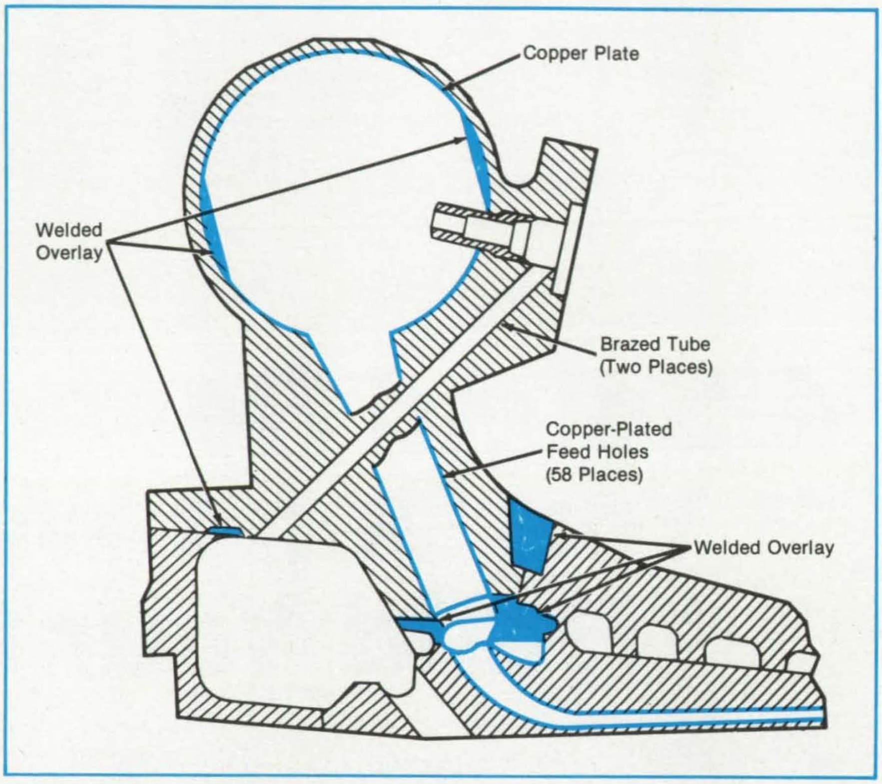
Parts exposed to high-pressure hydrogen can be made immune to hydrogen embrittlement if they are fabricated from a new alloy, Incoloy 903* (or equivalent). This material is strong and compatible with hydrogen at all temperatures and has been adapted for the outlet manifold of the Space Shuttle main combustion chamber.

The manifold was formerly made of Inconel 718*, an alloy that is susceptible to hydrogen embrittlement at the engine operating temperatures. For protection, it had to be plated with copper on internal surfaces. In addition, overlays of Incoloy 903* had to be welded to it in certain areas, and a tube of the same alloy had to be brazed to it (see figure).

Substituting Incoloy 903* for the entire part eliminated the plating, welding, and brazing operations. As a result, the part can be made in less time and with fewer manufacturing flaws.

(*"Inconel" and "Incoloy" are registered trademarks of the INCO family of companies.)

This work was done by T. C. Adams of Rockwell International Corp. for **Marshall Space Flight Center.** *No further documentation is available.*
MFS-29089



The **Complexity of Plating, Welding, and Brazing** becomes unnecessary if a hydrogen-compatible alloy is used for the entire casting instead of merely as a protective overlay.

Iron/Phosphorus Alloys for Continuous Casting

Continuous casting becomes practicable because of reduced eutectic temperature.

NASA's Jet Propulsion Laboratory, Pasadena, California

An experimental ferrous alloy has a melting point about 350 °C lower than that of conventional steels, making it possible to cast structural members and eliminating the need for hot rolling. The product has normal metal structure and good physical properties.

The casting process results in phosphorus steel — a strong ferrous alloy, rather than conventional iron/carbon-based steel. The alloy has important similarities to conventional steels: It includes a very hard phase of schreibersite (Fe_3P) similar to the cementite (Fe_3C) in conventional steel. Just as intimate mixtures of soft iron and hard cementite can be created by the cooling of conventional steels from the γ-phase region, so can intimate mixtures of soft iron and schreibersite be formed in phosphorus steels by the cooling from the liquid state. Furthermore, such elements as Mn, Ni, and Cr, which toughen conventional steels by forming finely divided hard carbides during the cooling from the γ region, also help to form finely divided hard phosphides on rapid cooling from a phosphorus-alloy melt.

The strongest Fe/P alloys contain 3 to 12 percent phosphorus by weight. The solidus (eutectic) temperature is 1,050 °C. In contrast, strong Fe/C alloys have a solidus temperature close to 1,400 °C. Materials that can contain the melt and extrude it are more readily available at the lower temperature than at the higher one.

The process could be used to make rails, beams, slabs, channels, and pipes. When fully developed, the process could be used where unrecyclable cooling water for hot rolling is not available. The process could be adopted by the developing countries to establish an indigenous product capability, without the high capital investment for rolling mills. More industrialized countries could make use of the readily available, lower grade ores without the beneficiation to remove phosphorus.

In the laboratory version of the process, steel bar stock is scalped to a diameter of 1 in. (2.5 cm) and cut to form a cylinder 1½ in. (3.81 cm) long. A hole 0.625 in. (1.59 cm) in diameter and 1 in. (2.5 cm) deep is bored in one end, leaving a cylindrical cup with a mass of about 110 g. A charge of phosphate is packed into the hole.

The cylinder is placed in an Alundum (or equivalent refractory alumina) crucible. Because the slag in the melt is highly corrosive to the alumina, the crucible is placed in another one on a layer of loosely packed alumina in a larger crucible. This provision ensures that the slag will not eat through the Alundum and pour the melt out of the crucible.

The cylinder and crucibles are placed in the coil of an induction furnace, and the radio-frequency power is gradually increased until the cylinder glows bright orange. At this point the reaction begins, and the iron, forming a eutectic with the phosphorus in the charge, melts at a lower temperature.

In a fully developed version of the process, a copper die would admit molten iron/phosphorus eutectic and extrude the solid alloy through its orifice. The orifice would be cooled internally, and recyclable water or a refrigerant could be used as the coolant.

Irregularly shaped parts could be made by sand casting the low-melting eutectic. The melt temperature would be low enough so that the sand could be selected from a variety of alternatives; for example, regolith or crushed dunitic rock.

This work was done by Eugene R. duFresne of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 55 on the TSP Request Card. NPO-16611*

Polyether/Polyester Graft Copolymers

Higher solvent resistance is achieved along with lower melting temperature.

Langley Research Center, Hampton, Virginia

Aromatic polyethers, also known as polyphenylene oxides, are a class of polymeric materials that have been used in a wide variety of applications. However, they have certain deficiencies, including solubility in the common halocarbon and aromatic hydrocarbon types of paint thinners and removers. This sensitivity to solvents limits their use in structural articles that must be painted and repainted. They also have relatively high melting points, making them difficult to fabricate into finished parts. A new technique provides a method of preparing copolymers with polypivalolactone segments grafted onto a poly (2,6-dimethyl-phenylene oxide) backbone. This process makes strong materials with improved solvent resistance and crystalline, thermally-reversible crosslinks. These resulting graft copolymers are easier to fabricate into useful articles, including thin films, sheets, fibers, foams, laminates, and moldings.

The preparative process uses a modified form of the polyphenylene oxide — one that has various quantities of organic carboxylic acid groups substituted upon the base polyether (readily achieved by metallation of the polyether, followed by treatment with carbon dioxide). Some of the carboxylic acid groups are converted to tetrabutylammonium carboxylate salts or similar quaternary ammonium salts. The resulting carboxylate-salt-modified polyethers, dissolved in suitable solvents, are then reacted with varying amounts of pivalolactone, the graft polymerization of which is initiated by the carboxylate anions and proceeds rapidly to completion. Finally, the treatment of the grafted copolymer with a mineral acid converts the terminal tetrabutylammonium carboxylate salts to free carboxylic acid groups, completing the graft operation.

The polypivalolactone graft segments tend to crystallize very readily, a characteristic of polypivalolactone itself. When the graft segments from a number of polyether molecules crystallize together, the crystalline domains tie all the polymer molecules into a pseudocrosslinked material, which is much more resistant than the base polyphenylene oxide to halogenated and aromatic hydrocarbon solvents. Further, if the polypivalolactone grafts are sufficiently long, the entire graft copolymer melts as a consequence of the polypivalolactone crystallites melting, at a temperature lower than that associated with the base polyphenylene oxide.

The molecular weight of the polyether starting material can be varied to influence the properties of the graft copolymer. The degree of carboxylation, and thus the number of graft sites available, is another factor influencing the nature of the copolymer. The lengths of the grafted polypivalolactone segments, determined by the degree of carboxylation and the amount of polypivalolactone monomer that is polymerized, determine in turn the final balance of properties between those of the parent polyphenylene oxide and those of the highly crystalline polypivalolactone.

This work was done by Vernon L. Bell, Jr., N. J. Wakelyn, Diane M. Stoakley, and K. Mason Proctor of **Langley Research Center.** *For further information, Circle 59 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 27].* *Refer to LAR-13447.*

Low-Resistivity Zinc Selenide for Heterojunctions

Magnetron reactive sputtering would enable doping of this semiconductor.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed method of reactive sputtering combined with doping shows potential for yielding low-resistivity zinc selenide films. Zinc selenide is an attractive material for forming heterojunctions with such other semiconductor compounds as zinc phosphide, cadmium telluride, and gallium arsenide. Such semiconductor junctions are promising for future optoelectronic devices, including solar cells and electroluminescent displays. However, the resistivities of zinc selenide layers deposited by evaporation or chemical vapor deposition have been too high to form practical heterojunctions.

In the proposed technique, an indium- or gallium-doped zinc target would be sputtered in an atmosphere of hydrogen selenide and argon. Separate indium and zinc targets could also be sputtered simultaneously. The sputtered zinc would react with the hydrogen selenide to form zinc selenide, which would deposit as a film on a substrate of gallium arsenide or other semiconductor compound.

The rate of selenium incorporation in the zinc selenide layer would be closely adjusted by control of gas flow, sputtering power, and substrate temperature. This control would help to assure stoichiometric deposition and minimize zinc vacancies, which would otherwise neutralize the dopant and prevent it from reducing the resistivity.

Magnetron sputtering would be used. This sputtering technique would promote stoichiometric deposition of zinc and selenium. Because it confines secondary electrons to a region close to the cathode, magnetron sputtering would also prevent unintentional substrate heating. Thus, lower substrate temperatures would be possible, and radiant heat could be used to control substrate temperature independently as a process variable.

Sputtering proceeds at relatively high rates in magnetron systems because of the absence of heating by secondary electrons and because the long spiral paths of the discharge electrons cause ionization of argon at a much higher rate. The argon ions in turn sputter more zinc. Yet another advantage of magnetron sputtering is that the confinement of electrons by the magnetic field substantially reduces damage to the substrate and thus improves the electrical properties of the film.

Studies of deposition of other materials by reactive sputtering have already been made. These studies indicate that the key parameters affecting the composition, crystalline structure, and conductivity of zinc selenide will be:

- Discharge voltage,
- Discharge current,
- Substrate temperature,
- Partial pressure of hydrogen selenide,
- Total sputtering gas pressure, and
- Substrate bias voltage.

This work was done by Richard J. Stirn of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, Circle 58 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 27].* *Refer to NPO-16475.*

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Complete technical information is available. Contact Aerotech, Inc., 101 Zeta Drive, Pittsburgh, PA 15238—phone 412-963-7470.

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Circle Reader Action No. 310

AT-397

Chemical Characterization of Phenol/Formaldehyde Resins

Analytical procedures characterize resin composition and behavior before and during use.

A report discusses tests of commercial phenol/formaldehyde resins to establish relationships among the composition before use, the behavior during curing, and the strength after curing. The resin is used in carbon/carbon laminates. In the curing process, two molecules of a phenol are joined together in a sequence of reactions involving a molecule of formaldehyde. In the last step of the sequence, a molecule of water is released. The sequence repeats until one of the ingredients is used up, leaving a solidified thermoset plastic. Among the issues to be resolved are the number and relative abundances of ingredients, the presence of certain chemical groups, the heat-producing ability of the resin, and the range of molecular weights present.

The laboratory methods used to chacterize the resins, reactions, and cured products include the following:

- Physical tests that reveal the relative quantities of volatiles and resin and the amount of resin flow during a cure at low pressure;
- Mechanical tests of the flexural strength, flexural modulus, and shear strength; and
- Instrumental analyses that distinguish among the compositions and chemical behaviors of different resin formulations.

The report presents the data from these tests in graphs and tables. The following were the results from the investigation:

- In order of decreasing utility and information yield, the instrumental analyses are liquid or gel-permeation chromatography; infrared spectroscopy; and differential scanning calorimetry, thermomechanical analysis, or thermogravimetric analysis.
- The resins are mixtures of commercially available phenols and coreactants.
- The phenols are typically substituted in the metaposition.
- The coreactants dissociate to produce compounds containing carbonyl groups.
- Phenol is one of the ingredients.
- Resins with low phenol content may be inadequate.
- The reaction between the metasubstituted phenols and the coreactant proceeds stepwise rather than smoothly.
- Resin mixtures are fairly reactive and start to react at low temperatures.

The report also presents the following:

- High-pressure liquid chromatography and gel-permeation chromatography should be adopted as the main instrumental analyses.
- Incoming resins and prepregs should continue to be examined by chemical and mechanical methods to build up the data base.
- The resin mixtures should be separated into components, which should be subsequently identified as specific compounds.

This work was done by Thomas H. Brayden of LTV Aerospace and Defense Co. for **Johnson Space Center.** *For further information, Circle 79 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Johnson Space Center ***[see page 27]****. Refer to MSC-21055.*

Computer Programs

COSMIC: Transferring NASA Software

COSMIC, NASA's Computer Software Management and Information Center, is the one central office established to distribute software that is developed with NASA funding. COSMIC's role as part of NASA's Technology Utilization Network is to ensure that NASA's advanced software technology is made available to industry, other government agencies, and academic institutions.

Because NASA's software development efforts are dynamic and ongoing, new programs and updates to programs are added to COSMIC's inventory on a regular basis. *Tech Briefs* will continue to report information on new programs. In addition, the 1986 edition of the *COSMIC Software Catalog* is available with descriptions and ordering information for available software. Several new programs for control systems/robotics, expert systems, thermal analysis, turbomachinery design, structural analysis, and computer graphics are offered.

For additional information on any programs described in this issue of *Tech Briefs*, circle the appropriate number on the TSP card at the back of the publication. If you don't find a program in this issue that meets your needs, you can call COSMIC directly at (404) 542-3265 and request a review of programs in your area of interest. There is no charge for this information review.

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John A. Gibson, Director

Computer Programs

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

Physical Sciences

Updated Thermal-Radiation Program

Used with other thermal-analysis programs, this program calculates the radiation components.

The Thermal Radiation Analyzer System, TRASYS II, is a computer-software system with generalized capability to solve the radiation-related aspects of thermal-analysis problems. When TRASYS II is used in conjunction with a generalized thermal-analysis program, such as the Systems Improved Numerical Differencing Analyzer (SINDA) program, any thermal problem that can be expressed in terms of a lumped-parameter R-C thermal network can be solved.

TRASYS II provides for the calculation of internode radiation-interchange data and for the calculation of incident- and absorbed-heat rate data originating from environmental radiant-heat sources. Data of both types are provided by TRASYS II in a format directly usable by such thermal-analyzer programs as SINDA (available from COSMIC).

TRASYS II consists of two major components: the preprocessor and the processor library. One primary feature of TRASYS II is that it allows users to write their own executive, or driver, programs, which organize and direct the library routines toward solving each specific problem in the most expeditious manner. The preprocessor first reads and converts the user's geometry-input data into the form used by the processor-library routines. Next, the preprocessor accepts the user's driving logic, written in the TRASYS II-modified FORTRAN language, that directs the user-provided and processor-library routines in the solution of the problem.

The processor library consists of FORTRAN routines that perform the functions commonly needed by the user to solve the thermal-radiation problems. In many cases, the user has a choice of solution techniques to perform the same function. As previously mentioned, users may provide their own routines where desirable. In particular, the user may write output routines to provide for an interface between TRASYS II and any thermal-analyzer program using the R-C network concept.

Input to the TRASYS II program consists of EDIT/CONTROL data and MODEL data. The EDIT/CONTROL data do not participate in the definition of the thermal-radiation problem, but provide for basic program control and for the definition of the mathematical model of the thermal-radiation problem. The MODEL data include surface-geometry data, documentation data, nodal data, block-coordinate-system data, form-factor data, operations data (the user's driver logic), and the user-supplied subroutines. TRASYS II currently allows problems with as many as 1,000 nodes and time-variable problem geometry. The edit capability allows for the easy modification of complex thermal-radiation problem models.

Output from TRASYS II consists of two basic types of data: internode-radiation-interchange data, and incident- and absorbed-heat rate data. A plot package provides for the plotting of input geometry, orbit data (for on-station spacecraft problems), the two types of data described above, and any other data generated by the user's driver logic.

The DEC VAX version of TRASYS II is written in FORTRAN IV for batch execution (only the plotting driver program is interactive) and has been implemented on a DEC VAX 11/780 computer under VMS. The UNIVAC version of TRASYS II is written in FORTRAN V and Assembler for batch execution and has been implemented on a UNIVAC 1100 series computer under EXEC 8 with a central-memory requirement of 40K to 115K of 36-bit words. TRASYS II requires the DISSPLA plot software package for graphics output and drives Tektronix terminals. The TRASYS II system was last updated in 1985.

This program was written by Robert A. Vogt of **Johnson Space Center**. *For further information, Circle 28 on the TSP Request Card.*
MSC-20448 and MSC21030

Mathematics & Information Sciences

NASA Test File

Comparisons among different computer-aided design systems are facilitated.

The Test File is a data file containing computer-aided design (CAD) data formatted according to the National Bureau of Standards Initial Graphic Exchange Specification (IGES). This file was created for the purpose of conducting NASA tests to determine to what extent dissimilar CAD systems can exchange data using the IGES standard formats and IGES translators.

The IGES Test File is used to test IGES translators by converting the IGES format data to and from the native internal format of the CAD system. The file contains 28 different IGES entities, which were chosen because they define the geometric, annotation, and display-formatting information that is important in CAD information transfer. The documentation contains a procedure for using the file to test IGES translators, along with sample output of the scaled, rotated, and translated entities. It has been verified by an independent company that the file does indeed conform to Version 2.0 of the IGES standard.

These data are in ASCII code and are machine-independent. The file was created in 1985.

This program was written by Scott Gordon of **Goddard Space Flight Center**. *For further information, Circle 65 on the TSP Request Card.*
GSC-12988

Mechanics

Hardware, Techniques, and Processes

Books & Reports

Measuring Hole Elongation in Bolted Joints

The measurement does not affect joint parameters.

Langley Research Center, Hampton, Virginia

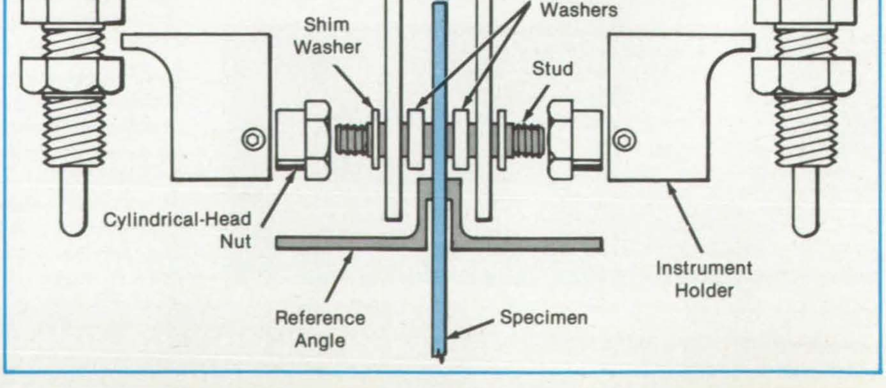
The verification of analytical and strength-prediction methods for bolted composite joints is based generally on data obtained experimentally from double-lap-joint specimens. In mechanically fastened joints, the stresses are maximal at the fastener holes. The ability to measure accurately hole elongations without affecting the joint parameters would provide a better understanding of the elastic and plastic behavior of the joint material leading to failure. The effective determination of the failure mechanisms in mechanically fastened joints is required for the design of more-efficient, lightweight composite joints.

A double-lap-joint-testing assembly for measuring hole elongation without affecting joint parameters is shown in the figure. The bodies of the linear variable-differential transformers (LVDT's) are rigidly attached to the stud. The movable cores of the LVDT's are in contact with the reference angles, which are securely bonded to the test specimen below the spacer washers. The center of the reference-angle area bonded to the specimen is one reference point, and the top of the stud in contact with the hole is the other reference point.

As the hole elongates under tensile loading, the distance between the stud and the reference angle increases because of the stress concentrations around the hole. The cores of the LVDT's move with the reference angles, and the change in distance between the two reference points is reflected in the output voltages of the LVDT's.

With increasing load, displacements caused by bending and bearing stresses within the stud will be measured along with the hole elongations. However, these stud displacements would, in many cases, be negligible with high-strength, hardened-steel studs. In cases where stud displacements must be taken into account, the magnitudes of elastic displacements could be analytically determined and subtracted from the measured displacements, yielding only the hole elongations.

This measurement technique offers a direct comparison between the displacements occurring at each outer-hole surface since the measuring instruments are equidistant from the specimen surfaces, and the reference angles are mounted opposite each other. Within the elastic limit of the specimen material, specimen bending or unequal loading through the load-transfer plates can be detected by comparing the displacement-versus-load responses. The technique is suitable for different bolt diameters, washer sizes



This **Double-Lap-Joint-Testing Assembly** is used to measure the elongations of holes in specimens.

(clamping areas), clamping forces (bolt torque), and joint materials, and for some multifastener arrangements.

This work was done by Gregory R. Wichorek of **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 27]. Refer to LAR-13453.

Redundant Pyrotechnic/Manual Release Mechanism

When all else fails, manual intervention is possible.

Marshall Space Flight Center, Alabama

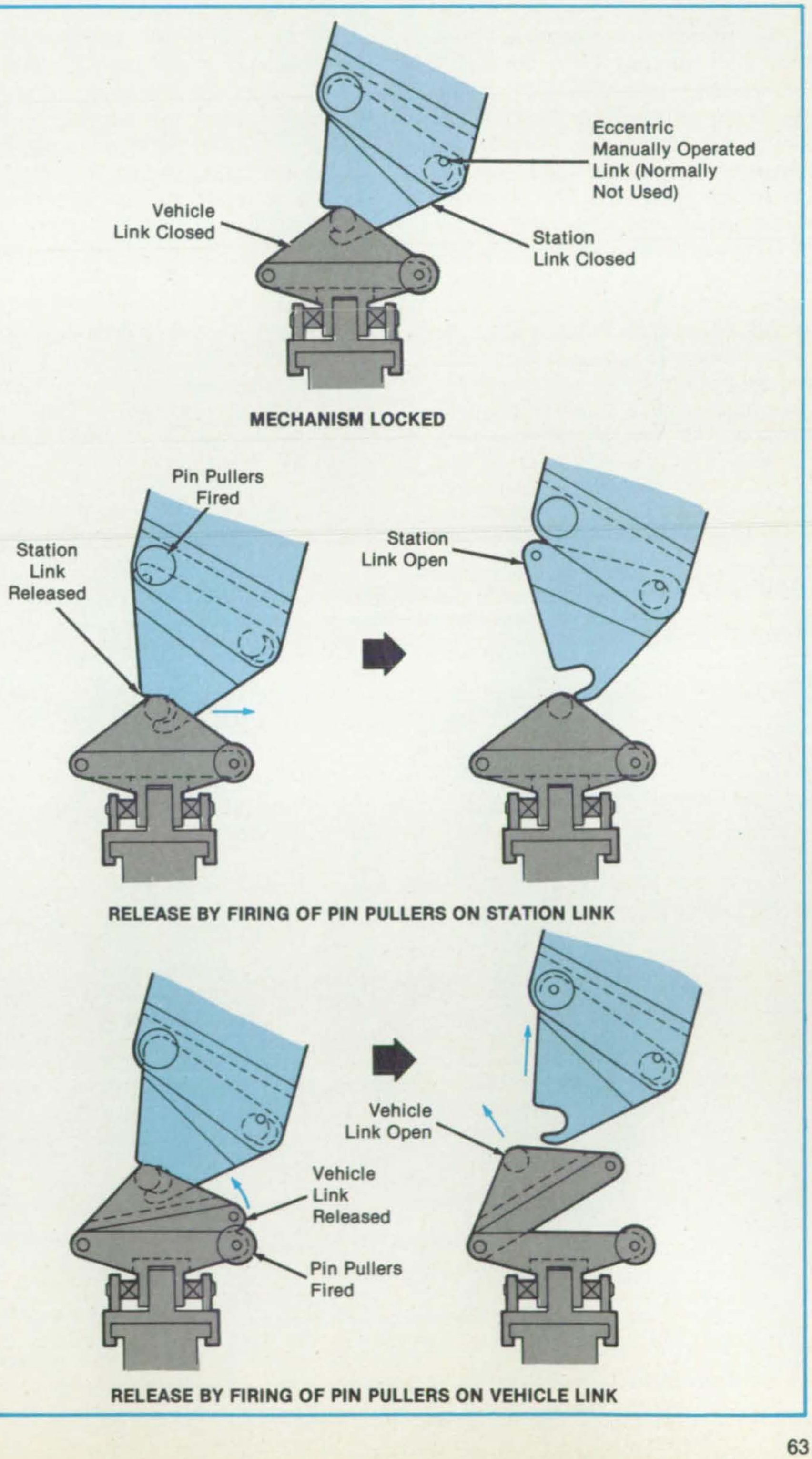
A release mechanism is designed to be operable by remote control even if many of its components fail. In the unlikely event that it does become inoperable, it can still be actuated manually.

The mechanism was developed for releasing the Space Station and its tether line from the Space Shuttle in orbit. There are two such mechanisms, each having two releasable links: one on the Space Station side and one on the Space Shuttle side (see figure). The actuation of either link on either mechanism will separate the two systems. Such a mechanism may be useful on Earth for the emergency release of modular structures or vehicle sections.

First, a pair of dual-initiator pyrotechnic pin pullers on the station side is fired by an electric signal from the station so that the open-faced link disengages from its cam roller. If one of the initiators or pullers in a pair should fail, the link will still disengage. If both sets of initiators and both pin pullers fail, the pair of pin pullers on the vehicle side would be fired by a signal from the vehicle. Again, if one of the initiators or pin pullers should fail, the link would still open.

Since there are eight pyrotechnic initiators altogether, the probability that no release will occur is very small indeed. But if it should, or if a power failure should prevent firing signals from being sent, a crew member, working outside would turn the cam roller on the station link by 180° and thereby open the link.

This work was done by Gilbert M. Kyrias of Martin Marietta Corp. for **Marshall Space Flight Center.** *For further information, Circle 99 on the TSP Request Card.*
MFS-28096



Two Modes of Separation—on the station side of the mechanism (top) and on the vehicle side (bottom) ensure highly fail-safe operation. If only one of the eight pyrotechnic initiators in the pin pullers fires, the links of the mechanism will separate.

One-Piece Force-Transducer Body

A rugged unit is designed to operate in severe environment.

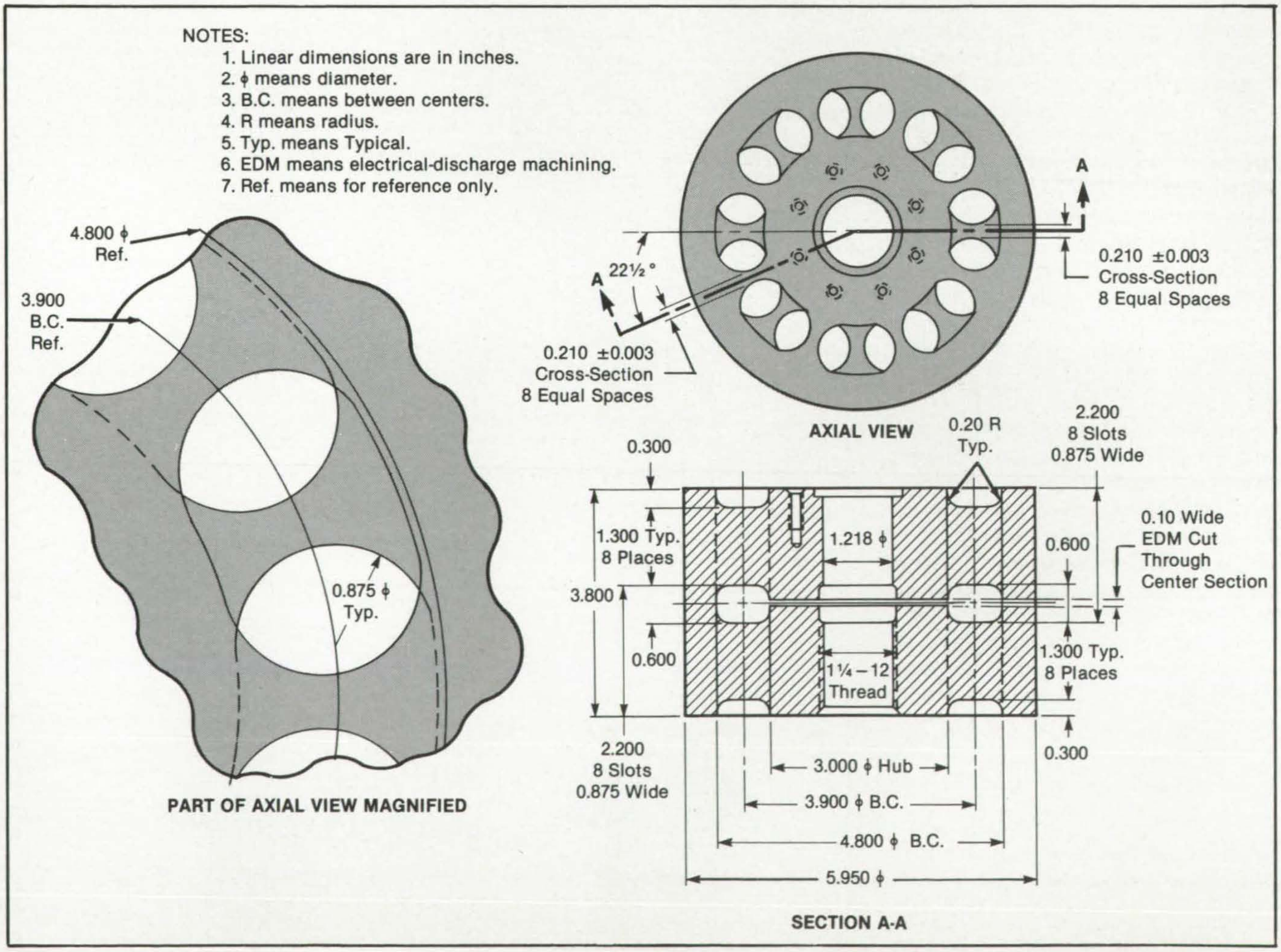
Marshall Space Flight Center, Alabama

A force-transducer body is designed for the measurement of loads on specimens tested in hydrogen gas at temperatures up to 2,000 °F (1,090 °C). The body has a symmetrical radial-shear-beam configuration and is machined in one piece from bar stock.

Shear-beam load cells are in general use. Some commercially available units are of the rectangular S-bend beam design, which is asymmetrical about the axis of load application. This asymmetry is considered undesirable. Another type of commercial unit is circularly symmetrical but is manufactured in several pieces, with spokes radiating from a central hub to an outer hub through a bolt circle. The sensing structure is bolted through the bolt circle to a second circular adapter plate that incorporates a central thread. A central loading thread is thus available at opposite ends of the load-cell assembly.

The symmetrical commercial units have several disadvantages. They are unreliable in the severe testing environment because of the large number of highly stressed joints between the parts. Assembly requires the painstaking concentric alignment of the two parts that contain the central thread. Mating parts can slip relatively to each other under load. The relative motion of parts can cause fretting fatigue of the joint surfaces under cyclic reversed loading. The slippage of bolted joints can cause hysteresis in the measurements. Even if properly designed, bolted joints exhibit asymmetry because they have different spring stiffnesses in tension and compression.

The new symmetrical load-cell body (see figure) is rugged. It has all of the stiffness, strength, accuracy, and low overall height of a conventional two-piece radial shear beam. However, because it is made in only one piece — as opposed to two major pieces and at least eight fasteners in the conventional design — it is both more reliable and less expensive. The concentricity between the opposite central threads is machined in, eliminating the need of alignment in assembly. The new configuration has no inherent asymmetry between tension and compression. Finally, the new unit is easier to seal against the environment because there are no bolted joints, each of which would otherwise have to be sealed individually.



The **Symmetrical Force-Transducer Body** is machined in this configuration from a piece of bar stock.

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This work was done by Richard A. Meyer of MTS Systems Corp. for **Marshall Space Flight Center**. *No further documentation is available.*
MFS-28140

Shape Determination for Large Static Structures

Parameter and shape estimates are updated from new measurements.

NASA's Jet Propulsion Laboratory, Pasadena, California

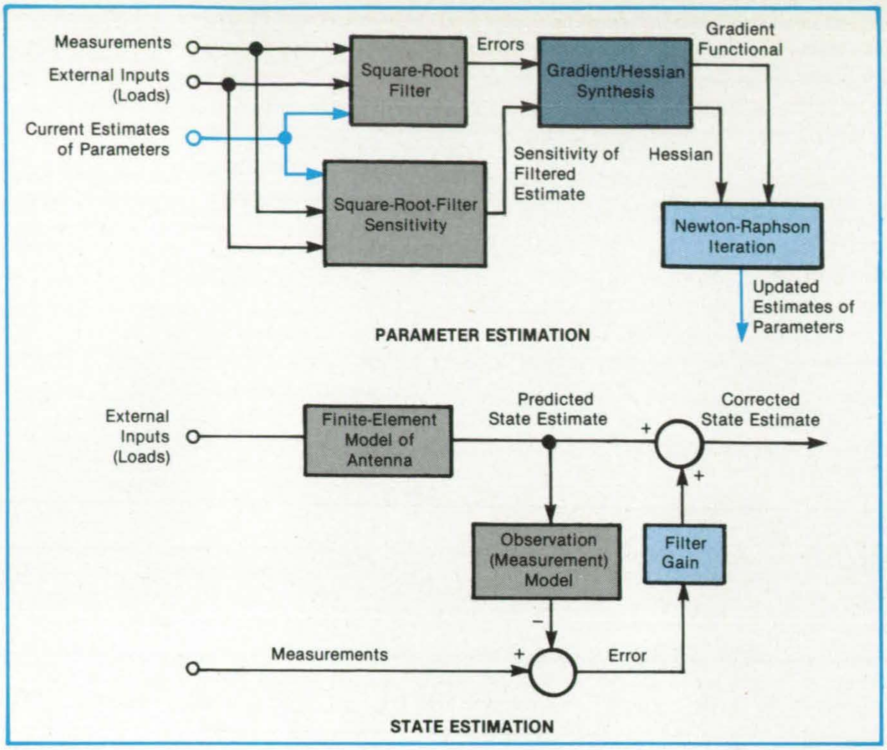
A set of algorithms generates updated estimates of state vectors representing the static deflections or other responses of large structures and of physical parameters of structural components (for example, the elastic moduli of beams or ribs in a truss of many such elements). The algorithms result from a generalization of the Kalman statistical-filter technique. A degree of computational economy is achieved in that there are mathematical elements common to the estimates of the parameters and of the responses. This is an advance over prior filter methods, which have treated the estimation of the two types of quantities in different ways.

The mathematical model of a structure in this analysis is a set of elliptic partial differential equations that may be interconnected. The model includes the parameters, which, in principle, can be determined through measurements of the structural responses to applied loads. Because the model and the response and load measurements are contaminated by random errors, a statistical analysis is needed to find the best estimate of the parameters. The measurement and model errors are represented in the model equations as weighted white-noise components.

The parameter estimation (see figure) involves a Newton-Raphson iteration process. The iteration begins with the current parameter estimate based on previous measurements and calculations. The square-root filter processes the external load inputs and measured deflections to obtain filtered measurements and filtered estimates of the deflections predicted theoretically from the load inputs and model. The square-root-filter output is the set of errors obtained by subtraction of the filtered predictions from the filtered measurements.

The gradient/Hessian synthesis block forms the function-space gradient of a likelihood functional and the approximate Hessian, which is the matrix of second derivatives of the likelihood functional. The likelihood functional takes an extreme value (usually a minimum) at the best estimate of the parameters. Using the gradient and the approximate Hessian, the Newton-Raphson iteration block calculates the updated parameter set, which is the next set that brings the likelihood functional closer to the extremum.

The state-estimation algorithms were derived primarily for the determination of the shapes of large parabolic antenna reflectors. These algorithms are based on two sets of measurements; namely, the measured structural deflections of the first model plus measurements of the electromagnetic far field, which is affected by the deflections. The first model is thus expanded to include additional equations relating the field measurements, the deflection (state or response)



The **Parameter and State Estimations** involve statistical structural analysis, statistical electromagnetic-field analysis, filtering, measurement modeling, and iterative prediction/correction procedures. The estimating algorithms result from generalizations of Kalman statistical-filter theory.

estimate, and the additional noise that enters through the field measurements.

The problem is solved in two prediction/correction stages similar to that described above for the parameters. In the first stage, a predicted state estimate is generated by a finite-element model of the structure. This estimate is entered in the model of an electro-optical deflection sensor to predict the sensor output. The actual and predicted sensor data are then compared; the differences are processed through a three-dimensional spatially-distributed Kalman filter to obtain correction terms, which are used to further correct the deflection estimate. The second prediction/correction stage performs similar operations, using the field model and field measurements.

This work was done by Guillermo Rodriguez and Robert E. Scheid, Jr., of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 89 on the TSP Request Card.* NPO-16781

Books and Reports

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

Measuring Atmospheric Turbulence With Lidar

Laser Doppler measurements promise to give reliably accurate indications of wind speed and turbulence.

A report compares two kinds of measurements of wind and turbulence: those from instruments aboard an aircraft and those from ground-based Doppler measurements by laser ranging equipment (lidar). The data on wind fields, turbulence intensities, and turbulence spectra from the two sources agreed well. The report concludes that lidar is potentially a reliable and accurate instrument for sensing atmospheric turbulence remotely.

The lidar was a variably-pulsed carbon dioxide laser system. During this study, the pulse intervals were 2 μs long. The lidar measured the radial wind velocities in each of a succession of 300-m-long conical frusta defined by the diverging lidar beam and the succession of pulse intervals.

The aircraft was flown in circular paths to capture the lidar beam during a conical scan. The lidar aim was then fixed at 6° above the horizon and the aircraft flown along a 4° glide slope. The aircraft measurements were converted to radial wind-gust velocities in 300-m intervals corresponding to the lidar range intervals.

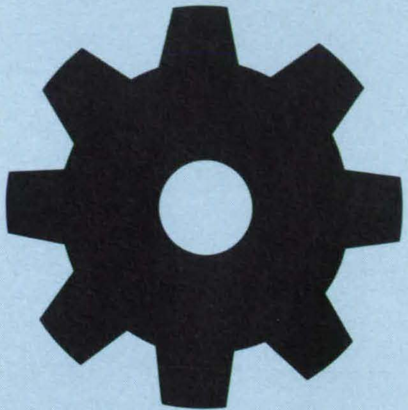
Turbulence intensities and spectra were calculated from the fluctuations in the radial component (the component along the lidar beam) of wind velocity with time. Attempts to measure turbulence intensities directly by lidar from the second moment or Doppler-frequency spectral width were disappointing. The second moment could be resolved only at very low altitudes. Moreover, turbulence intensities estimated from the spectral-width data were an order of magnitude higher than values measured from the aircraft.

An interesting boundary-layer condition occurred during the measurements: Winds blew in one direction above 600 m above mean sea level and in the opposite direction below this altitude. Both the aircraft and the lidar measurements clearly identified the condition and showed identical trends, giving added credence to the remote-sensing possibilities of lidar.

This work was done by Walter Frost and H. B. Kuang of FWG Associates, Inc., for **Marshall Space Flight Center**. *Futher information may be found in NASA CR-170976 [N84-17574/NSP], "Doppler Lidar Signal and Turbulence Study."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. The report is also available on microfiche at no charge. To obtain a microfiche copy, Circle 106 on the TSP Request Card.
MFS-27058

Machinery



Hardware, Techniques, and Processes

Books & Reports

Circulation-Control Variable-Pitch Propeller

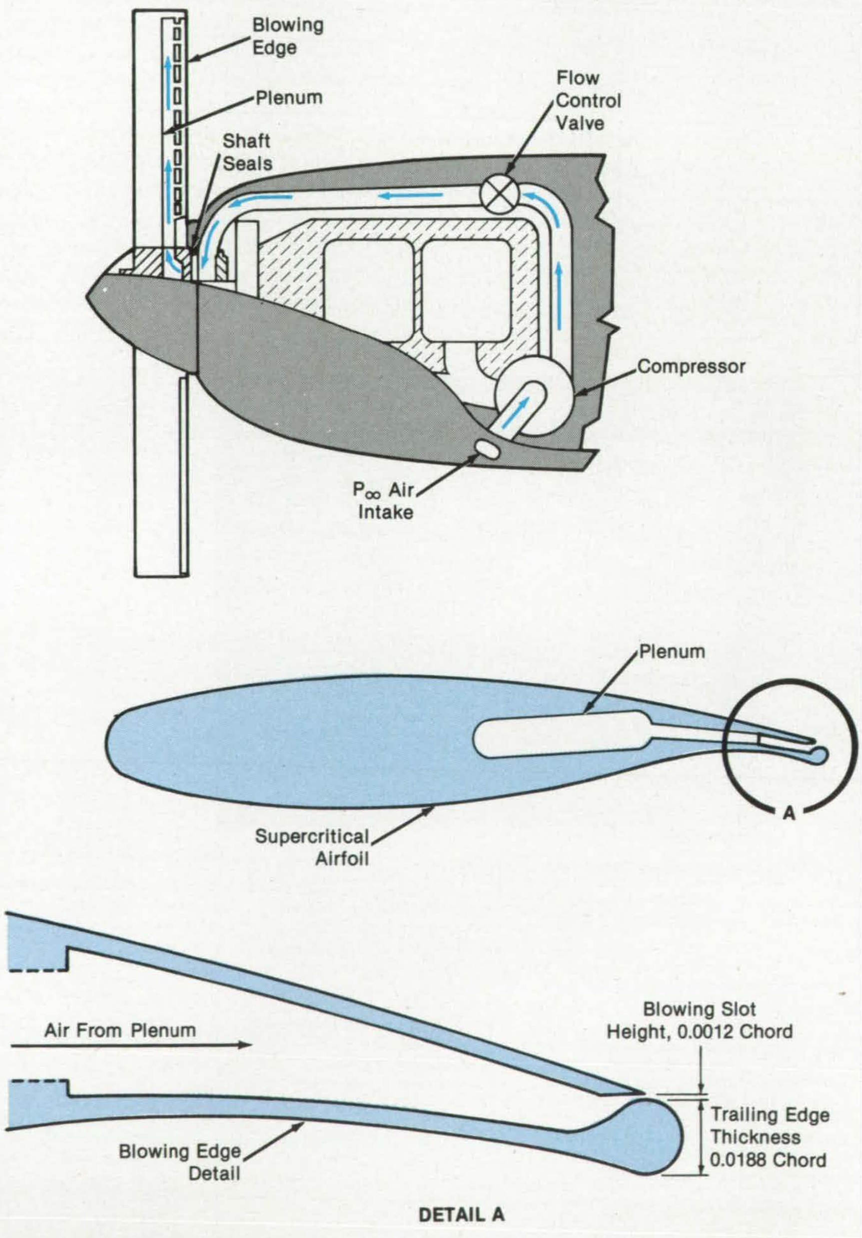
Blown aerodynamics concept would improve reliability and reduce costs.

Langley Research Center, Hampton, Virginia

A variable-pitch propeller based on the circulation-control airfoil concept has no moving parts other than those needed for propeller rotation. When substituted for a conventional variable-pitch propeller airfoil, it would lower manufacturing costs, reduce maintenance, and improve reliability.

In previous designs to vary pitch for different flight regimes (such as takeoff and cruise), the individual propeller blades are rotated about their span axes by hydraulic or electric motors. These approaches require precise, moving machine elements, increasing costs, maintenance requirements, and opportunities for failure.

The circulation-control airfoil concept (see figure), under development for a



Circulation-Control Variable-Pitch Propeller has a large lift value at very moderate blowing coefficients.

number of years, involves blowing a tangential stream of air from a thin upper-surface slot over the airfoil rounded trailing edge. The jet sheet remains attached to and turns around the trailing edge, thus controlling the circulation around the airfoil. In the current design, this principle controls the effective pitch of the propeller.

Air for the blowing slot is supplied by an engine-driven air pump through a labyrinth seal at the propeller hub. By controlling the flow of air to the propeller, the effective pitch of the propeller may be changed in flight.

Since large changes in angle-of-attack have little effect on coefficient-of-lift, a propeller using this airfoil would tend to be self-compensating for changes in aircraft forward speed, even without an adjustment of the air supply. However, an automatic system for sensing engine speed and controlling the airflow to maintain constant speed over a range of power settings could be easily incorporated into the design. This would be done preferably by fluidic control, for maximum reliability.

With the circulation-control variable-pitch propeller, the effective pitch of the propeller could be varied over a wide range, simply by controlling the flow of air to the blowing slot. In small aircraft, it would improve takeoff performance and increase fuel economy at little or no additional cost.

This work was done by H. Douglas Garner of **Langley Research Center.** *Further information may be found in NASA CR-165968 [N85-29959/NSP], "Circulation Control Propellers for General Aviation, Including a Basic Computer Program."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.
LAR-12740

Pitch Control for Helicopter Rotors

Blade pitches are controlled in synchronism.

Ames Research Center, Moffett Field, California

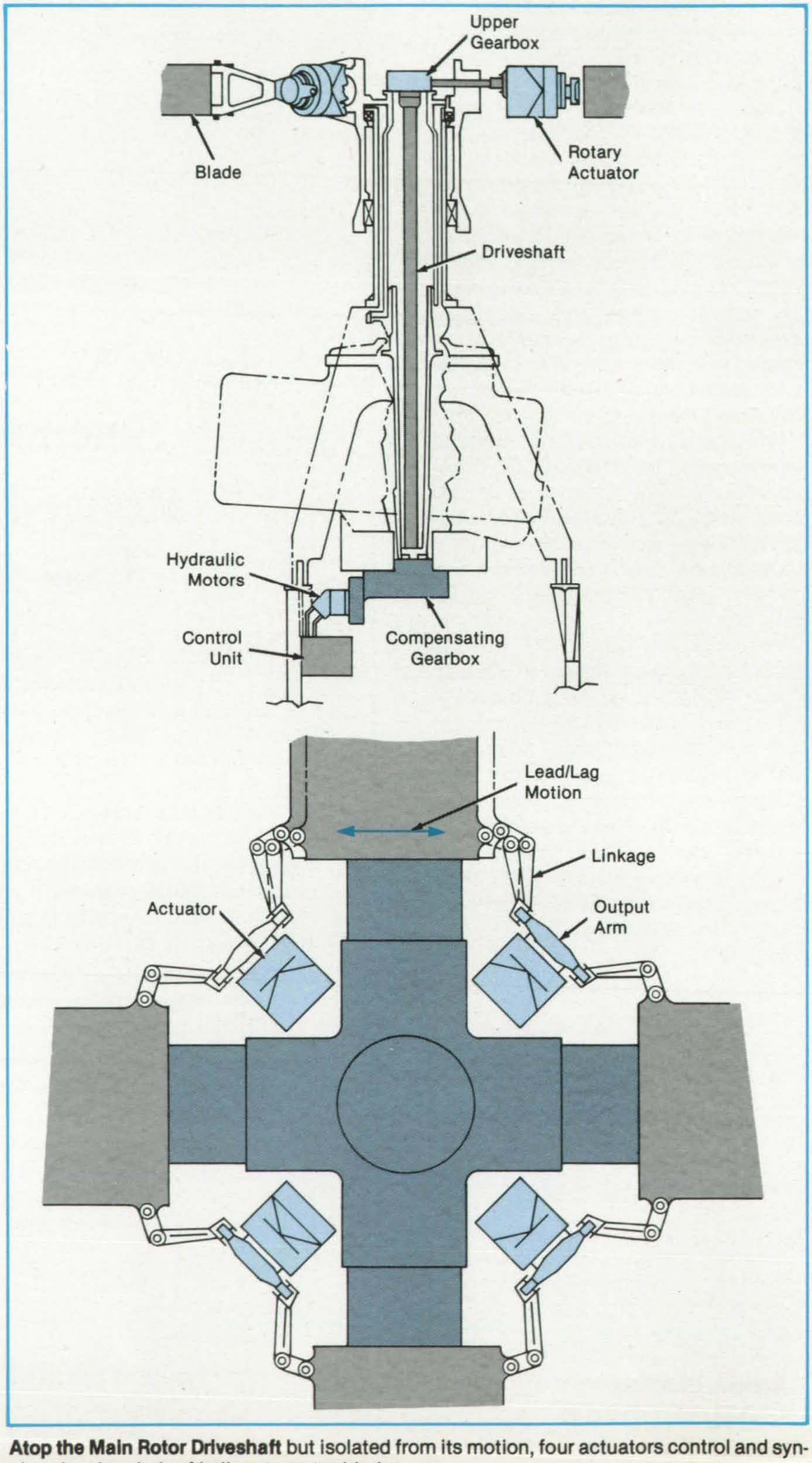
A pitch controller for helicopter rotors uses hub-mounted actuators located symmetrically between rotor blades. The new controller is designed for X-wing rotors that require collective pitch control; that is, the pitch of all blades must be changed by the same amount. The collective control allows the rotor to be trimmed during a variety of flight regimes, in particular during hovering and fixed-wing flight.

If a conventional pitch controller were used on an X-wing rotor, the load paths through the control linkages would be long and would add considerable weight if they were to provide satisfactory stiffness. In addition, a conventional controller can be used only if the blade roots are firmly supported against vertical deflection, and, with such support, it would be difficult for the conventional controller to allow lead/lag motion of the blades without coupling the motion to the blade pitch motion. Furthermore, it would be difficult to stiffen the open blade section for attachment of a horn arm.

The new controller, in contrast, has a short load path and is therefore stiff without excess weight. Its linkage permits large lead/lag motion of the blade without changing the blade pitch; the linkage also restrains vertical shear forces on the blade. Moreover, all linkages and drives are redundant: A single failure cannot cause catastrophic loss of control.

The new controller consists of four hub-mounted rotary actuators, each on an axis midway between a pair of blades, linkages that connect the output arms of the actuators to the root ends of the blades, and a drive system that synchronizes the operation of the four actuators (see figure). Each actuator arm can rotate through an angle of ±30°, which results in a pitch change of ±10° at the blade. Each linkage keeps its blade in the rotorplane while allowing in-plane lead/lag motion of ±1.75 inches (4.4 centimeters).

A hydraulic power unit drives the actuators. The unit is mounted on the airframe under the main-rotor-transmission gearbox. The unit includes two independent hydraulic motors and a control section. The combined output passes through a compensating gearbox to dual torque shafts inside the rotor shaft. The compensating gearbox removes the ef-



Atop the Main Rotor Driveshaft but isolated from its motion, four actuators control and synchronize the pitch of helicopter rotor blades.

fect of rotor rotation from the drive shafts. The shaft distributes torque to the actuators via an upper gearbox and four individual shafts, one connected to each actuator.

The pitch controller is operated by a redundant command signal, which controls flow of hydraulic fluid to the motors. Each motor is supplied by a separate hydraulic system. The malfunction of a motor or failure of its hydraulic supply causes a brake to be applied to the motor; the remaining motor then operates the actuators at half speed.

The actuator mounting is also redundant. One of the two pitch-control linkages on any one blade may fail, and the remaining linkage will continue to control the blade. Similarly, if any one actuator input shaft fails, the adjacent blades will be controlled from the neighboring actuators, the inoperative actuator being backdriven.

This work was done by P. Jeffery and G. Luecke of United Technologies Corp. for **Ames Research Center**. *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center [see page 27]. Refer to ARC-11517.

Algorithm for Fuel-Conservative Airplane Descents

Pilots use a small programmable calculator to plan descents.

Langley Research Center, Hampton, Virginia

The Federal Aviation Administration is implementing an automated, time-based metering form of air-traffic control (ATC) with profile-descent procedures for arrivals into the terminal area. These measures provide fuel savings by matching the arrival of airplanes to the airport acceptance rate through time-control computations and by allowing the pilot to descend at his discretion from the cruise altitude to a designated metering-fix altitude in an idle-thrust clean configuration (with landing gear up, flaps zero, and speed brakes retracted). An airborne descent algorithm was developed at Langley Research Center to be compatible with time-based metering and profile-descent procedures and was designed to improve the accuracy of delivering an airplane during a fuel-efficient descent to the metering fix at a time designated by the ATC system.

The simple, airborne flight-management descent algorithm (see Figure 1) was programmed into a small calculator (see Figure 2) for use with a McDonnell Douglas DC-10-10 airplane. In a time-metered mode, the airborne algorithm computes the specific mach number, airspeed, and point for the pilot to begin the descent to arrive at a metering fix at a predetermined airspeed, altitude, and time assigned by ATC. In the nonmetered mode, the algorithm computes the point to begin the descent based on the mach and airspeed descent schedule entered into the calculator by the pilot.

Flight tests were conducted on routine airline flights into various major airports.

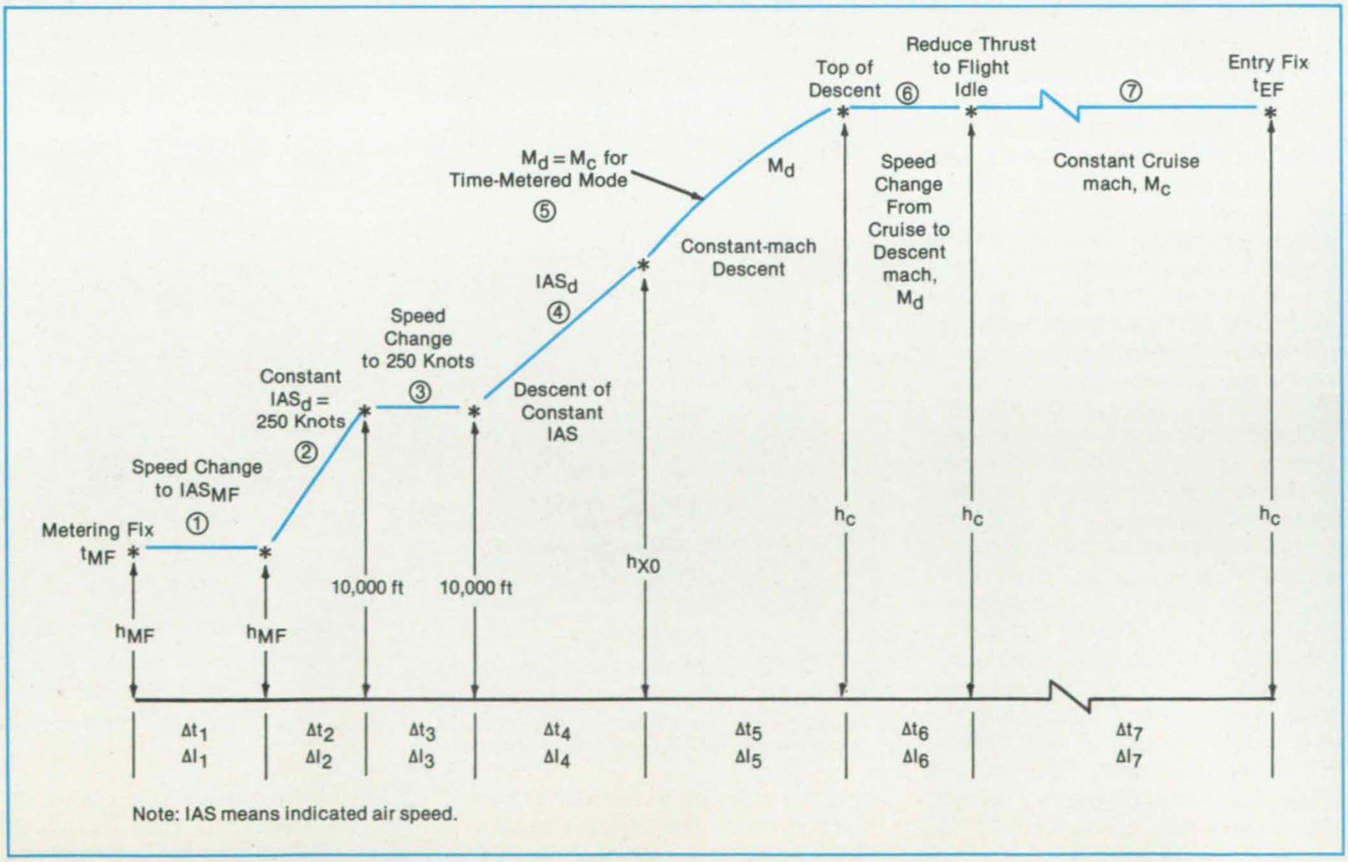


Figure 1. The **Flight-Management Algorithm** computes the parameters that describe a seven-segment cruise-and-descent profile.

The data obtained indicated that the time and distance to descend could be satisfactorily predicted with the use of relatively simple equations and modeling of airplane performance characteristics. The flight data also have shown that the descent profile could be satisfactorily flown with open-loop guidance provided by conventional cockpit mach and airspeed indicators; however, the pilot technique used to fly the descent can affect the accuracy of crossing the metering fix at the desired time.

The pilots who participated in the flight tests reported that the calculator was easy to use and did not interfere with normal flight duties. They felt that the open-loop guidance provided by the calculator would be of most value during the descents at nonstandard speeds or during time-metered operations.

This work was done by Charles E. Knox and Dan D. Vicroy of **Langley Research Center** *and David A. Simmon of United Airlines, Inc. Further information may be found in:*

NASA TM-85642 [N83-25707/NSP], "Description of the Computations and Pilot Procedures for Planning Fuel-Conservative Descents with a Small Programmable Calculator,"

NASA TM-86275 [N84-29871/NSP], "User's Manual for a Fuel-Conservative Descent Planning Algorithm Implemented on a Small Programmable Calculator," and

NASA TP-2393 [N85-26705/NSP], "Planning Fuel-Conservative Descents in an Airplane Environment Using a Small Programmable Calculator."

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

LAR-13492

Figure 2. **The Hand-Held Programmable Calculator** does not interfere with normal flight duties.

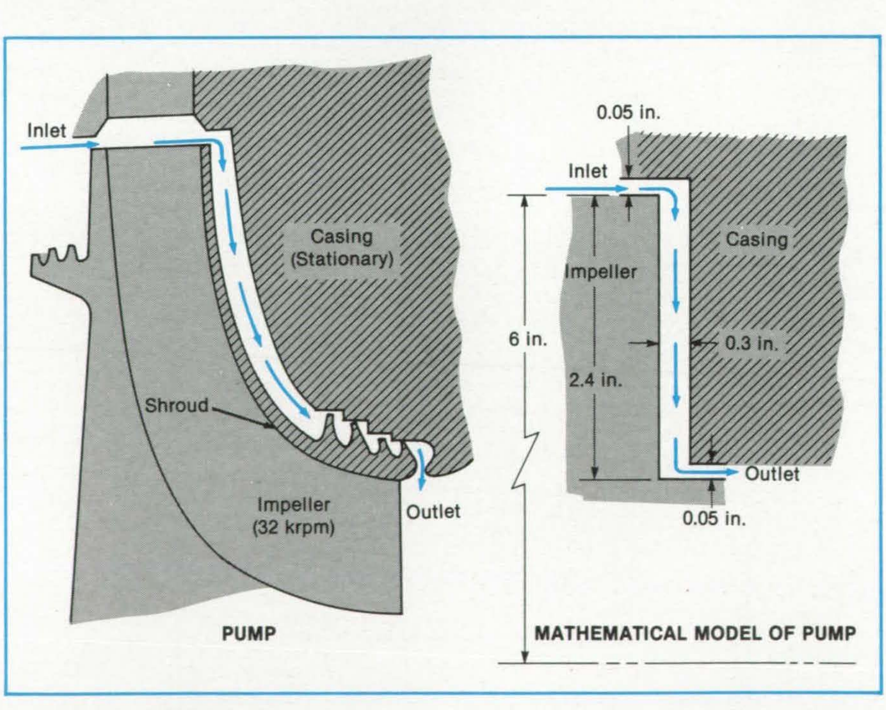
Analysis of Leakage Flows in Turbomachinery

Navier-Stokes calculations predict leakage flow in a high-pressure fuel pump.

Marshall Space Flight Center, Alabama

The accurate calculation of internal turbomachinery flow dynamics can help spot possible failure modes and can establish the coupling between cyclic loading and structural dynamics. Such an analysis has been applied to leakage flow between the impeller shroud and the casing in a high-pressure fuel pump used in the Space Shuttle main engine (see figure). The underlying approach should also be useful in analyzing two-and quasi-three-dimensional leakage flows in other turbomachinery components.

An existing computer program was modified to simulate this leakage flow. It uses a quasi-three-dimensional Navier-Stokes formulation. It solves the partial differential flow equations by an iterative under-relaxation procedure based on an integral control-volume analysis with hybrid finite differencing and staggered grids. A 63- by 81-node nonuniform mesh was used in the analysis to provide sufficient resolution in the regions of greatest flow variations, which are the inlet, the exit, and the regions near the surfaces of the impeller and casing. This mesh also reduces the effects of numerical diffusion. The high-Reynolds-number form of the k-ε model of turbulence (supplemented with wall functions near the walls) is used to close the equations for the turbulence and mean-flow fields. The computational technique has been tested extensively on other complex turbulent flows.



Leakage-Flow Geometries are shown for both the actual pump and for the simplified model used in the leakage-flow analysis.

The vector diagram in the figure depicts the flow for an arbitrary set of conditions. The vectors indicate the radial and axial components of fluid velocity at selected mesh points. Calculations were done for a variety of mass-flow rates and other conditions believed to bracket those expected in the actual pump. The numerical results indicate that significant radial and axial motion takes place only in the boundary layers in the immediate vicinity of the surfaces of the impeller and casing. In addition to the net leakage flow, there is a circulation consisting of outward flow along the impeller and inward flow along the casing. The portion of the fluid not in the boundary layers has small axial and radial velocities but rotates at a nearly uniform angular velocity that ranges from 60 to 78 percent of that of the impeller shaft.

This work was done by Munir M. Sindir of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information, Circle 23 on the TSP Request Card.*
MFS-29152

Balancing High-Speed Rotors at Low Speed

Flexible balancing reduces vibrations at operating speeds.

Marshall Space Flight Center, Alabama

High-speed rotors in turbomachines can be dynamically balanced at a fraction of the operating rotor speed. The method results in a precisely balanced rotor at, say, 30,000 r/min even though the rotor weight distribution has been adjusted at a much lower speed — for example, 2,000 r/min.

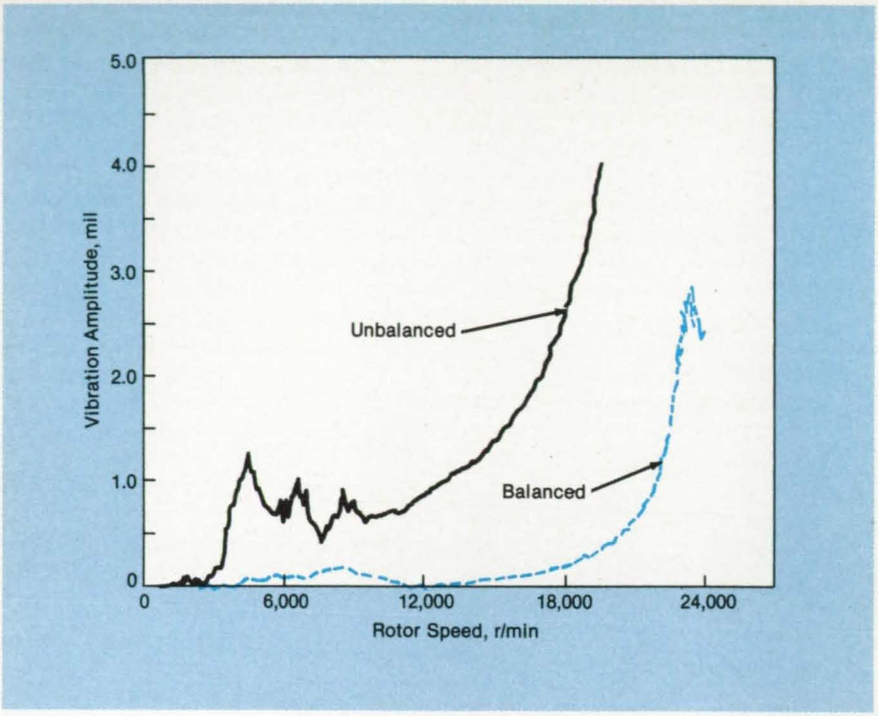
Unlike other low-speed, rigid-body balancing, the new method takes into account that the rotor is flexible rather than rigid. The method is based on balancing "windows" — combinations of speed and support flexibility at which two conditions occur simultaneously. The system behaves flexibly (that is, distinct balance planes can be discerned along the shaft), and the system response to the addition of balance weights is large enough to measure reliably.

The method consists of the following four steps:

1. The balance planes are selected. They must be in axial planes where weight can be added or removed at any circumferential location. They must not be at vibrational nodes at the speeds of interest, and they must be active at the low speeds at which balancing will be performed.
2. The speeds are determined at which there is separation among the planes; that is, at which a weight in each plane would cause a different rotor response.
3. The speeds are determined at which the rotor response is measurable with sufficient accuracy.
4. Finally, the influence-coefficient balancing is performed at speeds where the rotor is both flexible and responsive.

The low-speed flexible balancing method was evaluated empirically with a rotor-dynamic test rig. The rig was assembled with supports that simulated those of an oxygen turbopump. For this arrangement, a low-speed balancing window was predicted at 8,000 r/min. The rig was balanced at this and other speeds. The balancing resulted in smooth operation of up to 24,000 r/min, and the two critical speeds below it were traversed without excessive vibration (see figure).

By way of comparison, a high-speed balance was done on the test rig. The



quality of balance was approximately the same as it was for the low-speed, flexible balance. A low-speed, rigid-body balance was also done. This method produced little reduction in vibration amplitude, and the maximum speed was limited to 20,000 r/min.

This work was done by J. Giordano and E. Zorzi of Mechanical Technology, Inc., for **Marshall Space Flight Center**. *For further information, Circle 21 on the TSP Request Card.*
MFS-28130

Before- and After-Balancing Curves show that flexible-body balancing at 8,000 r/min ensures smooth rotation up to at least 24,000 r/min. The vibration peaks at the critical speeds and the sharp rise of vibrations at intermediate speeds are eliminated.

Books and Reports

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

Flexible-Rotor Balancing Demonstration

Treating the rotor as a flexible body at low rotational speeds allows balancing without high-speed tests.

A report describes a method for balancing high-speed rotors at relatively low speeds and discusses a demonstration of the method on a laboratory test rig. The method ensures that a rotor can be brought up to speeds well over 20,000 r/min smoothly, without excessive vibration amplitude at critical speeds or at the operating speed. The method was developed for balancing the rotors of turbopumps in the Space Shuttle main engine; these pumps are difficult or impossible to balance at their full operating speed [see "Balancing High-Speed Rotors at Low Speed" (MFS-28130), in this issue of *NASA Tech Briefs*].

The report presents the theory of low-speed flexible balancing and contrasts the new method with full-speed balancing and with low-speed balancing in which the rotor is regarded as a rigid body rather than as a flexible one. It describes the rotordynamic test rig used to demonstrate the method, analyzes the dynamics of the demonstration, and discusses the results. An appendix gives a sample computer output for test-rig critical speed.

The objective of low-speed flexible balancing is to add or remove weights from a rotor/bearing system to minimize unwanted vibrations. The weight distributions predicted by this method should produce vibrations, at the measurement planes, equal and opposite to those due to rotor imbalance. The weights are predicted on the basis of measurements at low speeds in such a way that vibrations are minimized at the balancing speeds and at the intended operating speeds.

The report concludes that low-speed flexible-rotor balancing is a viable technology and that the quality of balance achieved with low-speed flexible-rotor balancing is roughly equivalent to that of high-speed flexible balancing. The report also concludes that rigid-body balancing at low speed is unacceptable for high-speed operation.

This work was done by J. Giordano and E. Zorzi of Mechanical Technology, Inc., for **Marshall Space Flight Center.** *To obtain a copy of the report, "HPOTP Low-Speed Flexible Rotor Balancing — Phase I Final Report," Circle 20 on the TSP Request Card.*
MFS-28132

Liquid-Hydrogen Polygeneration System

The system utilizes coal as an alternate chemical feedstock.

A polygeneration system would use existing technology in an integrated process to produce liquid hydrogen space-vehicle propellant and such important secondary products as gaseous nitrogen, electrical energy, and thermal energy. The system can make the commercial launch services economically attractive against future competition. The system could lower the expected cost of liquid hydrogen by utilizing relatively cheap coal feedstocks and by reducing the electrical costs associated with producing liquid hydrogen.

The integrated process includes a coal-gasification and gas-cleanup system, a combined-cycle power-generation system, a hydrogen-production/liquefaction system, and an air-separation system. A clean, medium-BTU gas is produced by the coal-gasification system and is delivered to the power-generation system and the hydrogen-production/liquefaction system.

Steam, produced in the coal-gasification process, is delivered to a steam turbine combined with a gas turbine, to which the gas is delivered, to generate electrical and thermal power in a combined-cycle power-generation process.

Steam from the coal-gasification process is also delivered to a shift-conversion unit in the hydrogen-production system to increase the hydrogen content of the gas before liquefication.

The air-separation system produces oxygen and gaseous nitrogen. The oxygen is used in the coal-gasification process, and the gaseous nitrogen is delivered for storage to the launch site, where it is used as an inert gas to purge critical environments. The gaseous nitrogen is also used in the hydrogen-production system, where the nitrogen is liquefied and used to refrigerate the hydrogen.

This work was done by P. A. Minderman, G. P. Gutkowski, L. Manfredi, J. V. King, and F. S. Howard of **Kennedy Space Center**. *To obtain a copy of the report, "Liquid Hydrogen Polygeneration System and Process," Circle 53 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, Kennedy Space Center [see page 27]. Refer to KSC-11304.

Synopsis of Magnetohydrodynamic Power Generation

A summary reviews the state of development.

A concise summary of magnetohydrodynamic (MHD) theory, history, and future trends is presented in a report. Worldwide research on MHD is covered, and selected data from key research projects are included. A magnetohydrodynamic generator produces electric current by passing a fluid at high speed through a strong magnetic field. The fluid may be an ionized gas, a plasma, or a liquid metal. Although much work remains to be done in this field, magnetohydrodynamic generators offer the potential for high efficiency, low power cost, and cleaner emissions.

Operating at about 3,000 K, a typical magnetohydrodynamic generator presents major materials problems. For example, the channel and the electrodes are subject to erosion and to damage by heat. In addition, reducing heat loss and decreasing the cost of the magnet are major concerns.

The fact that magnetohydrodynamic generators produce direct current rather than alternating current can be a hindrance, since dc-to-ac inverters are expensive. However, many industries — metal processing, for example — need dc.

The report notes that despite the disadvantages, magnetohydrodynamic power generation appears to be one of the best ways to utilize domestic coal reserves. Over a period of time, the high initial costs would be absorbed by lower production costs. Equally important, a coal-fired magnetohydrodynamic powerplant would pollute the environment far less than does a conventional steam plant:

- It would reject only half the heat of a conventional plant.
- Particulate pollution would be removed by the alkali-metal seed-recovery setup that would be a necessary part of an ionic magnetohydrodynamic system.
- Nitrous oxide and sulfur dioxide could readily be removed.

This work was done by James L. Smith of **Marshall Space Flight Center**. *Further information may be found in NASA TP-2331 [N84-25458/NSP], "Magnetohydrodynamic Power Generation."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. The report is also available on microfiche at no charge. To obtain a microfiche copy, Circle 54 on the TSP Request Card. MFS-27073

Fabrication Technology

Hardware, Techniques, and Processes

Books and Reports

Lightweight, Nesting Struts

Hollow cones are easily assembled to form trusses.

Marshall Space Flight Center, Alabama

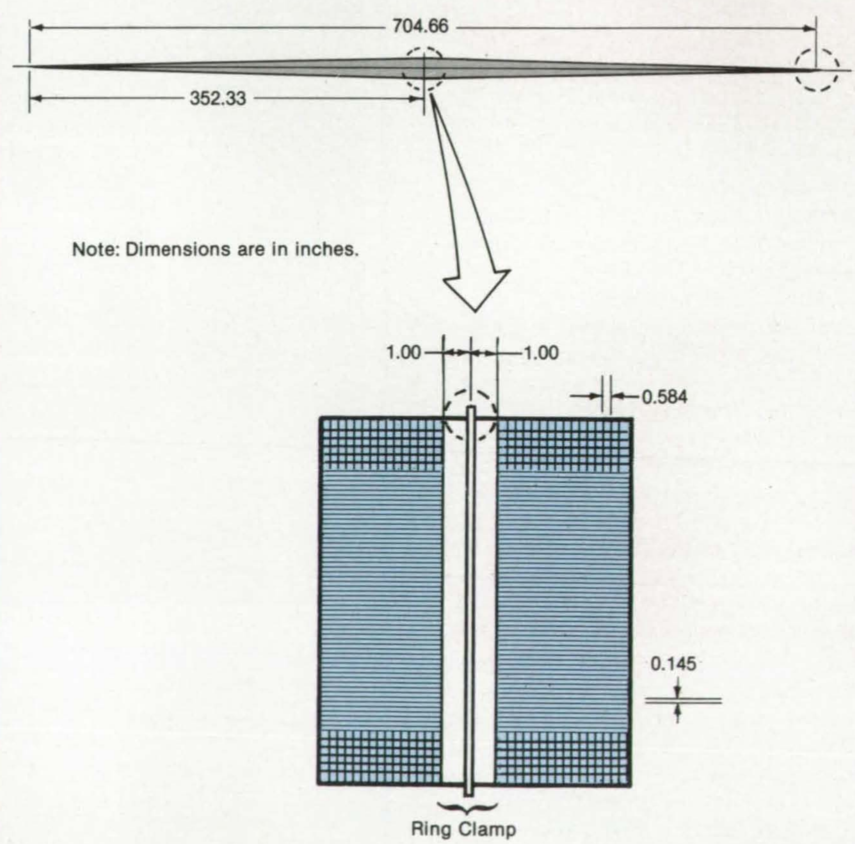
Struts made of graphite-fiber-reinforced epoxy resin are tapered for stiffness and for compact nesting for transportation. They nevertheless are fabricated with a constant load-bearing cross section. The struts were developed for building large truss structures in space. They can be readily carried to the construction site in the Space Shuttle and quickly assembled. They may also be useful on Earth in small structures where great strength is not required.

Each strut is 9 m long and 0.305 m in diameter at its large end, tapering to 0.025 m in diameter at its small end. In each strut, 260 graphite/epoxy fiber bundles run the length of the long, narrow, hollow cone. A single bundle is wrapped in a helix on the outside of the cone to stabilize the longitudinal fibers.

A pair of struts is joined by a ring clamp at the large-diameter end (see figure). The end fittings are bonded to the struts during manufacturing so that the double-strut assembly can be easily inserted in the truss as a structural member. A completed pair of struts with its fittings has a mass of 5.7 kg.

This work was done by Richard M. Gates and Kenneth P. Hernley of The Boeing Co. for **Marshall Space Flight Center**. *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 27]. Refer to MFS-28116.



A **Ring Clamp Holds Struts** together as a pair. Fibers extend longitudinally and helically along each tapered member.

Producing Refractory Microballoons

Metals, ceramics, and glasses are just some of the possible raw materials.

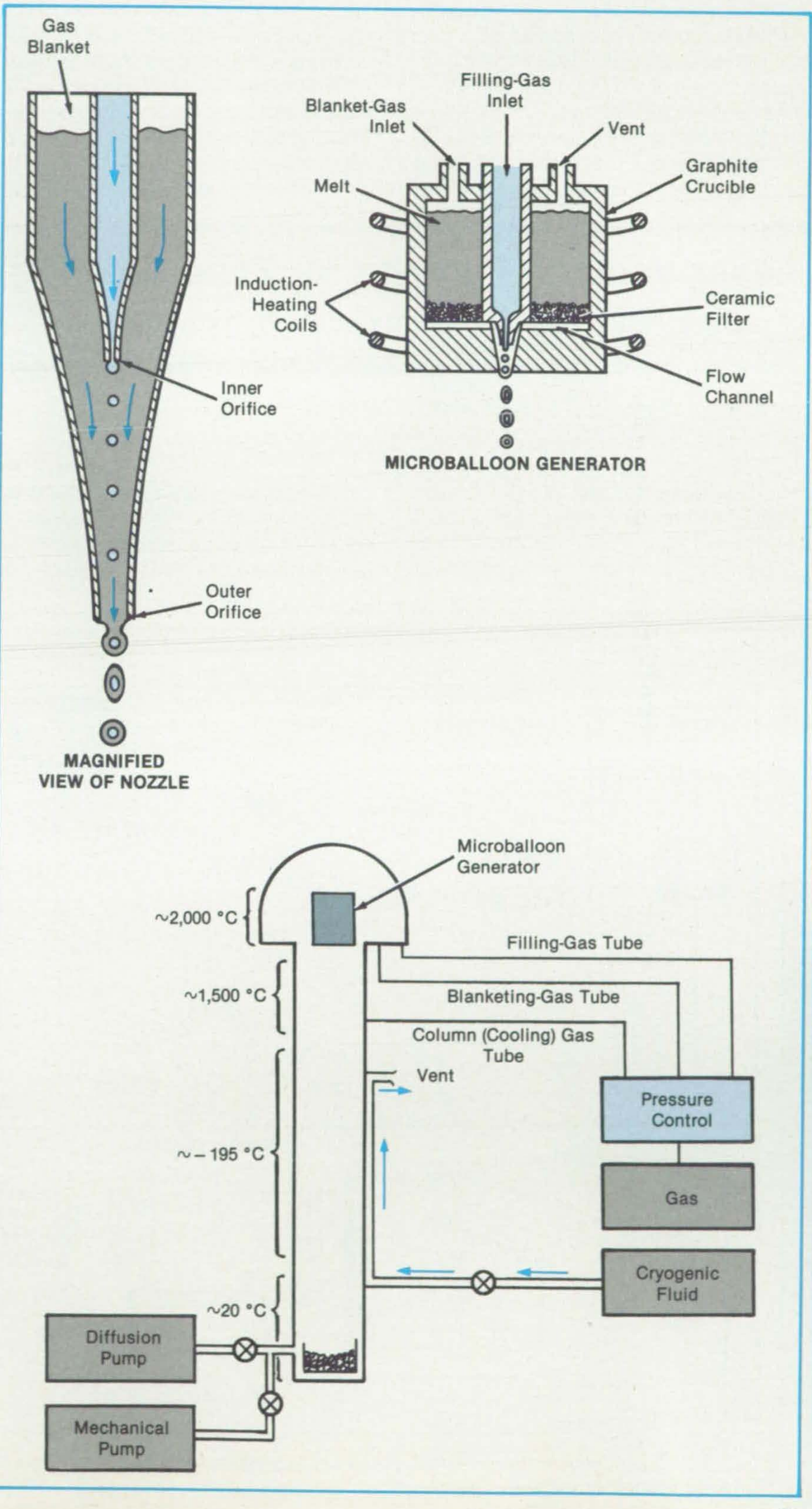
NASA's Jet Propulsion Laboratory, Pasadena, California

An apparatus produces tiny spherical shells, or microballoons, from refractory metals, ceramics, and glasses. The microballoons are generated at rates of 400 per second or higher with uniform shape and size. The size is selected from a wide range of diameters, ranging from 800 μm to less than 150 μm.

As in previous processes, microballoons are formed in two stages: Liquid-shell generation and free-fall solidification. Gas is ejected from an inner orifice into molten shell material in an outer orifice, thus forming a bubble that hardens as it falls through a vertical chamber. The new process, however, has several improvements over previous processes:

- The inner orifice is now recessed (see figure) instead of being coplanar with the outer orifice; as a result, the outer orifice can be fabricated with a smaller diameter than if it had to contain the inner orifice; therefore, smaller balloons can be generated;
- The Bernoulli acceleration in the flowing molten material in the nozzle as it converges toward the orifice tends to center the gas bubble in the emerging microballoon; thus, precise concentricity of the inner and outer orifices is no longer necessary;
- The recess distance of the inner orifice reduces the possibility of blockage of the outer orifice by impurity particles entrained in the melt; a ceramic filter further reduces the chances of undissolved particles from reaching the outer orifice; and
- The nozzle and crucible are made of the same material to eliminate differences in thermal expansion; this reduces the incidence of gross misalignment, overstress, cracking, and leakage.

In many cases, the crucible and nozzles could be made of machinable graphite, which is compatible with a variety of molten substances including refractory ones. With conventional machining, the inner orifice diameter can be made as small as 50 μm, enabling the formation of microballoons less



Key Components of equipment for the new microballoon fabrication process are the nozzle, crucible assembly, and drop tube. The recessed, conical inner orifice aids in producing uniform, symmetrical microballoons. The all-graphite crucible assembly is resistant to misalinement and cracks. The drop tube ensures timely solidification of the microballoons.

than 150 μm in diameter. Even orifices as small as 1 μm can be made with such techniques as chemical vapor deposition, laser machining, and slip casting. Materials other than graphite can be selected for special applications.

The inner nozzle is an integral part of the filling-gas tube, which supplies gas for bubbles at a constant flow rate. The flow of the melt is regulated by the pressure of a gas blanket above the melt in the crucible. The crucible and nozzle assembly is enclosed in a bell jar above a vertical drop tube.

The temperature decreases from the top to the bottom of the drop tube. This allows the normal oscillations of the liquid shell — which promote centering of the gas core in the shell — to dampen before the shell solidifies. Otherwise, the shell could contain frozen oscillation ripples on its surface. At the same time, the temperature profile is chosen to prevent solidification from occurring too late in the fall, when aerodynamic forces would have distorted and decentered the microballoon.

The drop tube is 45 ft (13.7 m) long. For a melt at a typical temperature of 2,000 °C, the gas in the upper part of the chamber might be kept at or near 1,500 °C. The microballoons then enter a cryogenic zone kept at about − 195 °C for rapid quenching. Finally, the microballoons collect in a room-temperature zone at the bottom of the chamber.

The product has many applications. The microballoons can be used, for example, in fluidized-bed heat exchangers; as containers for hazardous materials; catalysts in chemical and pharmaceutical processes; solid fuel for rockets; fuel containers for fusion power experiments; shock-wave dampers; and starting materials for high-strength, low-density sintered alloys and ceramics.

This work was done by Mark C. Lee, Christopher Schilling, George O. Ladner, Jr., and Taylor Wang of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 32 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 27].* *Refer to NPO-16489.*

Laser Vacuum Furnace for Zone Refining

A laser beam is scanned to produce a moving melt zone.

Marshall Space Flight Center, Alabama

An experimental laser vacuum furnace scans a crystalline wafer with a high-power CO_2-laser beam to generate a precise melt zone with precise control of the temperature gradients around the zone. Intended for the zone refining of silicon or other semiconductors in low gravity (where convection would be suppressed), the apparatus can also be used in normal gravity.

The wafer is mounted in a vacuum system near a set of salt windows that

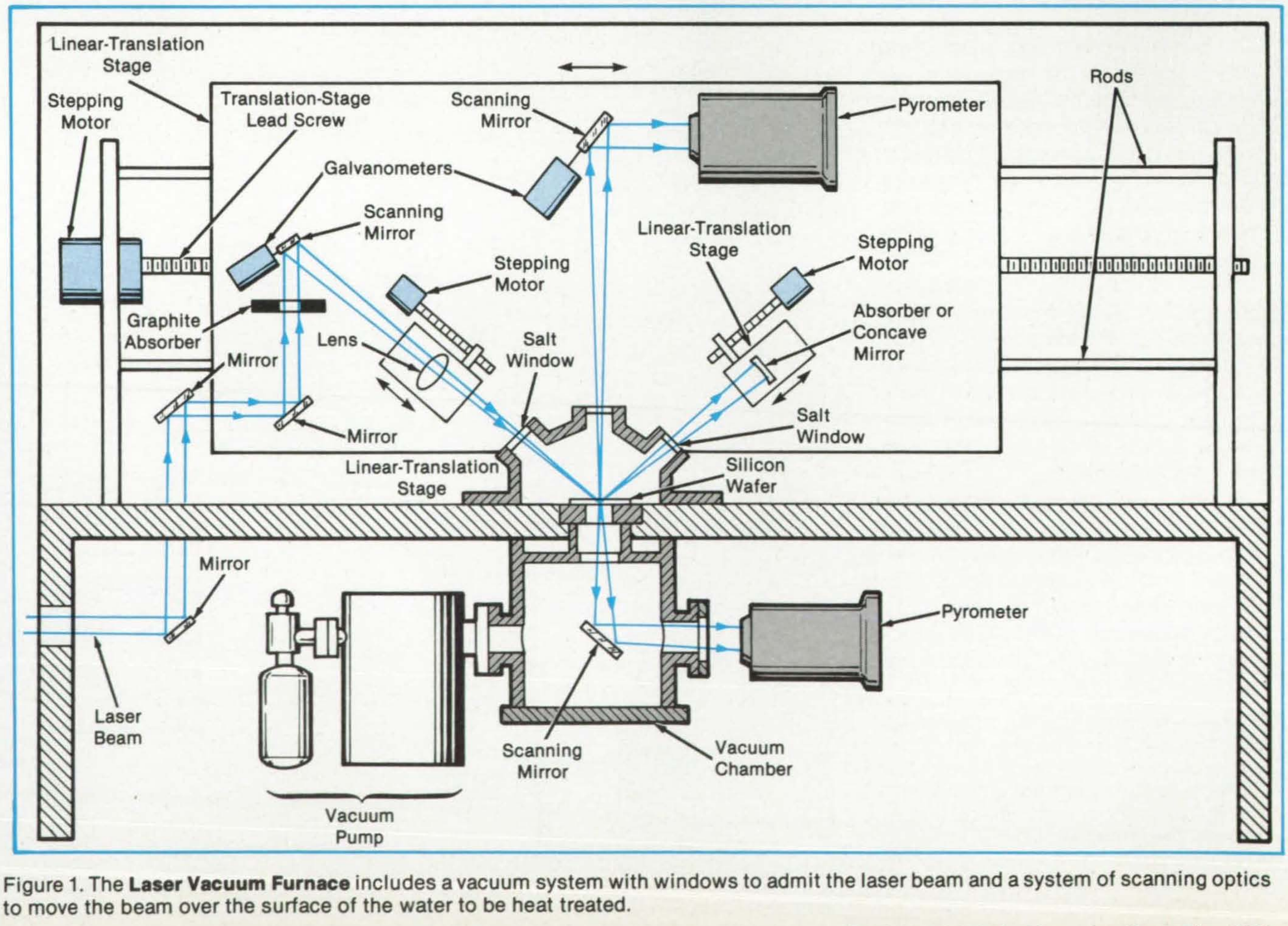


Figure 1. The **Laser Vacuum Furnace** includes a vacuum system with windows to admit the laser beam and a system of scanning optics to move the beam over the surface of the water to be heat treated.

permit the passage of infrared and visible light (see Figure 1). A system of mirrors mounted on a large translation stage directs the laser beam toward the wafer. A graphite absorber has a hole in the middle to allow the beam to pass but stops the beam if it becomes laterally misaligned. A lens mounted on a small linear translation stage focuses the beam to a spot on the wafer. By the motion of its transaction stage, the lens is focused or defocused slightly to obtain the desired spot size. The minimum spot diameter is about 0.5 mm.

The large translation stage moves slowly to the right or the left while the laser beam is scanned rapidly back and forth across the wafer (into and out of the page) by a scanning mirror on a galvanometer. When driven by a triangular wave at any convenient frequency up to about 60 Hz, the laser spot moves in the zigzag pattern shown in Figure 2. The horizontal spacing between lines is exaggerated here. To an observer, the illuminated region looks like a perpendicular line that coincides with the melt zone as it moves along the wafer.

A second small translation stage on the large stage holds an absorber to trap the portion of the laser beam reflected from the sample. Alternatively, the stage could hold a concave mirror to reflect this energy back onto the wafer to increase the heating efficiency. In this case, the stage is driven in synchronism with the beam-scanning galvanometer but at such a phase that the incident and back-reflected spots move in opposite directions across the wafer within the melt zone.

The temperature in the melt zone is monitored by either or both of two pyrometers that view the wafer perpendicularly to its surface. A scanning mirror moves in synchronism with the large translation stage to keep the melt zone within the view of the operating pyrometer.

A control computer (not shown) coordinates the operation of all the equipment. It monitors the laser output power, controls the laser power supply, generates the driving waveforms for the scanning galvanometers, and commands the stepping motors. The computer can be programmed to provide scanning speeds, scanning patterns, and laser powers over a wide range, thereby providing a range of melt-zone movements and temperature distributions.

This work was done by Donald B. Griner, Frederick W. Zurburg, and Wayne M. Penn of Penn-Penn Research Corp. for **Marshall Space Flight Center**. *For further information, Circle 145 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:

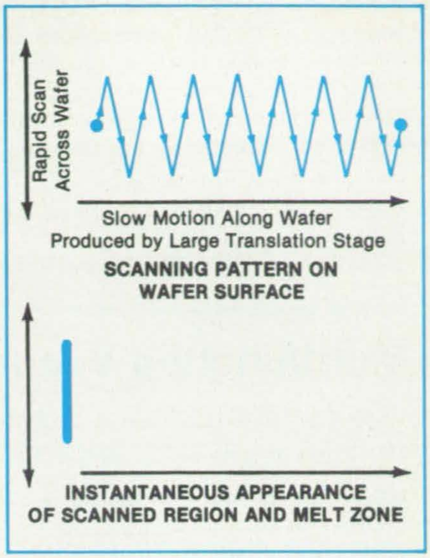


Figure 2. The **Laser Beam Scans** rapidly across the wafer while the wafer moves to the right or left. Since the crosswise scan is much faster than the lengthwise scan, to a human observer the scanned zone looks like a vertical line coincident with the melt zone at any given moment.

Penn-Penn Research Corporation
2652 South Main Street
P.O. Box 3357
Kennesaw, GA 30144

Refer to MFS-26043, volume and number of this NASA Tech Briefs issue, and the page number.
MFS-26043

Storing Chemicals in Packed Spheres

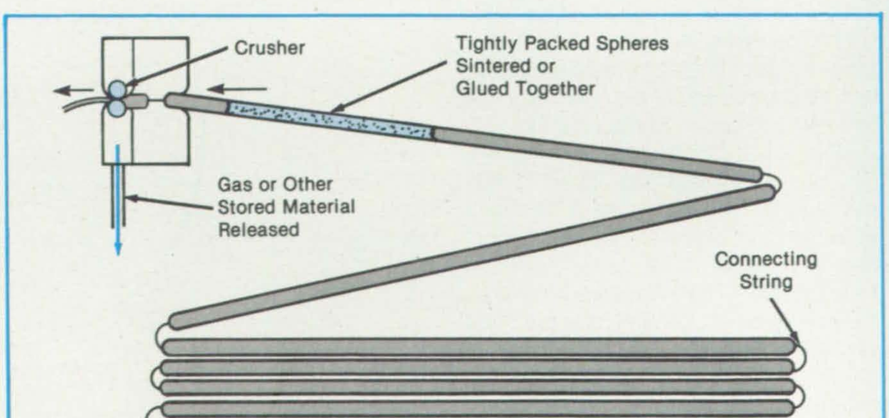
Reactants would be released by crushing or puncturing.

NASA's Jet Propulsion Laboratory, Pasadena, California

According to a concept for material storage, chemical reagents or other substances would be encapsulated separately in small, densely packed spheres. The spheres could be made of metal or other suitable material. They could be loose, forming a pourable mass, sintered, or glued together in a rigid structure (see figure).

The filling material could be a gas — for example, hydrogen to be burned as a fuel. There are two advantages to storing hydrogen in this way: Small quantities can be dispensed as needed, and a leak is likely to involve only the small volume of one or a few spheres, thereby presenting a smaller-than-usual risk of explosion.

Some of the spheres in a mass could be



Agglomerated Gas-Filled Spheres are hexagonally close packed and sintered or glued together into rods that are strung together at their ends. The rods are fed into a crushing machine to release the material in the spheres as it is needed.

filled with an epoxy resin or other monomer, while others could be filled with the corresponding hardener or catalyst. The spheres would be manufactured in the required ratio and mixed together in forming the mass. The catalyst and resin would be released for mixing by puncturing or crushing the required number of spheres at the mixing site.

Another variation might be the permanent storage of reusable materials in capsules — for example, magnetic material for use in magnetic brakes. The flowing magnetic material tends to agglomerate, thereby preventing the necessary even distribution over the magnetic-braking area. In such an application, agglomeration might be controlled by storing the magnetic material in small, loose aluminum spheres.

This work was done by Taylor G. Wang and Daniel D. Elleman of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 49 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 27]. Refer to NPO-16316.

Multifunction Vacuum Chamber for IC Metallization

One system performs several operations without transferring wafers between vacuum chambers.

Marshall Space Flight Center, Alabama

A vacuum system chamber for processing multilayer metallization on integrated circuits (IC's) performs four operations ordinarily done in separated equipment. The chamber etches holes, removes photoresist, cleans by sputter etching, and deposits the final layer of metal.

The combined-function chamber costs less than the separate equipment performing the same functions. The chamber avoids exposing the integrated circuits to room air and, consequently, to oxidation and dust, between steps. It also eliminates the time spent in transferring the circuits from one apparatus to the next.

Unlike the conventional process, the multifunction process does not use liquid acids and reducing agents for hole etching and photoresist removal. The cost of disposing of these hazardous materials is therefore avoided.

The chamber (see Figure 1) contains turntables that continuously turn silicon integrated circuit wafers to ensure uniform processing of several wafers at a time. It also contains radio-frequency and magnetron sputtering guns. External tanks furnish gases to the chamber.

Wafers are introduced into the chamber after transistors or other circuit elements have been formed in them and after layers of oxide, metal, more oxide, and photoresist have been built up. Holes yet to be formed are delineated by the photoresist pattern. In the first vacuum processing step, a mixture of helium, oxygen, and a chlorofluorocarbon gas is admitted to the chamber, forming a plasma under the radio-frequency sputtering gun. A permanent magnet directs the plasma to the wafer surface, where it etches away the oxide

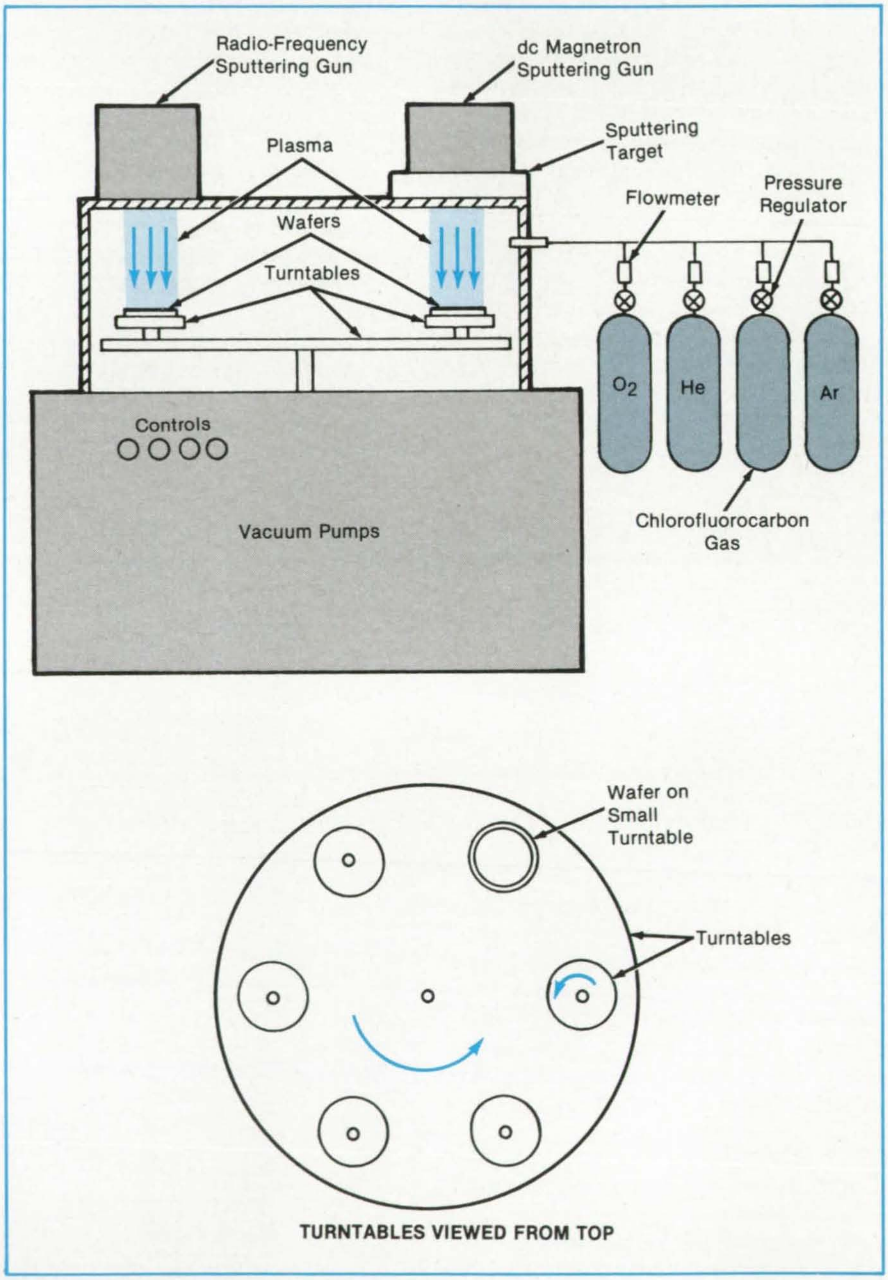


Figure 1. **External Tanks Supply Gases** to the vacuum chamber for forming plasmas. Permanent magnets direct the plasmas to the wafers as they pass under the sputtering guns. The wafers are continuously rotated about their own centers and about the center of the upper turntable for uniform coverage.

in the holes, exposing the metal layer at the bottoms of the holes (see Figure 2). When etching is done, the gas mixture is pumped out.

In the second step, oxygen is admitted and forms an oxygen plasma under the radio-frequency sputtering gun. This plasma etches away the photoresist layer. It also forms aluminum oxide at the bottoms of the newly etched holes. The oxide layer prevents the formation of good contacts and must be removed.

After the oxygen has been pumped out, argon is admitted. The argon plasma under the radio-frequency sputtering gun cleans the entire wafer surface, removing the aluminum oxide from the bottoms of the holes. The argon is then pumped out.

In the fourth step, the magnetron sputtering gun deposits a layer of metal from a target onto the wafers. This layer is the upper conductor and joins the lower conductor through the holes. The wafers can now be removed from the chamber for further processing.

This work was done by Donald E. Routh and Gian Sharma of **Marshall Space Flight Center.** *For further information, Circle 92 on the TSP Request Card.*

This invention has been patented by NASA (U.S. Patent No. 4,437,961). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 27]. Refer to MFS-25670.

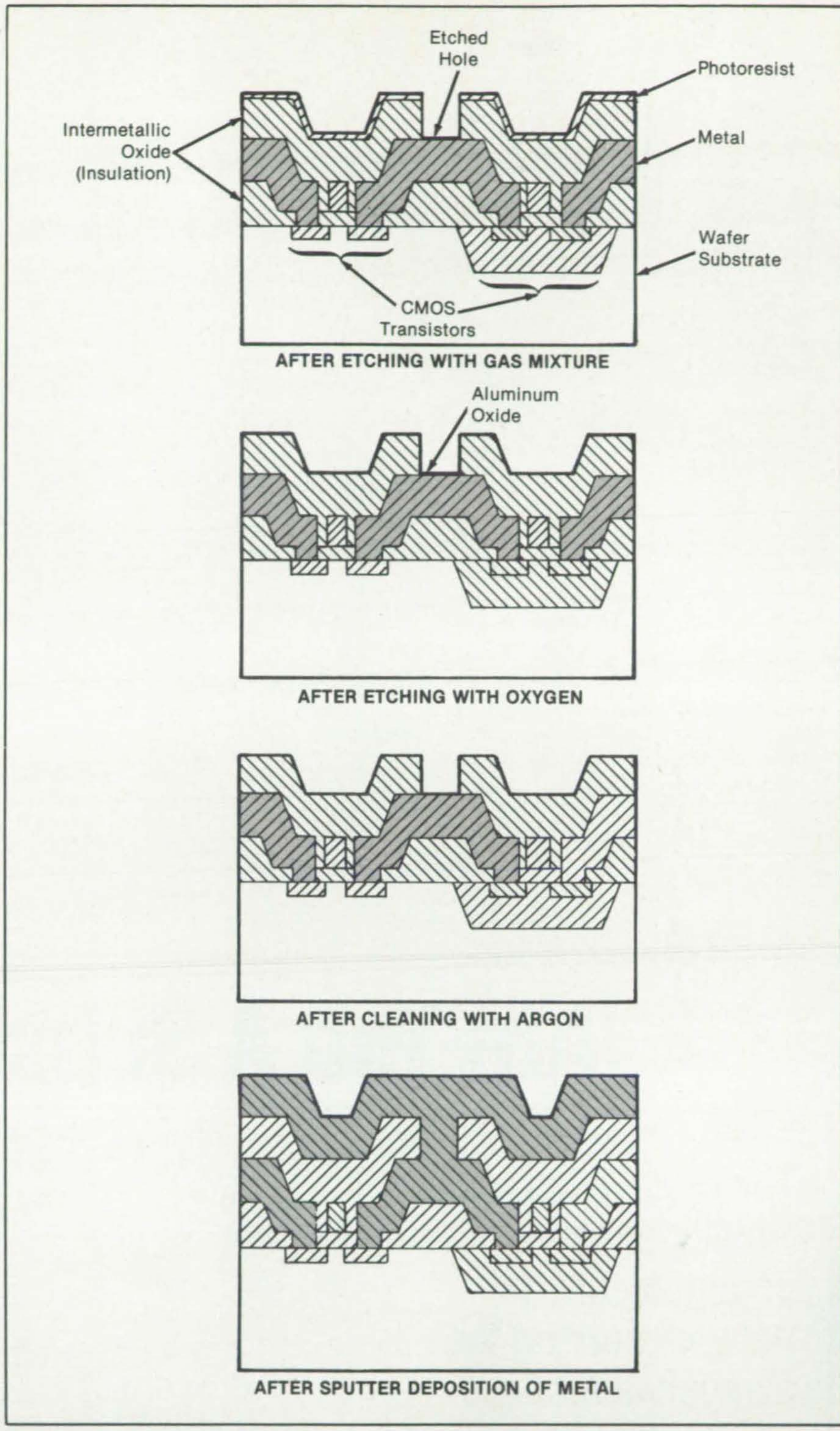


Figure 2. The **Layer Structure** of a silicon wafer changes at each processing step. The wafer structure shown here contains complementary metal-oxide/semiconductor (CMOS) transistors.

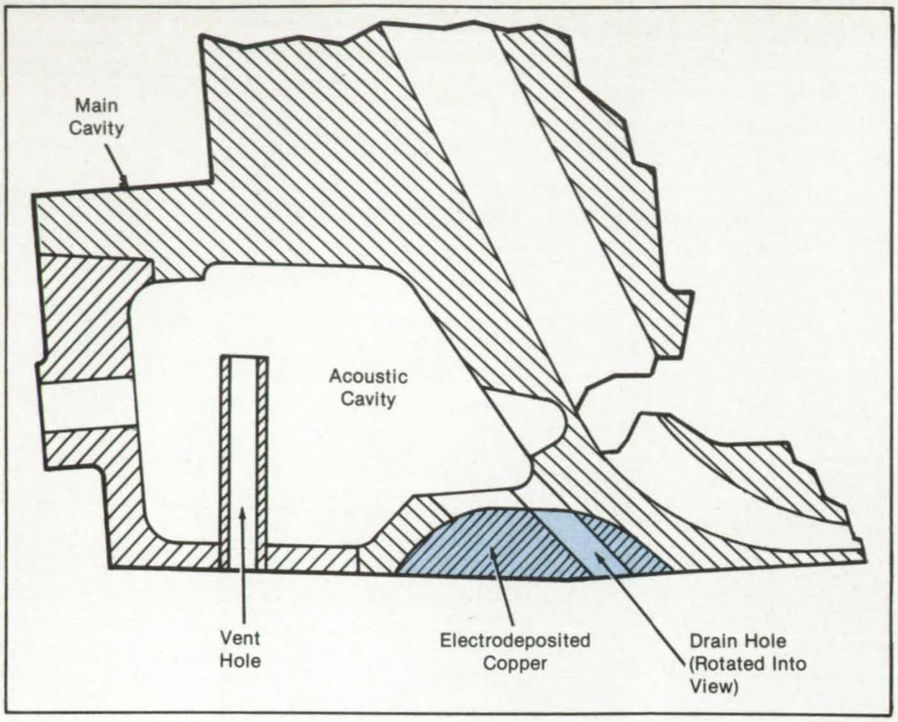
Covering Cavities by Electrodeposition

A reworking technique allows complex surfaces to be reshaped.

Marshall Space Flight Center, Alabama

The contours of large machined parts can be reworked quickly and inexpensively by electrodeposition and machining, with little risk of damage. The reworking method employs simple, reliable, well-known procedures.

The method was used to modify for testing the main combustion chamber of the Space Shuttle main engine. Thirty



Electrodeposited Copper Closes Off an acoustic cavity near the main cavity. A hole through the wall vents these two cavities to each other.

acoustic cavities adjoining the combustion chamber had to be sealed off to eliminate their stabilizing effect during a hot-fire test.

The cavities were filled with wax. A groove was machined around the inside circumference of the main combustion chamber wall to a depth of 0.3 in. (7.62 mm). The groove passed through the acoustic-chamber openings. Copper was then electrodeposited in the groove until the surface of the deposit protruded slightly out of the groove. The copper was then machined so that it was flush with the chamber wall (see figure).

For the combustion-chamber test, it was necessary to vent the acoustic cavities. Another hole was drilled through the electrodeposited copper into the bottom of one cavity so that liquid accumulated in the cavities could drain.

This work was done by Melissa Schmeets and Joe Duesberg of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*
MFS-29084

Books and Reports

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

Levitation With a Single Acoustic Driver

Using one driver instead of three makes levitation easier to control.

A pair of reports describes acoustic-levitation systems in which only one acoustic resonance mode is excited, and therefore only one driver is needed. The systems employ levitation chambers of rectangular and cylindrical geometries.

Until now, a typical acoustic levitator contained three acoustic drivers that produced three orthogonal acoustic waves or modes. However, there are many complicated interactions among the three drivers. It is necessary to monitor and continually adjust each driver to ensure that a sample remains levitated, does not rotate, and does not become distorted or broken up. The single mode levitators eliminate the interactions among drivers and are therefore simpler to operate. They thus make acoustic levitation more practical as a means of containerless processing of materials.

The reports first describe the single mode concept and indicate which modes can be used to levitate a sample without rotation. Each of these single modes has one or more unique positions inside the chamber at which the sample will stably levitate. Thus, the location of the sample inside the levitation chamber can be controlled by choosing the appropriate single mode.

The reports then go on to describe systems in which controlled rotation of the sample can be introduced. For both geometries, one primary driver is used to excite a single mode for levitation as described above. Auxiliary drivers are used to excite other modes to rotate the sample. The axis of rotation is chosen by selection of appropriate chamber dimensions and the auxiliary modes. These new driver configurations differ from a rectangular three-axis levitator with rotation in that the levitation and rotation controls are separated from each other.

This work was done by Martin B. Barmatz, Mark S. Gaspar, and James L. Allen of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the reports, "Single Transducer Rectangular Levitator" and "Single Transducer Cylindrical Levitator," Circle 131 on the TSP Request Card.*

This is the invention of a NASA employee, and a patent application has been filed. Inquiries concerning license for its commercial development may be addressed to the inventor, Mr. Edward Ansell (CIT Waiver), Director of Patents and Licensing, California Institute of Technology, Pasadena CA 91125. Refer to NPO-16246/NPO-16376.

Mathematics and Information Sciences

Hardware, Techniques, and Processes

Computer Programs

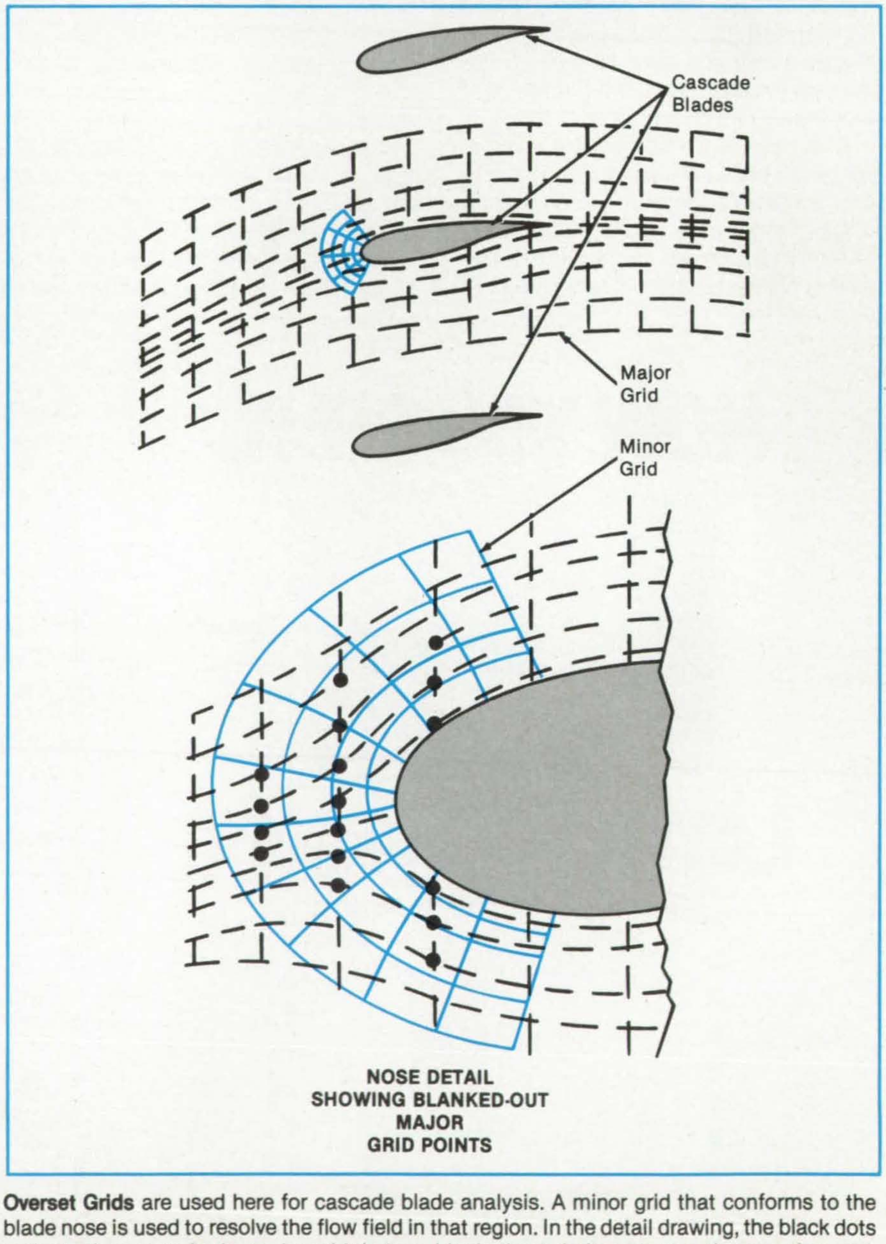
Multiple Grids in Finite-Difference Flow Analysis

Multiple solutions are superimposed to resolve flows about complex configurations.

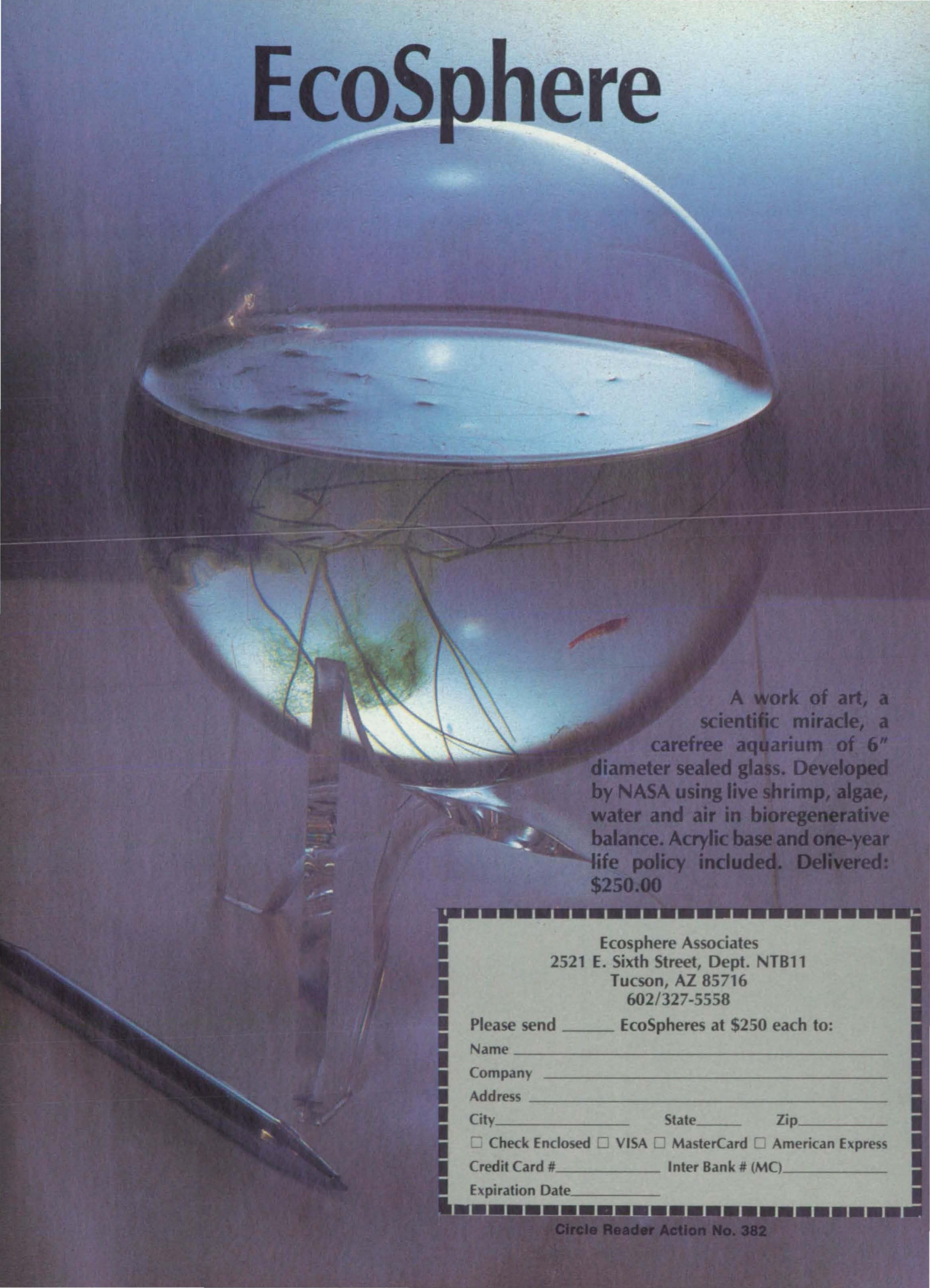
Ames Research Center, Moffett Field, California

The use of multiple, overset grids in computational fluid dynamics extends the application of finite-difference methods to more complex configurations. Rather than trying to generate a single mesh about all components of a configuration, multiple, individual meshes are used, then overset on a major grid. The major grid may be used to resolve the flow field or may be wrapped around the main component. One or more minor meshes may be used to resolve flows around appendages or near singularities in the main grid. The boundaries of the minor grids need not conform to the major grid in any particular way. Boundary data are transferred among the meshes each time step so that all meshes are aware of all components of the flow field.

Overset grids have been used previous-



Overset Grids are used here for cascade blade analysis. A minor grid that conforms to the blade nose is used to resolve the flow field in that region. In the detail drawing, the black dots indicate the points in the major grid that are blanked out during computations on that grid, which are then updated by interpolation from the minor grid.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ly for other types of flow problems, such as transonic flow about airfoils, using the potential equation and resolution of gradient regions in two-dimensional shallow water equations. This study applies overset grids to an existing class of implicit finite-difference algorithms for solving the stream-function equation and the Euler equations. These applications show that the technique can be handled within a general framework, that grid generation about complex configurations can be simplified, and that only minor modifications to existing flow solvers are necessary when combined with this grid approach.

The cases studied were all two-dimensional aerodynamic applications. In the case shown in the figure, a rectangular major grid fits well along a cascade blade element everywhere except at the blunt nose region. A minor grid is wrapped about the nose to resolve the flow suction peak. Flow variables at the boundaries of the minor grid are interpolated from the major grid. The dot-marked points in the major grid near the nose are blanked; that is, omitted from the computations. Instead, the flow values at the major grid points at the perimeter of the blanked area are found by interpolating results from the minor grid.

To use the overset grids, the finite-difference algorithms must be altered in three ways. First, the data base must be structured for a number of grids, rather than for just one. This can be done in various ways, depending on the architecture of the computer used. Second, the algorithm must skip blanked points. In approximate factorization algorithms and other time-like algorithms, blanked points are excluded by multiplying by a flag array that contains a 0 or 1 for each grid point, indicating exclusion or inclusion, respectively. Third, the boundary conditions must be recoded in a modular fashion to allow for the possibility that a minor grid may require a boundary-condition treatment different from that of the major grid.

Grid boundary data have been interpolated from one grid to the other with second-order Taylor-series approximations. This simple technique does not maintain conservation of mass, energy, or momentum; for example, while the flow equations may be differenced in divergence form, the divergence property is not numerically preserved if some of the values are obtained by interpolation. This could be a problem if a jump discontinuity, such as a shock wave, were to cross the interpolation boundary. In that case, the interpolated values could be adjusted to satisfy a numerical line integral of flux.

This work was done by F. Carroll Dougherty of **Ames Research Center**, *Joseph L. Steger of Stanford University and John A. Benek of Calspan Corp. For further information, Circle 138 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center, [see page 27]. Refer to ARC-11491.

"Noiseless" Data-Compression Algorithm

Gamma-ray spectrometer data are compressed to enable more frequent sampling.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed data-compression algorithm will efficiently represent gamma-ray spectrometer spectra at any spectrum collection interval from 5 seconds to 5 minutes. The data representation is "noiseless" (data can be exactly reconstructed). Depending on the spectrum interval, compression factors of from 2.5:1 to 20:1 compared to a standard spectrum representation were demonstrated (see figure). The techniques would be useful in designing data-compression algorithms for other spectral instruments, which have varying data-rate requirements.

For the gamma-ray case, the raw spectra are 8,192-bin histograms in which the expected number of counts per bin decreases by a factor of 1,000 in going from the low to the high energy end of the distribution. Additionally, varying the collection interval could change the expected number of counts in all the bins by as much as a factor of 60.

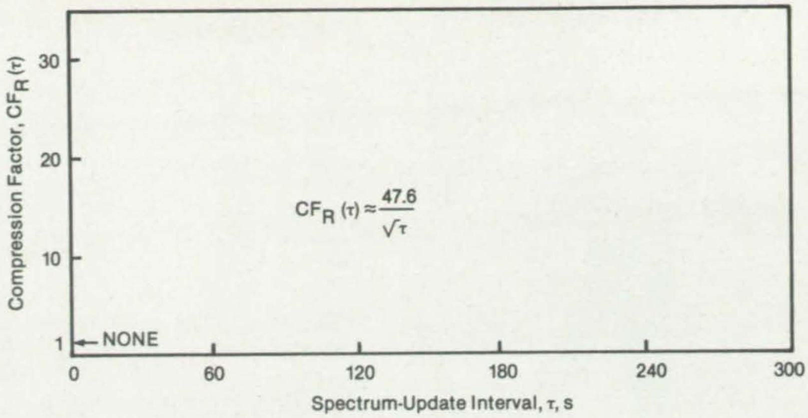
The proposed approach applies adaptive variable-length coding techniques to large blocks of energy bins. The algorithms automatically adapt to changes in block statistics resulting from the position in the overall spectrum or changes in the collection interval. Only the general shape of the spectrum is needed as a priori knowledge. Test results demonstrated performance close to a theoretic minimum for a coder that incorporated separate coders for each energy bin (optimally designed from known Poisson distributions).

Under one set of assumed conditions, the transmission of a spectrum every 30 seconds would require 2,500 bits/s, using the standard representation, whereas the compression algorithm would enable the transmission of a spectrum every 10 seconds, using only 500 bits/s. The compression factor representing the shortening of the sampling interval is plotted in the figure as a function of the data rate.

An experimental encoder using this scheme was built with an 8086 microprocessor, 1 Kbyte of memory for instructions, and 1 Kbyte of memory for internal buffers. The associated decoder was only about half as complex. The throughput capability of this system was about 20 Kbits/s.

This work was done by Robert F. Rice and Jun-Ji Lee of Caltech for **NASA's Jet Propulsion Laboratory.** *Further information may be found in NASA CR-176201 [N85-35219/NSP], "Noiseless Coding for the Gamma-Ray Spectrometer."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.
NPO-16712



The **Data-Compression Factor** achievable with one version of the proposed data-compression algorithm decreases asymptotically with the spectrum-update interval.

Life Sciences

Hardware, Techniques, and Processes

Books & Reports

Photoelectronic Monitor of Motion Sickness

An instrument measures the drop in skin infrared reflectance accompanying nausea.

Lyndon B. Johnson Space Center, Houston, Texas

The nausea that accompanies human motion sickness is monitored by an instrument that records the reflectance of the skin at a wavelength of 940 nm. Pale skin, a cardinal symptom of motion sickness, is probably caused by a decrease in the volume of blood in the microcirculation system of the skin, although the mechanisms that trigger it are not yet understood.

The instrument includes a gallium arsenide light-emitting diode (LED) and a silicon phototransistor with an infrared filter, all cast in a single plastic housing. The housing is attached to the subject's face with transparent double-sided adhesive tape. The LED directs pulses of infrared light to the skin, which reflects them to the phototransistor. The phototransistor produces a signal that is processed by external circuits to yield a plot of infrared reflectance with time. The external circuits are temperature-compensated and respond only to the pulsed component of the detector output, rejecting those components caused by stray light. The circuits also extract the blood-volume pulse amplitude and the heart rate.

The amplitude of the LED pulses can be adjusted so that the light reflected to the detector can be standardized; the instrument therefore works equally well on dark-skinned and light-skinned people. The LED power is low enough to have a negligible skin-heating effect.

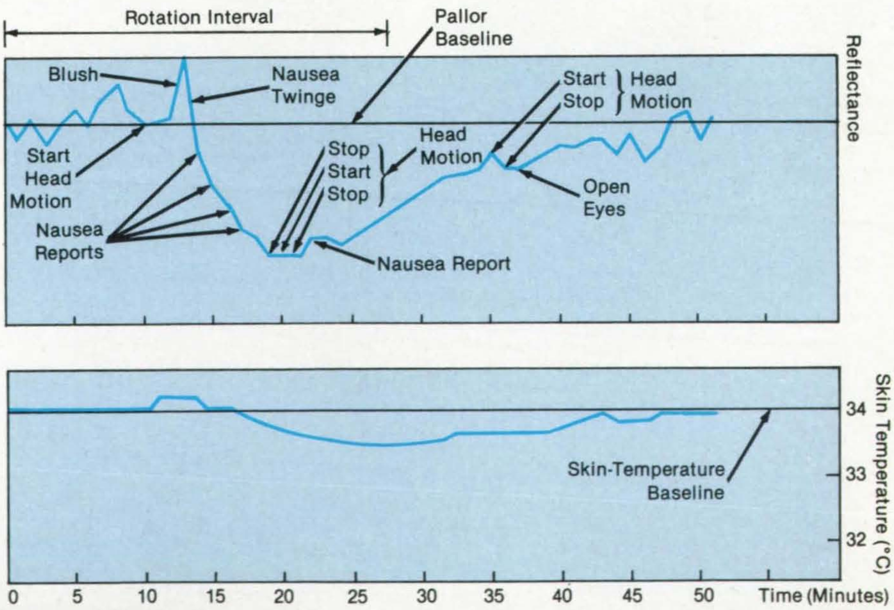
Tests of the instrument were made on subjects who were asked to make head movements while seated in a rotating chair or while wearing left/right vision reversal goggles. The onset and remission of pallor and extent of pallor, as measured by the instrument, correlate well with reports of nausea by the subjects and with changes in skin temperature (see figure) measured elsewhere on the face.

This work was done by Charles M. Oman and Walter J. C. Cook of the Massachusetts Institute of Technology for **Johnson 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:

Room E19-722
MIT
77 Massachusetts Ave.
Cambridge, MA 02139

Refer to MSC-20794, volume and number of this NASA Tech Briefs issue, and the page number.



This **Recording of Pallor** for a test subject also shows periods of head movement and reports of nausea. The peak of the curve indicates a transient blush that precedes nausea in some subjects. The label "rotation" indicates the period during which the seated subject was spun at 54 degrees per second.

Books and Reports

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

Collection of Human Wastes on Long Missions

A report evaluates and compares three alternative approaches to hygienic containment of human wastes.

A report presents a study of methods for the collection of human wastes. The findings of the study, which was done for the Space Shuttle and space stations, are potentially useful in airplanes, buses, boats, trains, and campers and in temporary toilets for construction sites and outdoor gatherings.

The primary requirements for acceptable waste collection on long missions are effective and hygienic separation of the waste from crewmembers and storage in a safe, odorless form in a place separated from the crew compartment. The waste-collection equipment should retain waste and paper for at least 210 person-days. It should be quickly and easily replaceable in flight and disposable on the ground.

The study identified three practical means of waste collection: (1) filter-bag collection with compaction by fan suction, (2) canister collection with compaction by force applied to compaction cups or disks, and (3) sleeve collection with compaction by rollers and winding on a reel. The report notes that canister collection and compaction are more acceptable to crews than bag collection and compaction and are more reliable than sleeve compaction. Canister collection therefore is preferable.

The study was conducted on the premise that waste-collection methods used successfully on the Space Shuttle should be retained. These methods have employed the following:

- Sanitation and odor control by containment, seals, inward airflow, and filters; and
- Mechanical waste separation from the crewmember by crewmember positioning, seat, air jets, slide valve, transport tube, and airflow.

For long missions on a space station, nonventing treament by microwave drying, thermoelectric refrigeration, and biodegradation were found to be acceptable.

This work was done by David C. Jennings, Tod A. Lewis, and Harlan F. Brose of United Technologies Corp. for **Johnson Space Center.** *Further information may be found in NASA CR-171836 [N85-17552/NSP], "Waste Collection Sub-system Study"[$13]. A copy may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Johnson Space Center [see page 27]. Refer to MSC-20968.

Subject Index

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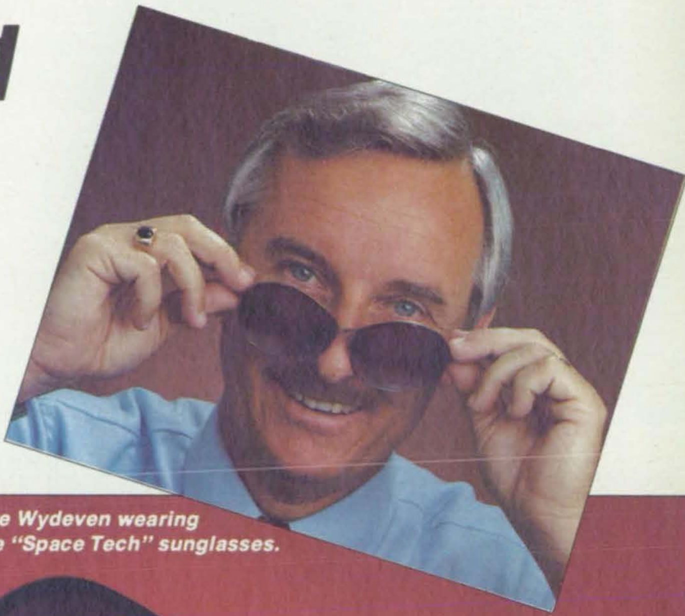
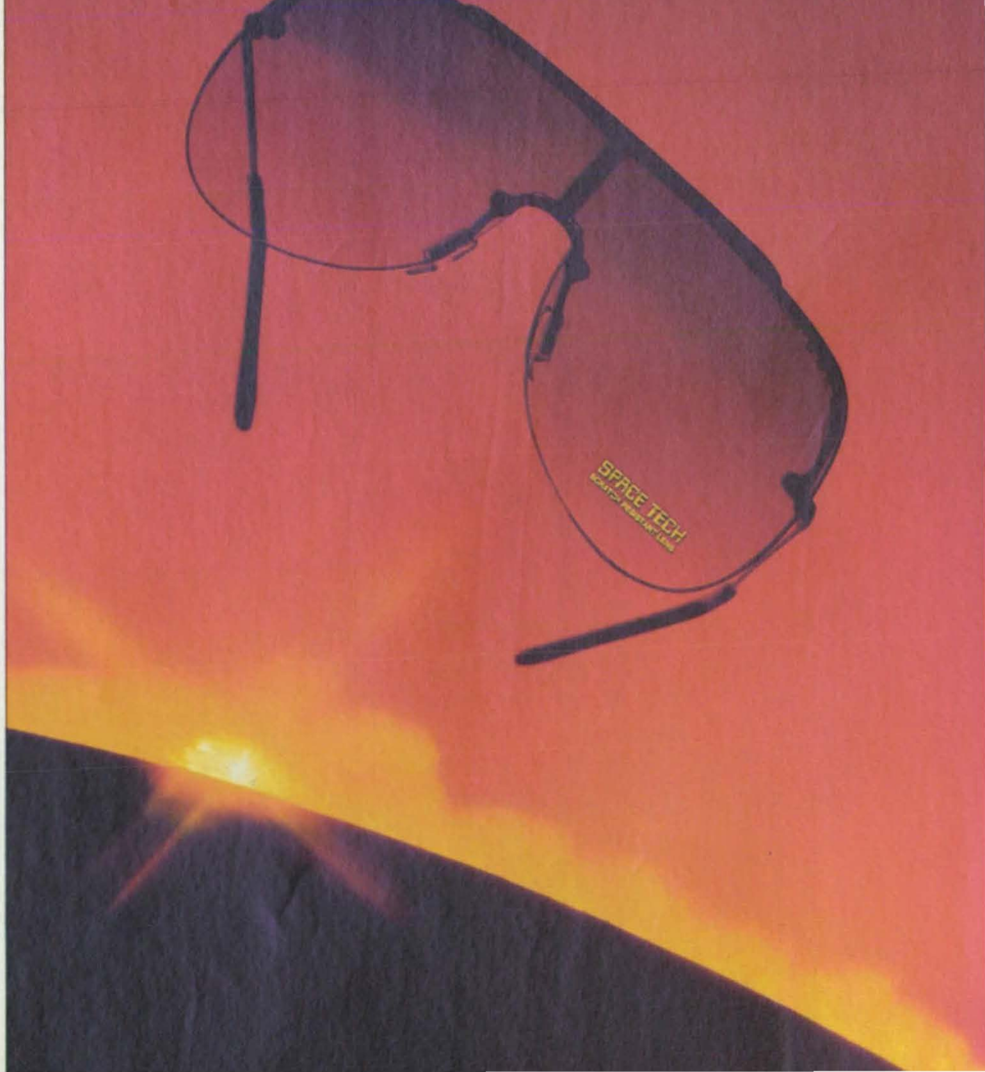
Mission Accomplished

Through the technology transfer process, many of the systems, methods and products pioneered by NASA are re-applied in the private sector, obviating duplicate research and making a broad range of new products and services available to the public.



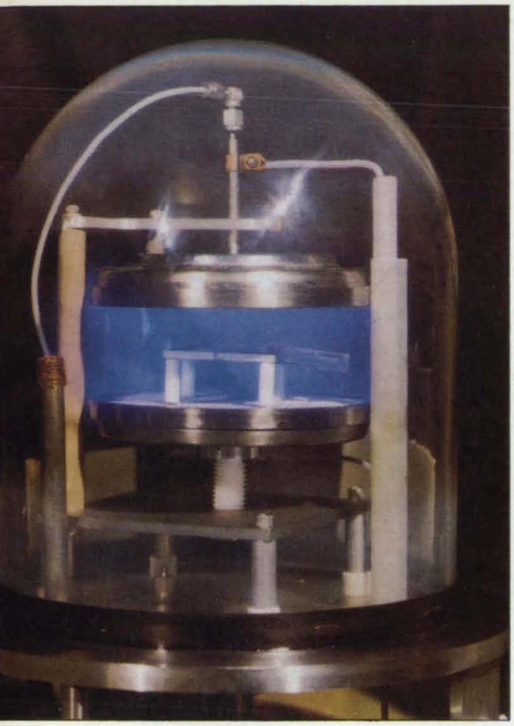
Dr. Theodore Wydeven wearing a pair of the "Space Tech" sunglasses.



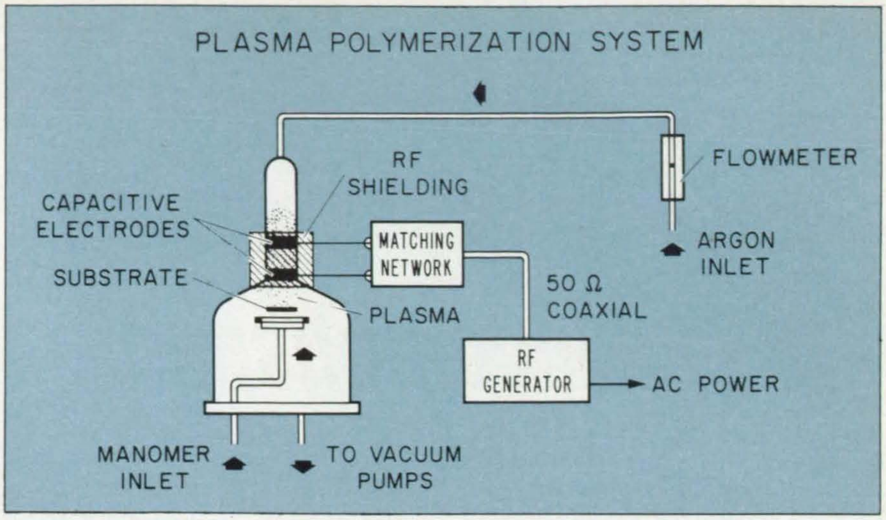
The NASA Ames research scientist peering over his new Foster Grant sunglasses, Dr. Ted Wydeven, developed a chemical process that significantly improves sunglass lens technology. A greater degree of lens hardness and, consequently, greater scratch resistance is achieved by depositing a thin plastic coating on a dissimilar plastic sheet. Under normal wear conditions, the new scratch-resistant lenses last ten times longer than the most widely used plastic optical lenses. The moderately priced sunglasses are sold under the trade name "Space Tech."

While improving a spacecraft water purification system, the physical chemist at the Ames Research Center discovered the key elements for this new technology. To modify the thin, semipermeable membranes used in the purification process, a porous filter was coated with a thin plastic semipermeable film using an electric discharge of an organic vapor. Later, an abrasion-resistant coating and process for polycarbonate visors was developed for NASA space helmet visors. Increased surface hardness, or scratch resistance, results from a process in which organosilane compounds are plasma polymerized and then treated for a short time with an oxygen glow discharge. More than five million pairs of sunglasses have been coated using this process since 1983.

Although ground and polished tempered glass has traditionally been the preferred lens in the eyeglass industry, polarized and other plastic lenses have made important inroads in recent years due to their lower manufacturing costs, excellent optics, and better absorption of ultraviolet radiation. In addition, they are lightweight, resistant to shattering, and easier to shape. Susceptibil- ►



Plasma polymerization apparatus showing the deposition of an anti-reflection coating on a plastic lens. The vapor being used is Perfluorobutane - 2.



A typical plasma polymerization system used to deposit an organosilane on a plastic substrate.

ity to scratching and subsequent reduction of visibility have been the major limitations of plastic lenses. The coating process, made available through NASA licensing, substantially corrects these deficiencies.

Foster Grant Corporation, one of the world's largest manufacturers of nonprescription sunglasses, obtained a license from NASA to use the process in 1983. Since then, the resulting products have improved the company's sales by over $75 million. The new process, known as plasma or glow discharge polymerization, holds the NASA record for the most units made and sold under a NASA license and is second in highest royalties to NASA. □

Letters

The "Letters" column is designed to encourage a wide exchange of ideas among *NASA Tech Briefs* readers. To contribute a request for information or to respond to such a request, use the feedback cards in this issue, or write or call: Manager/Technology Transfer Division, P.O. Box 8757, Baltimore/Washington International Airport, MD 21240; (301) 859-5300. While we can print only a small number of letters, we will endeavor to select those that are of varied and wide interest.

IT'S OUR PLEASURE

Thank you and your staff for the Technical Support Packages on Foamed Materials and Water-Jet Coal Evacuation.

As usual you have been very prompt in your response to my request for information. The format of the documents I receive from you is informative and concise, which helps me considerably.

I know that your objective is to assist in the development of products and processes that will stimulate the creation of jobs and strengthening of the economic base of this country. I praise you for your efforts in this respect. If we are able to maintain our industrial position in the world, it will be through the development and dissemination of technology. Your efforts will play a great part in achieving that goal.

The information I have received has been a catalyst to me and my associates in our thinking, evaluations and problem solving efforts.

I am a firm believer in the Gestalt method of analysis, and your services have helped greatly in collecting information necessary to that process.

Again, I wish to say thanks to you and your staff. Your efforts and the efforts of others in the information dissemination process are, in my opinion, the mainstay of our nation's future.

Raymond D. James, Jr.
Architect
Ray James
Architect and Associates, Inc.
Ada, OK

We wish to extend our sincere thanks to NASA Tech Briefs for publishing our Multiple Output Sequencing Controller article (NTB, Mission Accomplished, Volume 10, Number 5). NASA Tech Briefs serves as a superb catalyst for enhancing the transfer of information in the world of high tech. The mere fact that NASA Tech Briefs published a non-NASA contractor's design paper (an improvement over one of NASA's original circuits) shows that your periodical is unbiased, willing to show all facets of an idea, and truly devoted to aiding the engineering world in attaining its goals. All of these characteristics, combined with a flair for introducing the "human element," lead to a more interesting and readable source of information.

Once again—Thanks!!

Joseph D. King
John A. Carvalho
RCA Automated Systems Division
Burlington, MA

[Editor's note: Mission Accomplished highlights successful transfers of NASA technology to non-NASA use. Actual Tech Briefs are developed exclusively by NASA or its contractors.]

WE AGREE

It would be nice if you would publish more frequently, budget withstanding.

David J. Bassett
Software Engineer
Source Two Incorporated
Palmer, MA

[NTB will be published 10 times a year, starting in 1987. July/August and November/December will be combined issues.]

ABOUT THE NASA TECHNOLOGY UTILIZATION PROGRAM

Thumb Index

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- Subject Index

This document was prepared under the sponsorship of the National Aeronautics and Space Administration. NASA Tech Briefs is published bi-monthly and is free to engineers in U.S. industry and to other domestic technology transfer agents. It is both a current-awareness medium and a problem-solving tool. Potential products...industrial processes...basic and applied research...shop and lab techniques...computer software...new sources of technical data...concepts...can be found here. The short section on New Product Ideas highlights a few of the potential new products contained in this issue. The remainder of the volume is organized by technical category to help you quickly review new developments in your areas of interest. Finally, a subject index makes each issue a convenient reference file.

Further information on innovations—Although some new technology announcements are complete in themselves, most are backed up by Technical Support Packages (TSP's). TSP's are available without charge and may be ordered by simply completing a TSP Request Card, found at the back of this volume. Further information on some innovations is available for a nominal fee from other sources, as indicated. In addition, Technology Utilization Officers at NASA Field Centers will often be able to lend necessary guidance and assistance.

Patent Licenses—Patents have been issued to NASA on some of the inventions described, and patent applications have been submitted on others. Each announcement indicates patent status and availability of patent licenses if applicable.

Other Technology Utilization Services—To assist engineers, industrial researchers, business executives, Government officials, and other potential users in applying space technology to their problems, NASA sponsors Industrial Applications Centers. Their services are described on pages 26-27. In addition, an extensive library of computer programs is available through COSMIC, the Technology Utilization Program's outlet for NASA-developed software. See special section on computer programs on page 60.

Applications Program—NASA conducts applications engineering projects to help solve public-sector problems in such areas as safety, health, transportation, and environmental protection. Two applications teams, staffed by professionals from a variety of disciplines, assist in this effort by working with Federal agencies and health organizations to identify critical problems amenable to solution by the application of existing NASA technology.

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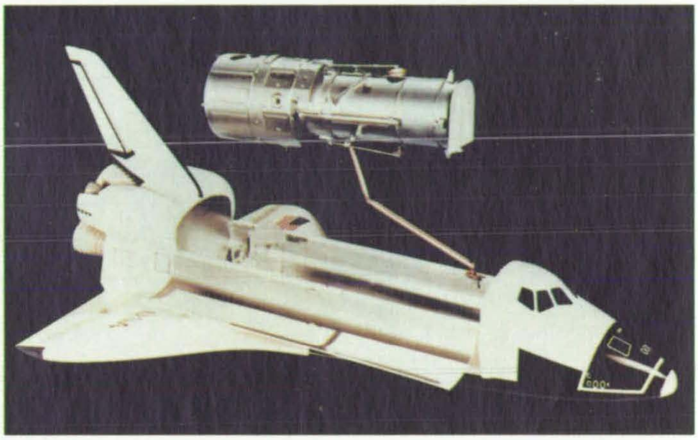
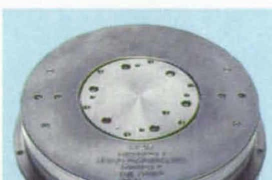


BEI's LED-equipped optical encoders help position the space shuttle arm and provide guide star position data on NASA's Hubble Space Telescope.

This totally integrated motor-encoder system for the Hubble Space Telescope provides resolution and accuracy to 21 bits.



The space shuttle's remote manipulator arm uses high-reliability BEI encoders.

BEI's two-axis pedestal with integral motor-encoders.

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