NASA Tech Briefs

National Aeronautics and Space Administration

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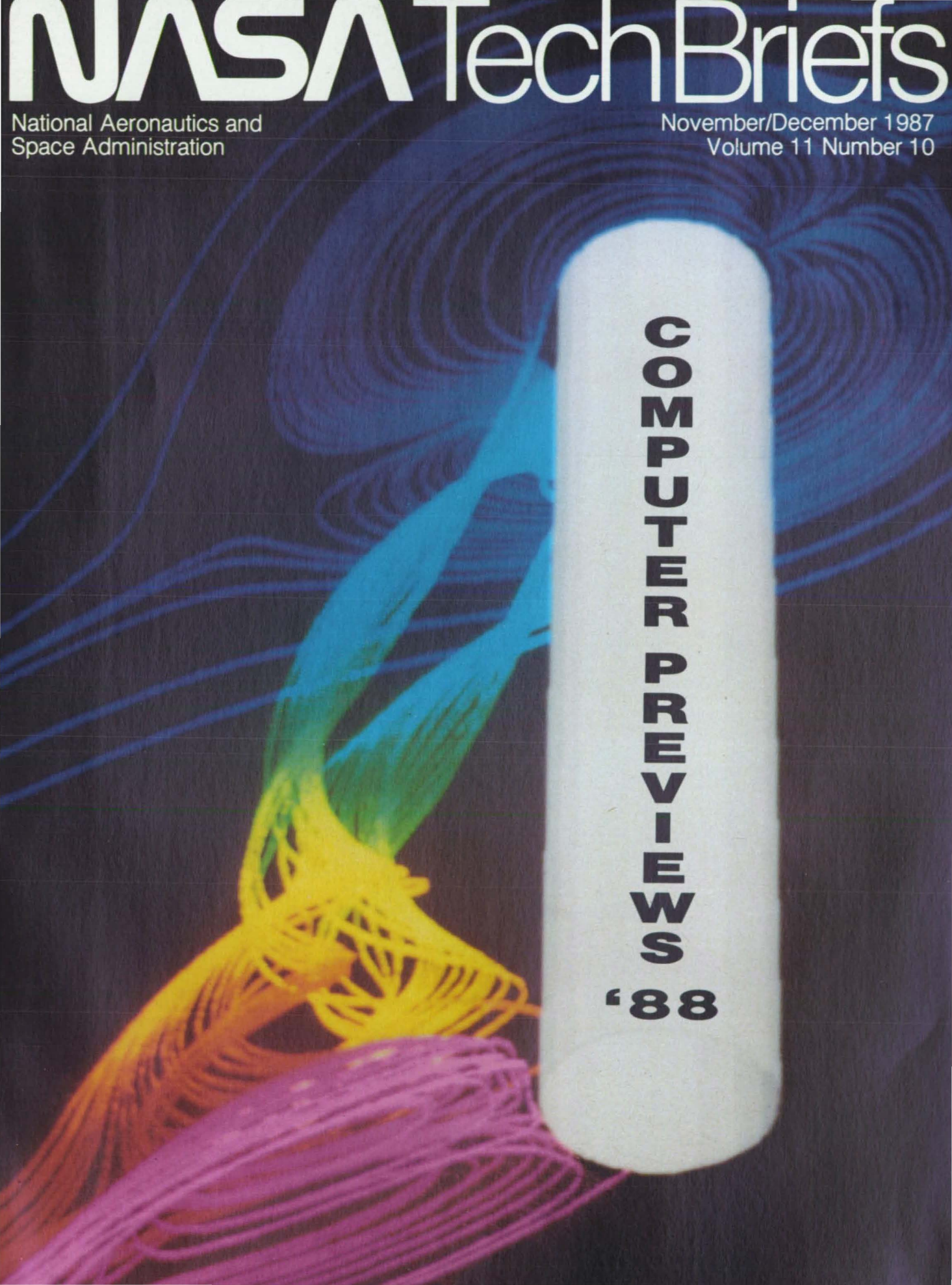
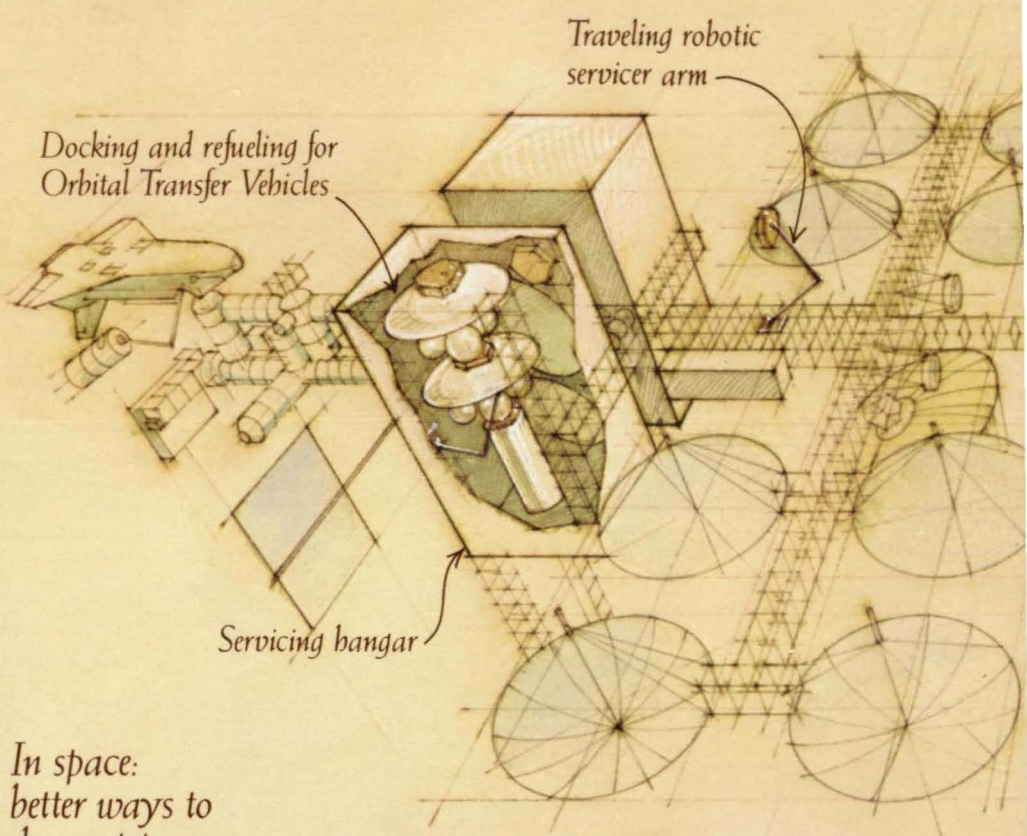
Volume 11 Number 10



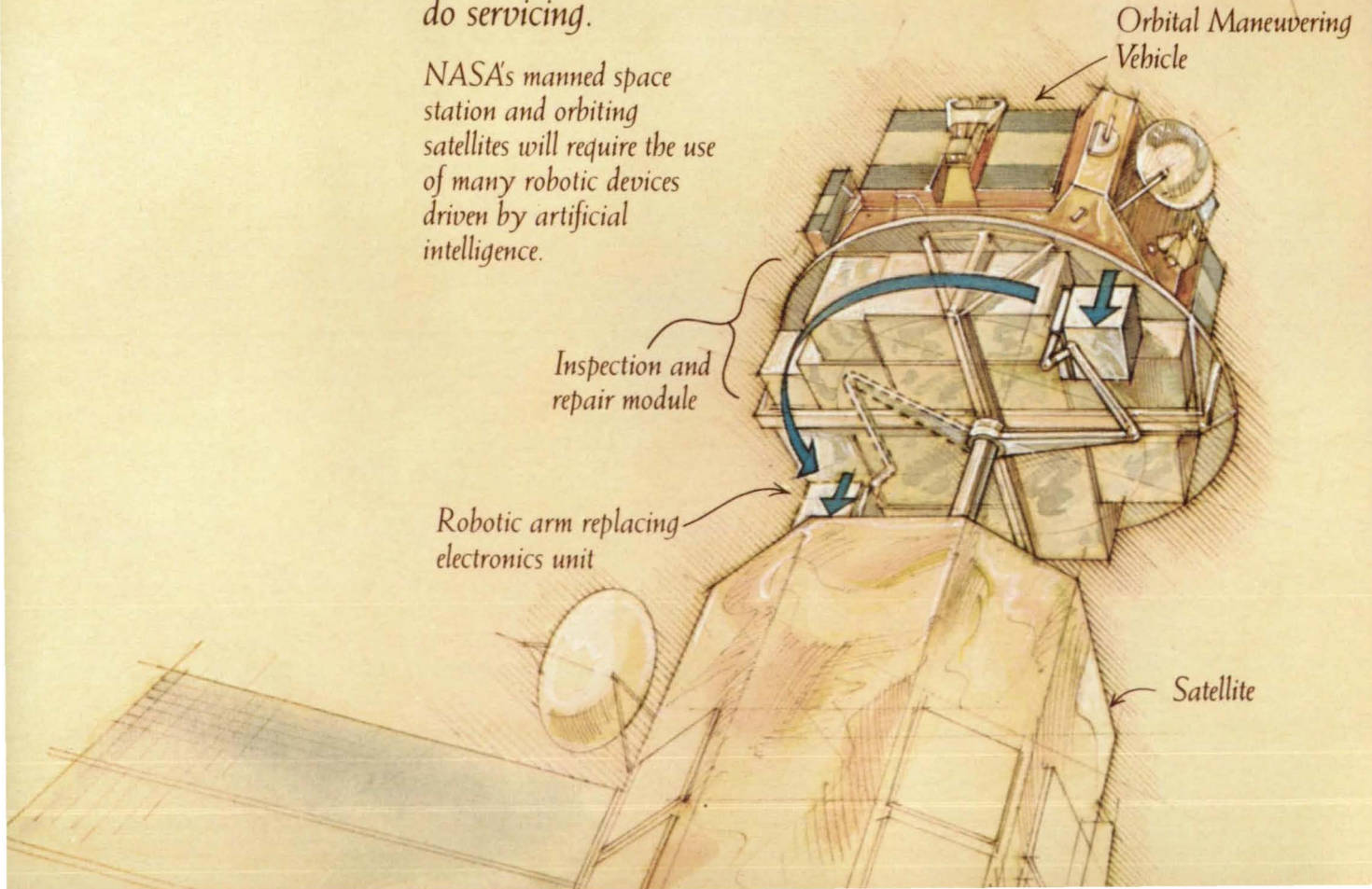
Artificial intelligence and robotics: giving machines the ability to sense, reason and act.

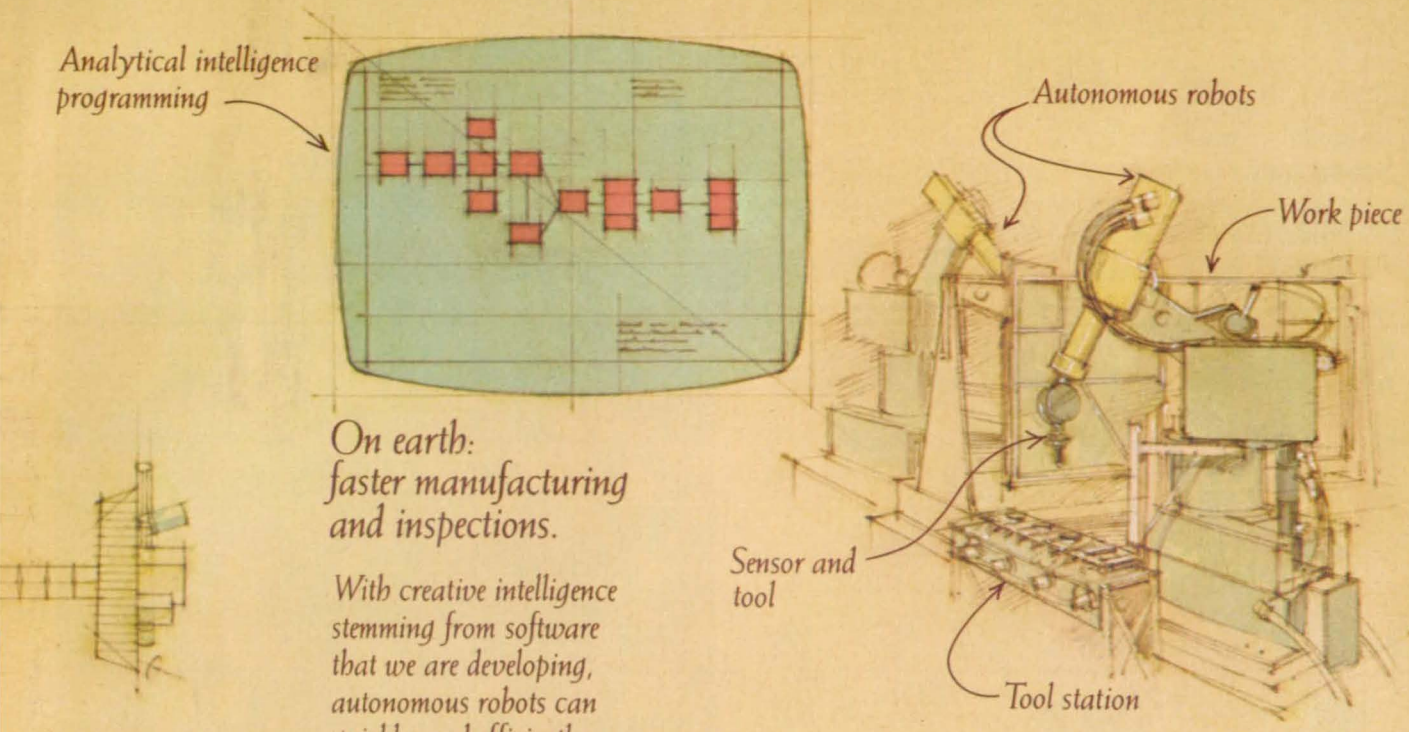
Much as it may hurt to think so, many things might be done better by independently functioning machines than by humans. Certain tasks may require superhuman precision or speed, or need to be done where humans can't go. Martin Marietta is creating systems that combine the ability to sense, reason and 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.

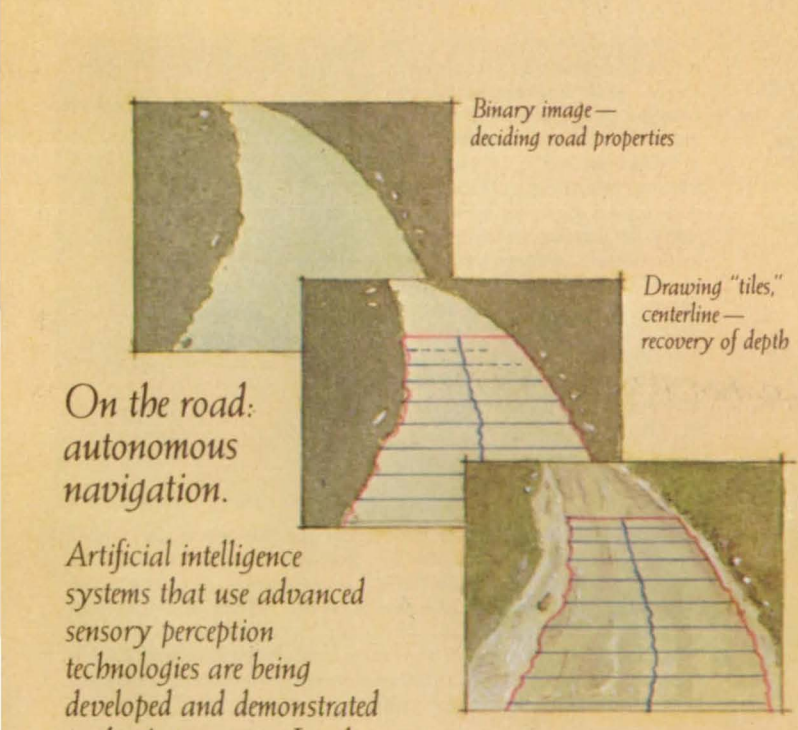
NASA's manned space station and orbiting satellites will require the use of many robotic devices driven by artificial intelligence.





On earth: faster manufacturing and inspections.

With creative intelligence stemming from software that we are developing, autonomous robots can quickly and efficiently perform batch manufacturing and precision inspections, even choose their own tools.



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.

Masterminding tomorrow's technologies

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NASA Tech Briefs
National Aeronautics and Space Administration

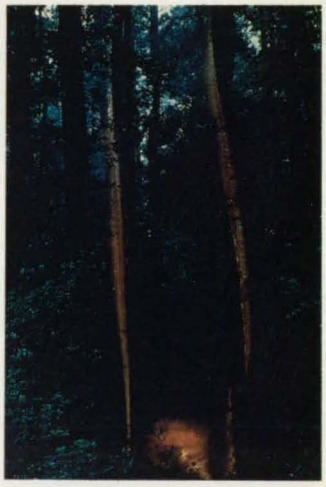
NOVEMBER/DECEMBER 1987
Volume 11 Number 10

ABP BPA

SPECIAL FEATURES

TECHNICAL SECTION

This month's Mission Accomplished describes a NASA-originated programming language designed to ease scheduling and resource management problems. In one of many aerospace applications, NASA's Goddard Space Flight Center uses the PC-based language for management of the Tracking and Data Relay Satellite (pictured above), an orbiting communications satellite. See page 101.



Explosives simulate a lightning strike on a pine tree. Research at Texas A&M University on the relation of lightning strikes and outbreaks of bark beetles led to a forecasting system that defines the distribution, abundance and location of infestations. An Intelligent Geographic Information System uses rule-based reasoning to interpret within and among landscape data themes. Researchers use the CLIPS expert system development tool for rule-base management. ***(Photo courtesy Dr. Robert N. Coulson)***

ON THE COVER—NASA's Numerical Aerodynamic Simulator (NAS), at Ames Research Center displays incompressible flow over a cylinder. The simulation is a simplification of the gaseous hydrogen flow around the posts in the space shuttle main engine. To the right of the cylinder is a tornado-like vortex wake. The most powerful supercomputing system in the world, NAS is used for research in computational chemistry, weather modeling and computational astrophysics.

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The Clinical Spectrum

The Clinical Spectrum

Medical diagnoses sometimes depend on the ability to trace or detect minute amounts of biological species. Now researchers at the General Motors Research Laboratories have developed a method of spectrometry using a tunable diode laser that could lead to simpler, less costly, non-invasive diagnostic techniques.

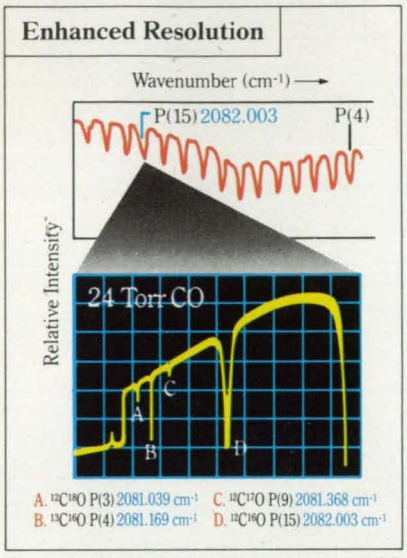
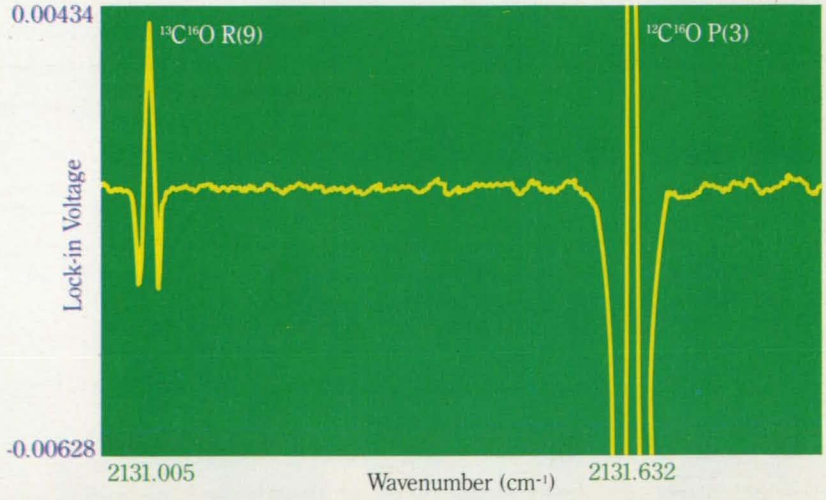


Figure 1: (Top) The absorption spectrum of CO obtained with a conventional spectrometer showing the P series rotation-vibration transitions separated by about 4 cm⁻¹. (Bottom) The diode laser spectrum centered at $^{12}C^{16}O$ P(15) region showing the complete resolution of $^{12}C^{17}O$ P(9), $^{12}C^{18}O$ P(3) and $^{13}C^{16}O$ P(4) transitions.

Figure 2: The second harmonic detection of the $^{13}C^{16}O$ and $^{12}C^{16}O$ as naturally present in exhaled human breath.



Carbon monoxide in exhaled human breath.
The scale has been expanded to show the excellent signal-to-noise ratio for $^{13}C^{16}O$. Other than removal of water vapor, no specific sample preparation or separation was needed.

In the process of living and growing, the body routinely takes in chemicals in the air we breathe and the food we eat, uses them, and converts them into other chemicals. These chemical activities, therefore, are often very good indicators of the health of the body or of its individual systems. The detection and measurement of particular chemical species is also of value in environmental, scientific and engineering studies.

Radioactive isotopes of elements in these chemicals have been extensively used as tracers. Many investigations, however, preclude their use either because no suitable radioisotope is available, or because radiation exposure raises health or environmental concerns.

The use of stable, non-radioactive isotopes for detection and tracing predates that of radioisotopes. But routine application of stable isotopes has been hindered by the lack of a detection method as versatile and simple as the scintillation counting used for radioisotopes. Mass spectrometry is the traditional method of detection of stable isotopes, but it requires extensive sample preparation, expensive equipment, and a highly trained operator to distinguish and measure chemically different molecules of the same nominal mass—nitrogen gas $^{14}N^{14}N$ and carbon monoxide $^{12}C^{16}O$, for example.

It was this need for high resolution and greater versatility that prompted Dr. Peter S. Lee and Richard F. Majkowski to develop a system for stable isotopic tracer analysis based on the molecular absorption of infrared light. A tunable, single-mode diode laser, developed originally by the Physics Department of the General Motors Research Laboratories to measure automobile exhaust gases, was used as the IR emitting source in what has proved to be a remarkably sensitive spectrometer.

The infrared absorption spectrum of molecules normally consists of transitions between series of vibration-rotation energy levels. When an atom in a molecule is replaced by an isotope of the same element, there is a shift in the energy levels due to a change in mass. The resulting frequency shift in the transitions forms the basis of the laser spectroscopic analysis system.

In the case of carbon monoxide, for example, there are six possible forms of the molecule involving stable isotopes: $^{12}C^{16}O$, $^{12}C^{17}O$, $^{12}C^{18}O$, $^{13}C^{16}O$, $^{13}C^{17}O$, and $^{13}C^{18}O$. Consequently, there would be six sets of overlapping spectral lines. Within a region of 1 cm⁻¹, there can be lines from several isotopic molecules, with as little as 0.1 cm⁻¹ or

less between adjacent lines.

This adjacency presents no problem for a diode laser system. The spectral resolution (the laser linewidth) is typically better than 10^{-4} cm^{-1}, which is orders of magnitude less than the isotopic line spacings. Since the diode laser is tunable, it can be centered in a region where the absorption lines of several isotopic molecules can be scanned within a single longitudinal laser mode (Figure 1).

In the initial experimental system, the source of the monochromatic IR radiation was a diode laser, made out of a single crystal containing layers of doped lead telluride and a lead-europium-selenium-telluride alloy. The IR light was collimated through a cell containing the sample to be studied and then focused onto an IR detector.

The cell was designed to have two optical path lengths that can be varied so that isotopic molecules with vastly different abundances can be determined from the measurement of the incident and transmitted laser intensities. U.S. Patent 4,684,805 covers this spectroscopic detection system.

The laser system can be made extremely sensitive using wavelength modulation and harmonic detection. Figure 2 shows the detection of $^{13}C^{16}O$ in exhaled human breath, where $^{13}C^{16}O$ is naturally present at a typical level of 1 to 10 parts per 100 million.

The present system can be used to measure stable oxygen isotopes in biological and organic samples that can be converted into CO. However, the method is applicable to any sample that can be converted into a gas with a suitable IR absorption spectrum.

"The use of radioisotopes as tracers is already well established," says Dr. Lee. "The potential is just as great for stable isotopes if more versatile analytical methods are made readily accessible.

"Packaged as a simpler, relatively inexpensive instrument, a tunable laser IR system could be adapted to many clinical tests—for fat malabsorption, ileal dysfunction, small-intestine bacterial overgrowth, alcoholic cirrhosis and liver function, lung function, nutritional assessment, and diabetes, to name a few.

"Diabetes could be diagnosed from the lung exhalate of a subject who had been fed a stable isotopically tagged sugar sample. No taking blood, no long waits, no radiation health and safety concerns.

"Simpler isotopic tracer measurements could broaden the scope of tracer methodologies, could supplement some of the radioisotope studies now common, and could have significant economic implications."

THE MEN BEHIND THE WORK

Dr. Peter S. Lee (right) is a Senior Staff Research Scientist in the Biomedical Science Department at the General Motors Research Laboratories. He received his undergraduate degree in Chemistry from the National Taiwan University. Dr. Lee also holds a Ph.D. in Physical Chemistry from the University of Illinois at Urbana-Champaign. His current research interests at GMRL include the study of biosensors and laser spectroscopy along with his work in stable isotopes. Dr. Lee came to GM in 1977 from the University of Illinois Medical Center in Chicago.

Richard F. Majkowski was, at the time of the work described here, a Staff Research Scientist in the GMRL Physics Department. Both his B.S. and M.S. degrees are from the University of Detroit in Physics and Mathematics. His research interests have included emission spectroscopy, coherent optics, holography and laser spectroscopy. Dick joined General Motors Research Laboratories in 1955 and retired in September, 1987, to become a Professor of Physics at Lawrence Institute of Technology.

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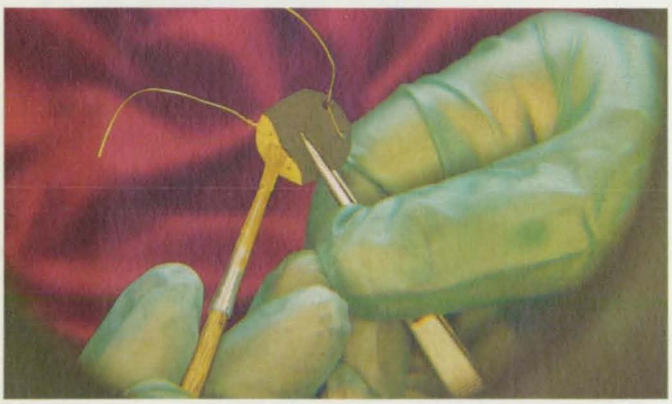

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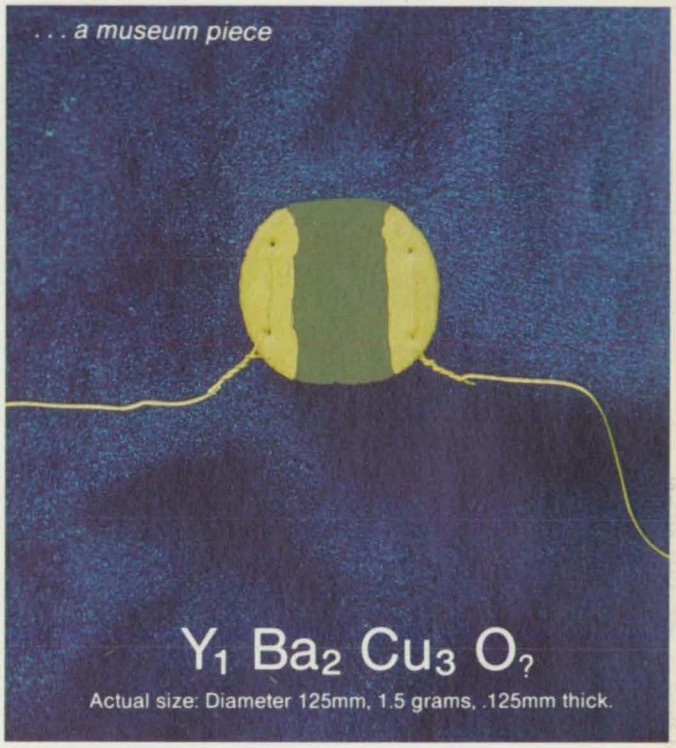

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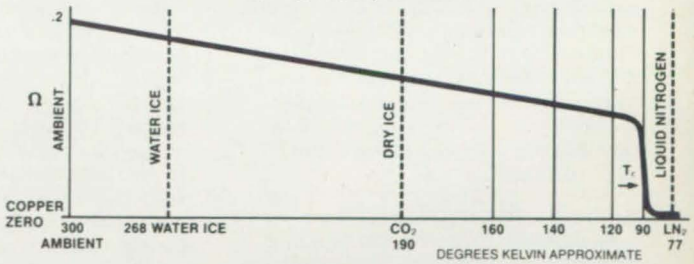

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Symbolics AI and advanced software development workstations start at just $36,000.

And $36,000 doesn't buy a stripped-down version of our most expensive machine. It gets you a general purpose workstation with full support of industry standards that's also the industry's most technologically advanced AI workstation. Our systems, complete with the Genera™ software environment, outshine the competition in four key areas: faster problem solving, ease of integration, advanced technology, and price performance.

FASTER PROBLEM SOLVING

With Symbolics systems, programs can be written from 5 to 50 times faster than on conventional workstations. This reduces costs by improving programmer productivity. And it decreases your time-to-market for new software products, giving you an edge on your competition.

More built-in facilities

Symbolics has over 40 times as many precoded Lisp functions as systems that offer just a Common Lisp compiler. By acting like prewritten "mini programs" these functions add speed and reliability. Your development time is shortened and programs are much more reliable because programmers can use pre-tested, built-in facilities such as user-interface programs and formatted output packages.

Automatic data-type checking

Symbolics systems solve data-type problems, not the programmer. The architecture of the system provides automatic run-time data-type checking with no performance penalty. Programmers spend their time making the application work; they don't waste time making the computer work.

Advanced debugging

Symbolics' advanced debugging facilities allow you first to examine the state of the run-time environment, and then choose either to abort the execution or modify intermediate results and continue. Also, unlike other systems, Symbolics' multi-processing environment allows you to use the editor and all other programming tools to determine the cause of an error, without throwing away the error context.

Fastest edit-compile-debug loop

To make a change to a program on conventional systems, the changed file must be written to disk, compiled, linked with other files, loaded, and then executed. To do this for every bug and change is very time consuming. With Symbolics, only the change is recompiled; linking and all other steps are eliminated. Where conventional systems might require hours to relink and reload hundreds of files for one change, it takes Symbolics only seconds.

Rapid prototyping

Built-in facilities, automatic data-type checking, advanced debugging, and fastest edit-compile-debug loop give Symbolics systems the best environment for prototyping applications. While others are still writing specifications, on a Symbolics system you can be showing a customer a demo or prototype application.

Smart garbage collection

Garbage collection is an essential attribute of all Lisp systems. Symbolics' advanced hardware and software provide it fast, and in parallel with other operations. Smart garbage collection means programmers need only manage applications, not memory. This increases programmer productivity and the runtime speed of applications because there's no need to slow down or stop to collect garbage. Some programs can even run faster with garbage collection turned on.

32-bit data *turbo charged*

The performance of garbage collection and data-type checking are improved by Symbolics' unique 36-bit design. Dedicated bits are used to reduce the size of data storage and to establish and check data-types. Simultaneously, Symbolics supports IEEE standard 32-bit floating point formats.

Faster program maintenance

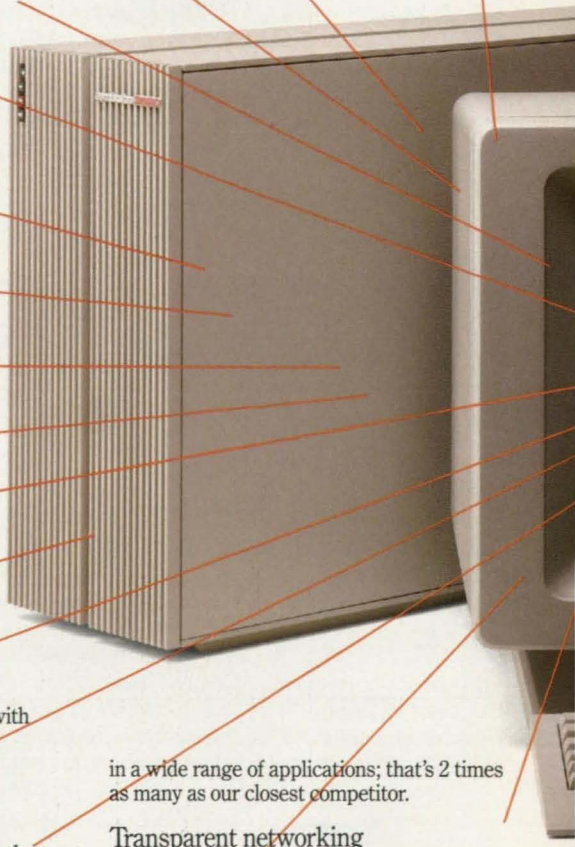
All of the above allow you to periodically update your software quickly, accurately, and incrementally, while consuming a minimum amount of programmer hours and investment dollars.

EASE OF INTEGRATION

No other AI system or workstation vendor offers the ease of integration into heterogeneous computer environments like Symbolics. If you own a multivendor network, the best AI workstation for you is a Symbolics.

Largest installed base for AI

Symbolics has over 3000 systems installed in a wide range of applications; that's 2 times as many as our closest competitor.



Transparent networking

Upwards of 90% of all Symbolics systems delivered to date are used in heterogeneous environments. That's because Symbolics is the only vendor that networks *transparently* to UNIX,™ Digital™ and IBM.® One simple command is all it takes to access information from those systems, because the Symbolics workstation is "intelligent" enough to initiate the proper protocols. Also, Symbolics supports

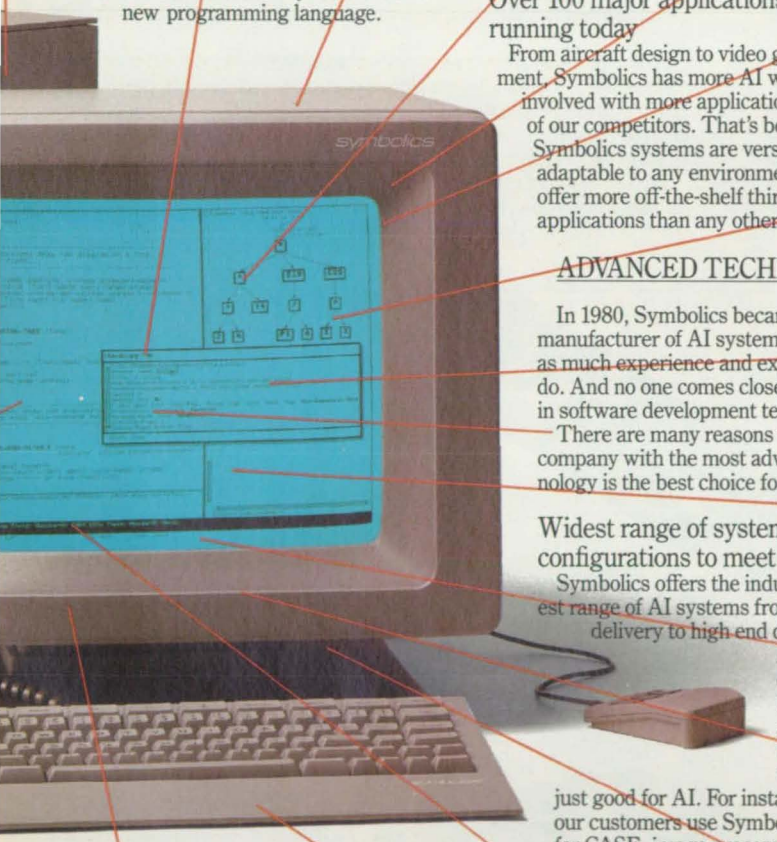
pect for $36,000?

Ethernet, TCP/IP, DECnet,™ and SNA standards to integrate AI into existing environments.

Comprehensive integration of standard computer languages

Symbolics offers full support of a range of industry standard languages. Using Symbolics workstations, software can be written in Common Lisp, Prolog, Fortran-77, Pascal and Ada.® No matter which language you use, you'll still be able to take advantage of Symbolics' built-in facilities, rapid prototyping and reduced maintenance features.

There's no need for anyone to learn a new programming language.



Current software investment protection

Your current software written in standard languages can still be used on a Symbolics system. And using Symbolics workstations, you'll be able to upgrade your software with AI functionality in Lisp or Prolog.

Best team-oriented software development

Symbolics systems allow programs or program updates to be distributed to all developers as they're written, continuously integrating the work of individual contributors.

Similar benefits apply where both users and developers of a program are working together in the same network environment. Users can choose a supported version, and developers can choose the latest experimental one.

Over 100 major applications running today

From aircraft design to video game development, Symbolics has more AI workstations involved with more applications than any of our competitors. That's because Symbolics systems are versatile, and adaptable to any environment. And we offer more off-the-shelf third party applications than any other AI vendor.

ADVANCED TECHNOLOGY

In 1980, Symbolics became the first manufacturer of AI systems. No one has as much experience and expertise as we do. And no one comes close to Symbolics in software development technology.

There are many reasons why the company with the most advanced technology is the best choice for you.

Widest range of system configurations to meet your needs

Symbolics offers the industry's broadest range of AI systems from low end delivery to high end development. And our technologically advanced workstations aren't just good for AI. For instance, many of our customers use Symbolics systems for CASE, image processing and database management. So you can buy Symbolics knowing there's a system that's right for your application.

Investment in R&D

Symbolics' investment in R&D is significantly larger than the industry average. That's why we're the industry leader in developing advanced technology. And why customers can depend on us to keep them on the leading edge with fully compatible systems.

Best training in the industry

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Excellent consulting services

Worried the most advanced AI technology might be too advanced for your needs? Symbolics consultants can implement a cost-effective system that makes sense for you today, while allowing for your company's increasing needs tomorrow. We can help get your system up-and- running fast, giving you any necessary help along the way.

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NASA's Space Station – An Update

By Mark Hess,
NASA Public Affairs Officer,
Office of Space Station

In just seven years, America's boldest project to date, NASA's Space Station, will gleam from the sky. A laboratory for scientific research and the development of new technologies, the Space Station will be a permanent observatory enabling us to look down on earth and up at the stars.

As this issue goes to press, contractors are vying for the four major work packages comprising the detailed design and development of Space Station systems and components.

Work package 1, managed by the Marshall Space Flight Center in Huntsville, AL, includes the laboratory, habitat and logistics modules and resource node structures. Johnson Space Station, in Houston, will manage work package 2. Johnson's work package will include the structural framework and station subsystem development. The third work package, managed by the Goddard Space Flight Center in Greenbelt, Md, includes the free-flying polar-orbiting platform and attachment points for externally-mounted instruments and payloads. Work package 4 will be managed by Lewis Research Center in Cleveland, Ohio. It consists of the Space Station's power system, which includes power generation, conditioning and storage, and management and distribution.

For the role of Program Support Contractor, NASA selected Grumman Corporation of Bethpage, NY. Grumman will assist the Program Office with systems engineering, analysis and integration activities, and will also support the NASA field offices.

NASA's Space Station concept includes both manned and unmanned elements. The manned base will be parked in earth orbit, about 250 miles high. The unmanned free-flying platform will be launched into a 495-mile-high polar orbit. As part of NASA's Earth Systems Science program, the platform's equipment will permit synergistic studies of the earth's atmosphere, land masses and oceans, helping us understand the global impact of changes to any one of the millions of factors influencing the environment.

The baseline configuration of the manned base consists of a horizontal truss nearly 445 feet across and 5 meters wide. Two identical house-trailer-sized modules will be attached to the truss. One a laboratory and the other a habitat, they'll have the same atmosphere as earth. Inside these modules, eight-person Space Station crews will live and work year-round, on shifts lasting up to six months. Five shuttle flights a year are planned to visit the station. They'll bring new experiments, raw materials for processing, spare parts and other supplies, and return finished products to the earth. Four nodes will connect the laboratory and habitation modules. The nodes will house many of the Space Station's utilities and subsystems. Eight solar cell arrays will provide 75,000 watts of electricity.

NASA estimates the Space Station will cost about $14.6 billion in 1987 dollars, spread out over 11 years. At its peak, the program will create 20,000 to 25,000 direct jobs around the country. If indirect employment is included, this figure would rise to about 50,000 to 60,000 jobs.

The Space Station has an international flavor to it as well. The 11-nation European Space Agency, Japan and Canada performed parallel design studies with NASA and identified elements they plan to contribute once negotiations on the management and use of the station have been signed by their respective governments.

Space Station personnel won't commute to work, but less than 10 years from now, they'll have the best scenery of all, and the most unique offices in or out of this world. □

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For a brochure or demonstration of the new Model 580 Micro-ohmmeter, call your local Keithley representative or the Product Information Center at the address below.

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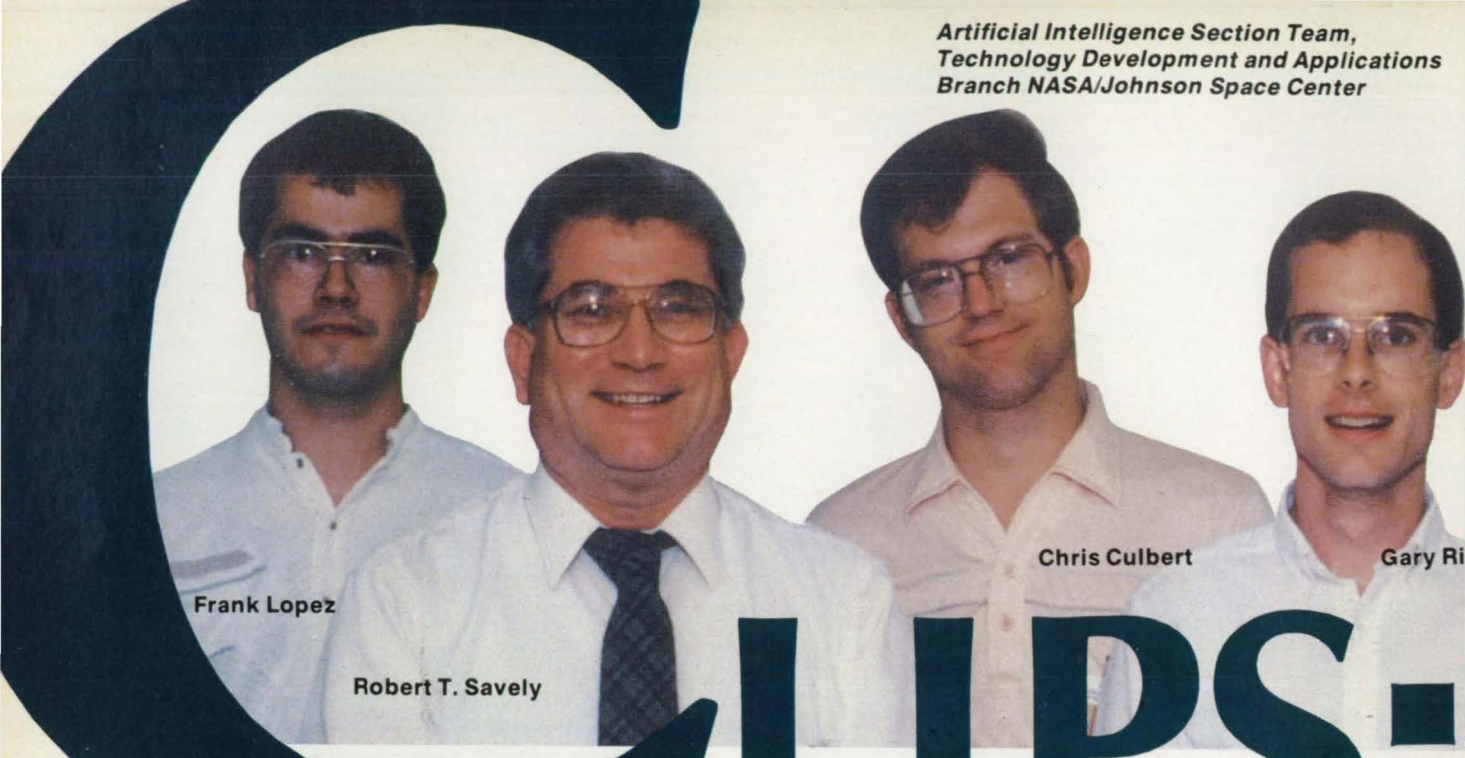

CLIPS:

Rain sluices down as the 747 holds at the runway. Passengers grumble impatiently. The holdup? Avoiding windshear. An alert from a computer-based expert system, "Airline Operations AI" evaluated current and past weather, runway length, aircraft weight, time of day and similar conditions at other airports, compared them to those stored in its memory, and gave the "no-go" recommendation. How did it come about? Another outgrowth of NASA technology.

NASA, in its long and short-term goals—which include, but are not limited to the Space Station, a manned lunar base and extended probes of the solar system—will rely to a great extent on the effective use of automation technologies, which call for increased availability of artificial intelligence and expert systems. To answer this need, the Artificial Intelligence Section (AIS) of the Mission Planning and Analysis Division at Johnson Space Center (JSC) developed CLIPS, the C Language Integrated Production System, a software tool to develop and deliver expert systems (see box). The prototype version of Airline Operations AI is based on CLIPS.

CLIPS incorporates a number of features required for general use on conventional computers. It requires only a small amount of memory, and can be easily ported to PCs. Unlike LISP, a computer language commonly used for expert system applications, CLIPS is written in the familiar C language. Distributed by NASA's COSMIC, the program costs only $200, compared to the $30,000 to $60,000 for commercial expert systems programs. CLIPS also includes numerous hooks to allow easy integration with other software, enhancing its portability. Rule-based expert systems developed on expensive, user friendly AI hardware systems can be converted to run in CLIPS, which is specifically designed to allow such easy conversion. Once in CLIPS format, the expert system can be easily embedded into any application hardware.

Applications

One of these applications may take place on NASA's space station, where a radio link to earth will transmit audio, video, operational and payload status reports 24 hours a day, at over 300 Megabits per second. To keep this communications system dependable, the Communication and Tracking Control and Monitoring Subsystem branch at JSC uses CLIPS to model an intelligent fault management system. One part of the system uses Travelling Wave Tubes to generate the radio signals. High voltages at the tubes' contact points are continuously monitored by the expert system. Should they vary past predefined limits, CLIPS will detect the impending failure, isolate it, and come up with a recommendation to resolve the problem.

Another JSC application uses CLIPS to prototype the TRACKEX program. This expert system helps the Space Shuttle mission planners schedule radar tracking stations to support Shuttle missions. During a mission, the Shuttle is continually tracked by both ground radar stations and the orbiting Tracking and Data Relay Satellite System (TDRSS). These radars provide ground controllers information about the Shuttle's position and velocity, for use in satellite rendezvous or launch activities. In addition to being expensive to operate, not all of the radars are needed all the time. Mission planners examine pre-flight information to optimally schedule the radars to provide adequate coverage at the lowest cost. With TRACKEX, this job was telescoped from two weeks down to two hours for each mission. Other expert systems at JSC under development using CLIPS include an expert system to train Mission Control Center flight controllers who monitor the onboard navigation systems in the Space Shuttle and an intelligent interface to the Macsyma problem solving tool, which derives the roots of complex mathematical equations. CLIPS allows for easy information input to the software.

CLIPS is also used at other NASA centers. To control teleoperated robots during space station construction projects, a group at Langley Research Center has designed an expert system that converts high level task commands such as "connect a strut to a node" into the 50 or 60

At Texas A&M University, CLIPS has helped develop a Weed Control Advisor program for rice producers. It will help farmers select the optimal herbicides for their rice fields. *Photo courtesy Dr. Robert N. Coulson*

Sharon Des Rosiers at the University of Arizona developed an expert system with CLIPS that diagnoses mulberry tree diseases. This photo shows the effect of the fungus* Hendersonula Toruloides*—a sooty canker eating into the tree. Photo courtesy Tom Kruk

A NASA Developed Expert System Tool

specialized menu commands required for even the most elementary of construction tasks. The expert system will also enhance manual control, overseeing inputs made by a human operator to prevent them from confusing or contorting the robot. Alternatively, an operator can override or assist the expert system as it guides a robot; the operator's joystick input will be smoothly meshed with the robot's instructions.

Another Langley application uses CLIPS in a program that integrates graphics, databases, and a rule base as part of a structural design system. The program will help select the best structure to support point loads in two dimensions. At Marshall Space Flight Center, an expert system that arranges mission manifests for Spacelab missions was developed in CLIPS. Goddard Space Flight Center researchers use CLIPS for ground support systems that perform fault isolation and diagnosis of TDRSS communication links. CLIPS has also been used at Goddard to develop an expert system that performs quality assurance and data integrity testing of data files from the Spacelab output system.

CLIPS has found acceptance outside of NASA as well. Texas A&M University uses CLIPS in several applications. One example is an expert system that helps rice farmers choose the proper herbicide to use on their rice fields. The system recommends a solution for the farmer by combining information about the various kinds of rice, the type of weeds common to south Texas, the maximum allowable dosages per acre, and previously used herbicides. It has been developed on an IBM PC AT with an interactive interface that allows non-computer users to easily consult the system. Another application at Texas A&M uses CLIPS as part of an Intelligent Geographic Information System which models pine bark beetle infestations in the southern United States. The University of Arizona also uses CLIPS in a number of applications, including an expert system to diagnose plant diseases and one to advise on irrigation scheduling that will interface directly with existing evaporation monitoring systems. Inference Corporation, a major expert system tool vendor, will be marketing

Expert Systems Defined

Expert systems are computer programs that emulate complex human expertise in well defined problem domains. General purpose intelligence of the kind humans routinely use has proven to be very difficult to understand and even harder to duplicate. However, specialized knowledge about a clearly defined problem is much simpler to model in a computer program. Usually a well understood, carefully bounded set of information is analyzed by an expert who uses "rules of thumb" or heuristics, gained through training or experience, in order to solve the problem. Software techniques for modeling this type of expertise in a computer program are well developed. Since certain characteristics of all problem solving methods are generic, they can be separated from the knowledge specific to the problem and used to create a tool for building expert systems. Expert system tools are designed to provide a base for storing specific information as well as a mechanism for applying the knowledge. The typical tool has many parts, including an inference engine, a user-interface and a structure for representing information.

Although they have reached a point of high commercial visibility, expert systems were originally developed in artificial intelligence (AI) research environments. Most of the available tools still work best in such environments. These environments typically utilize special hardware such as LISP machines and relatively unfamiliar languages (at least within science and engineering communities) such as LISP or Prolog. However, the vast majority of NASA applications require integration of an expert system with conventional software on conventional computers. This proved to be difficult with existing expert systems tools. Also, the cost of commercial tools and the specialized hardware needed to run them prohibited widespread use of the technology. To meet the goal of providing expert system technology to every NASA engineer, the Artificial Intelligence Section at JSC developed CLIPS.

CLIPS has helped schedule operation of NASA's worldwide space communications and tracking network, which includes this S-band antenna. *NASA Photo*

an enhanced version of CLIPS as part of their ART product line.

Training

The low cost and relative ease of use of CLIPS has made it an attractive language for teaching new users about expert system technology. The availability of the CLIPS source code and high portability allow universities and other organizations to quickly install CLIPS on both small computer systems and their multi-user machines, making widespread training possible. Texas A&M University and the University of Houston-Clear Lake both teach CLIPS in their expert system classes.

The program is also used by the Air Force Institute of Technology and the University of Arizona, for introduction and training in expert systems.

Expert systems hold great potential for improving the use of automation, not only for NASA programs, but for other government, academic, and industry applications as well. Despite its recent emergence from research environments, expert system technology is well understood and ready for applications. Through the use of tools like CLIPS, it can be made available in almost any computing environment for a wide range of applications. □

Appendix: *NASA, Dod, or other government agencies may obtain CLIPS by contacting the CLIPS Help Desk 9:00 AM to 4:00 PM CST weekdays at (713) 280-2233. CLIPS is available for nongovernmental use through COSMIC, whose address is given on page 20.*

About CLIPS Team Members:

Robert T. Savely, a NASA employee since 1963, heads the Artificial Intelligence Section at NASA/JSC. He obtained a B.S. in Math and Physics from the University of Nebraska in 1961. Savely has been presented with numerous NASA awards and received the Presidential Medal of Freedom as a member of the Apollo 13 operations team. He developed the AI lab at JSC and, in the past, has either designed or directed the design of the Shuttle Onboard Navigation System that contains several expert systems for failure detection, isolation, and reconfiguration. Motivated by the goal of placing expert system technology on every NASA computer, Savely conceived the original CLIPS concept.

Chris Culbert, a NASA employee since 1981, is a member of the Artificial Intelligence Section. He holds a B.S. in Aerospace Engineering from the University of Arizona (1981), and a M.S. in Physical Sciences from the University of Houston-Clear Lake (1986). Prior to joining the AIS, Mr. Culbert was a flight controller for Space Shuttle missions where he participated in 10 Shuttle flights. Since joining the AIS, Culbert has played a lead role in evaluation, transfer, and development of AI technology with special emphasis on expert system development and verification methodologies. He has also been responsible for coordinating CLIPS documentation and has developed utilities and interfaces for the program.

Gary Riley received his B.S. in Computer Science from Texas A&M University in December of 1984. Since graduation, he has worked in the Artificial Intelligence Section. His work includes the evaluation and transfer of AI technologies, the construction of several expert systems, and the development and maintenance of release versions of CLIPS.

Frank Lopez, a former co-operative education student, recently rejoined the Artificial Intelligence Section after receiving his B.S. in Computer Science from Purdue University in 1986 and his M.S. in Computer Science from the University of Illinois in 1987. While with the AIS in 1985, Lopez developed the initial version of CLIPS. □

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New Product Ideas

New Product Ideas are just a few of the many innovations described in this issue of *NASA Tech Briefs* and having promising commercial applications. Each is discussed further on the referenced page in the appropriate section in this issue. If you are interested in developing a product from these or other NASA innovations, you can receive further technical information by requesting the TSP referenced at the end of the full-length article or by writing the Technology Utilization Office of the sponsoring NASA center (see page 20). NASA's patent-licensing program to encourage commercial development is described on page 20.

Temperature-Controlling Circuit

A simple circuit switches the current to an electrical heater on and off to maintain the temperature of a room at 25 ± 0.5 °C. The circuit is lightweight, compact, reliable, insensitive to electrical noise, and uses a single 5-Vdc power supply. A thermistor provides the input signal for a simple temperature controller. The output of the controller is applied to a solid-state relay, which in turn switches the current to a resistance heater. (See page 28).

Thermosetting Fluoropolymer Foams

A new process makes fluoropolymer foams with controllable amounts of inert-gas fillings in the foams cells. The filling gas can be air, oxygen, nitrogen, or any of a variety of elements and compounds that do not react chemically with the mixture. Unlike foamed thermoplastic fluoropolymers, the thermosetting fluoropolymers do not require foaming additives that leave undesirable residues and need no molding and sintering at temperatures of 240 to 400 °C. (See page 54).

Dual-Energy X-Radiography With Gadolinium Filter

In a proposed dual-energy x-ray imaging system, the continuous bremsstrahlung spectrum from an x-ray tube would be filtered by a foil of nonradioactive gadolinium or another rare-earth metal to form a two-peaked energy spectrum. After passing through the patient or object under examination, the filtered radiation would be detected by an array of energy-discriminating, photon-counting detectors. The images formed at the two peaks reveal more than a single image. (See page 36).

Powered Lift for Paraplegics

A battery-operated lift is designed to aid paraplegics by raising or lowering them from or to a bed, toilet, or wheelchair, for example. The paraplegic controls the operation of the lift with a toggle switch and a joystick. When it is not in use, the lift can be plugged into a household electrical outlet for recharging. (See page 88).

Interface for Color-Video Monitor

A commercially produced color-video monitor is modified by the addition of an interface circuit to accommodate a wider-than-usual range of scanning rates and resolutions. The monitor displays a properly adjusted picture, as long as the input video signal conforms to one of several industry standards. The interface adapts the monitor within 1 second to changes in rates or resolutions, with little or no intervention by the operator and without having to be turned off for adjustments. (See page 46).

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

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

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

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

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

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

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

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

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Semiconductor-laser arrays would be more reliable, more powerful, and easier to make.

NASA's Jet Propulsion Laboratory, Pasadena, California

A type of index-guided semiconductor-laser array now under development is expected to exhibit performance and amenity to manufacturing superior to those of gain-guided arrays. The improved design is intended, in part, to eliminate the undesired electromagnetic modes and mode shifts that sometimes occur in the gain-guided variety. Potential applications for such arrays include optical communications, ranging, printing, and recording.

Ordinarily, it is desired to make all the lasers in an array oscillate in or near the same phase. However, in gain-guided arrays, evanescent-wave coupling distributed along the laser cavity tends to make adjacent units operate in opposite phases. Even in gain-guided arrays designed for operation in phase, gain-saturation effects can alter the modal characteristics.

In the improved, index-guided array the lasers are uncoupled in their guided sections; instead, they are coupled by diffraction in the common section of the resonator. Upon reflection from the mirror (see Figure 1), a fraction of each laser field is fed to the adjacent laser, where it helps to establish the phase of the oscillation. Overall, the phase relationships among the lasers in the array are determined primarily by the length of the common resonator section.

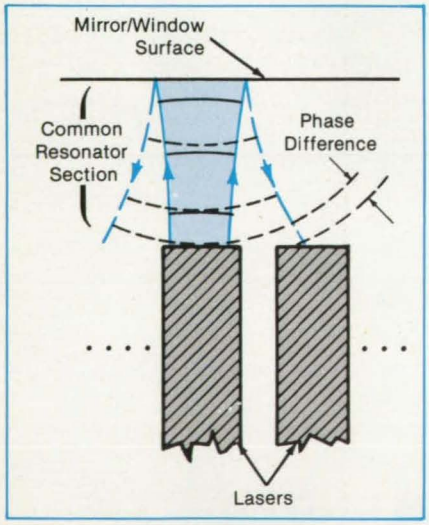

Figure 1. **Reflected From the Mirror/Window** at the end of the common resonator section of the laser, energy refracted from each laser enters the adjacent laser. This mutual coupling establishes the phase relationships among the lasers.

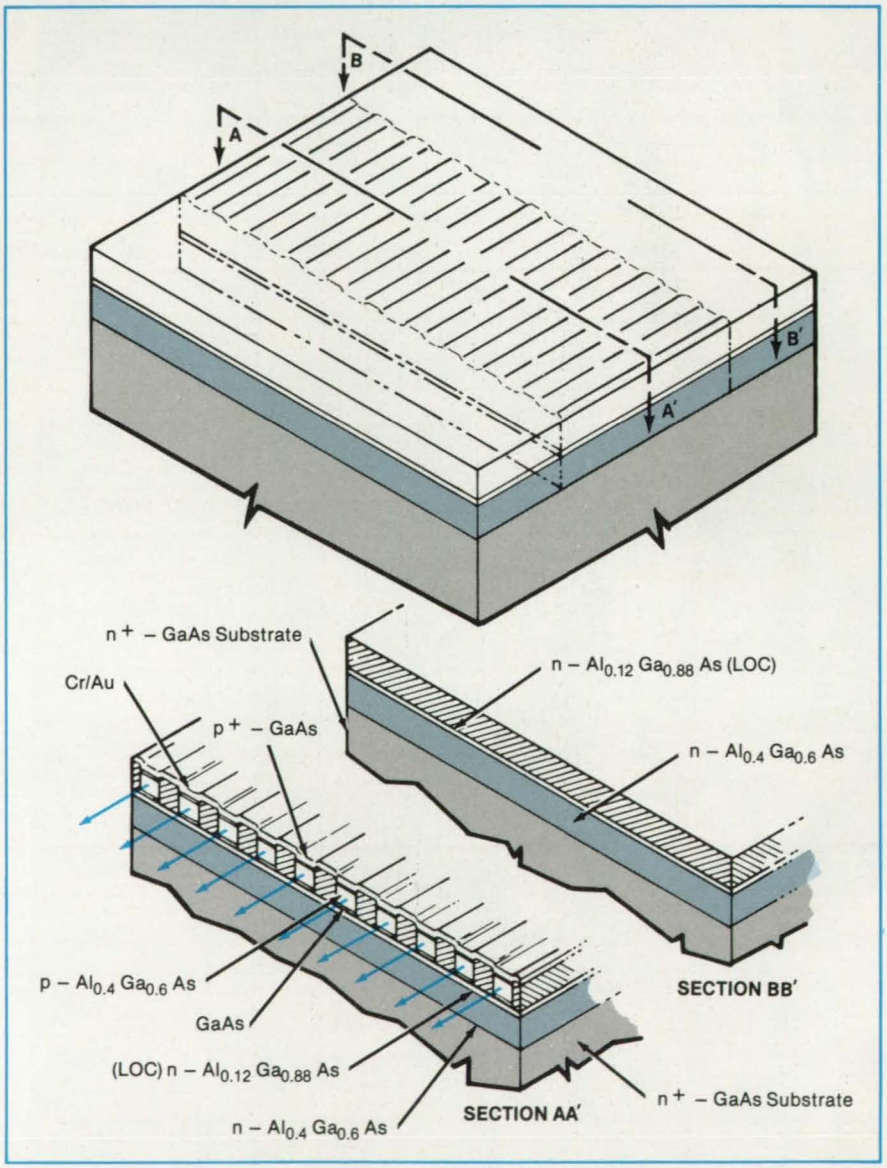

Figure 2. A **Monolithic Laser Array** could be made by standard epitaxial techniques. It could also be made in part with polymeric materials to mitigate some of the deleterious effects of all-epitaxial processing.

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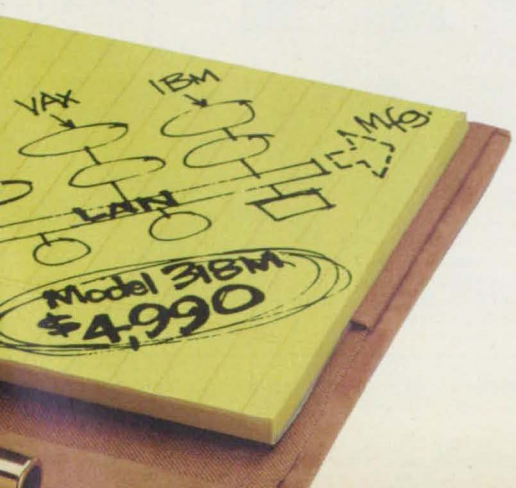


HEWLETT PACKARD

Circle Reader Action No. 416

DS15722

The array (see Figure 2) includes strip buried heterostructure lasers. The fabrication of the array could start with the growth of a large-optical-cavity (LOC) layer on a GaAs substrate by liquid-phase epitaxy. The individual lasers could be defined by selective etching down to the LOC layer. The spaces between the layers could be refilled, either by the deposition of polyimide or by epitaxial regrowth followed by metallization and cleaving.

Because most of the optical field is contained in the LOC layer, the dominant reflection is from the cleaved (end) mirrors, not from the etched interfaces of the active regions. The LOC-layer configuration helps to assure high output in each laser even in the absence of coupling. Each laser can be designed independently of the waveguide coupling with the other lasers because that coupling is relatively small.

Because the diffraction section of the laser is not pumped, it acts as a nonabsorbing mirror/window. This reduces the susceptibility of the mirror/window to damage, thereby increasing the power level at which the array can be operated without breakdown.

This work was done by Joseph Katz, Jim Cser, and William K. Marshall of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 112 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 20]. Refer to NPO-16927.

Temperature-Controlling Circuit

Operational amplifiers control large current to a resistance heater.

Ames Research Center, Moffett, California

A simple circuit switches the current to an electrical heater on and off to maintain the temperature of a room at 25 ± 0.5 °C. The circuit is lightweight, compact, reliable, insensitive to electrical noise, and uses a single 5-Vdc power supply. The circuit can handle ac loads of 10 A. It is designed to operate outside the temperature-controlled environment over a range of −55 to +85 °C.

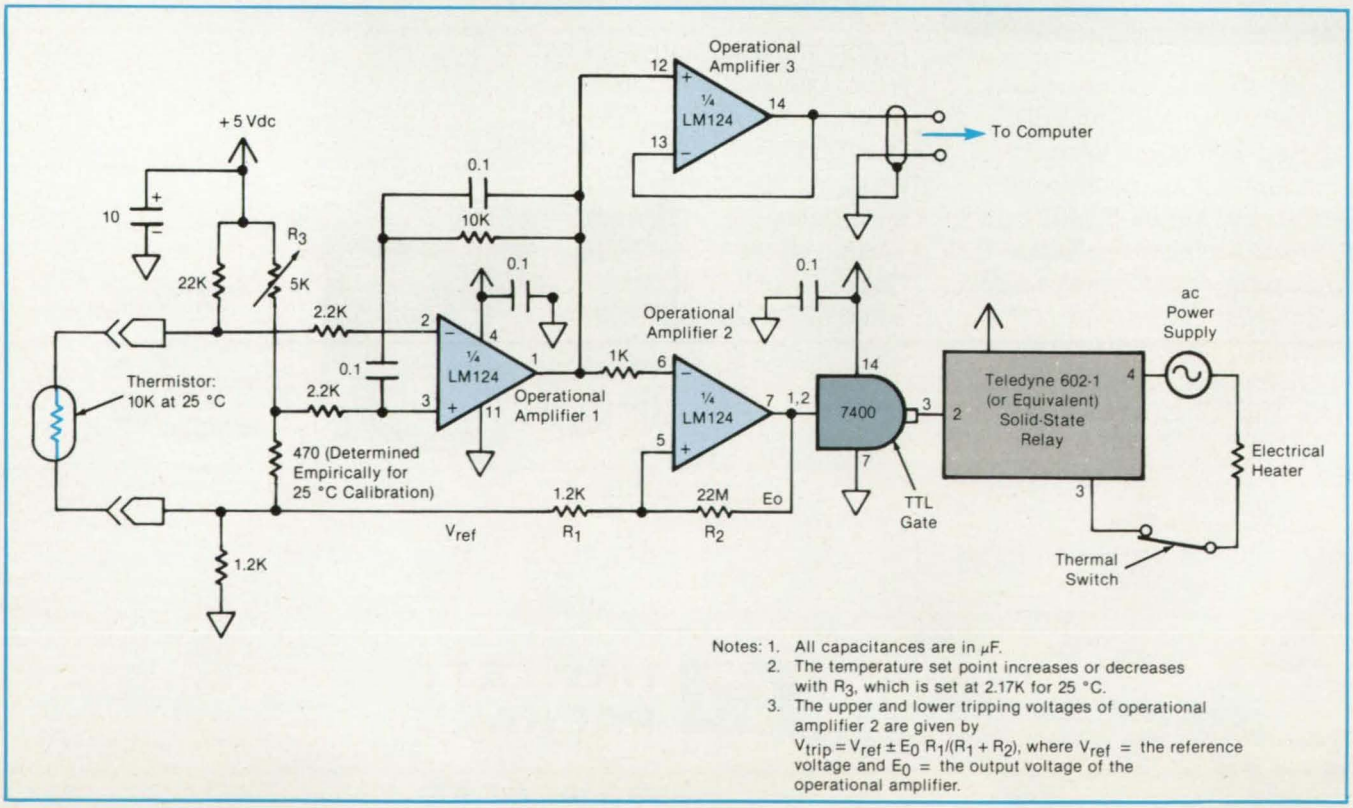
The temperature sensor is a thermistor, which provides a differential input (for reduced noise) to an operational amplifier connected as a differential amplifier with a small amount of gain (see figure). A 5-kilohm potentiometer is used to adjust the set point through a voltage divider; a value of 2.17 kilohms yields the 25 °C setting.

A second operational amplifier is connected as an inverting differential-input comparator. The hysteresis voltage of the output of operational amplifier 2 is determined by resistors R_1 and R_2. A value of 1.2 kilohms was chosen for R_1 to furnish the requisite input-level-setting voltage for the comparator. A value of 22 megohms was selected for positive-feedback resistor R_2 to provide a moderate amount of hysteresis for adequate immunity to noise while enabling rapid response to the slowly varying input. A reduction of R_2 would increase the hysteresis and therefore the delay in response to temperature changes, but would decrease the sensitivity to noise.

The output of operational amplifier 2 controls the electrical heater through a zero-crossing solid-state relay. A transistor/transistor-logic (TTL) gate adjusts the output to the proper level for the relay. A thermal switch is placed in series with the heater and the ac supply for safety in case of thermal runaway. A third operational amplifier monitors the output of the thermistor, providing a signal to a computer for data logging.

This work was done by Gerald Temple 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 20]. Refer to ARC-11707.



Notes:
1. All capacitances are in μF.
2. The temperature set point increases or decreases with R_3, which is set at 2.17K for 25 °C.
3. The upper and lower tripping voltages of operational amplifier 2 are given by $V_{trip} = V_{ref} \pm E_0 R_1/(R_1 + R_2)$, where V_{ref} = the reference voltage and E_0 = the output voltage of the operational amplifier.

A **Thermistor Provides the Input Signal** for a simple temperature controller. The output of the controller is applied to a solid-state relay, which in turn switches the current to a resistance heater.

Long-Life Electrolyte for Nickel/Hydrogen Cells

Decreased initial capacity is more than compensated by increased cycle life.

Lewis Research Center, Cleveland, Ohio

State-of-the-art nickel/hydrogen cells use electrolytes containing 31 percent KOH. It is known that the cell capacity decreases as the concentration is decreased from this value and increases as the concentration is increased. Because of this observation, the recommendation had been to increase the electrolyte concentration in the cell.

However, experiments have shown a surprisingly substantial increase of cycle life of nickel/hydrogen cells when the KOH concentration in the electrolytes was decreased from the industry standard of 31 percent, while the life was decreased when the concentration was increased. This discovery is particularly important in view of the prior recommendation to increase the concentration to increase the cell capacity. The benefit of the increase of the cycle life as the concentration is decreased is expected to outweigh the reduction of the capacity at the beginning of life.

Life tests were carried out at 23 °C, using nickel/hydrogen boilerplate cells containing flight-type nickel electrodes and electrolyte of various KOH concentrations (21, 26, 31, and 36 percent). The regime of the life test was a continuous cycling by 17.5-min discharge at the 2.74-C rate and 27.5-min recharge at the 1.92-C rate, resulting in a charge/discharge ratio of 1.10 and a depth of discharge of 80 percent of the rated capacity. The results of this life test to date are summarized in Figures 1 and 2.

The test cells with 36 and 31 percent KOH failed by low end-of-discharge voltage of 0.9 V after 1,300 and 3,300 cycles on the average, respectively, as shown in Figure 1, while the cells with lower KOH concentrations exceeded those lifetimes. The cell capacities at various life cycles are shown in Figure 2. The initial capacity decreased as the KOH concentration was decreased. However, the capacity change (decrease) with cycling was also reduced as the KOH concentration was decreased. This benefit appears to outweigh the initial capacity loss in many applications.

High cycle life is critically important for nickel/hydrogen cells, especially for a low-Earth-orbit satellite application where

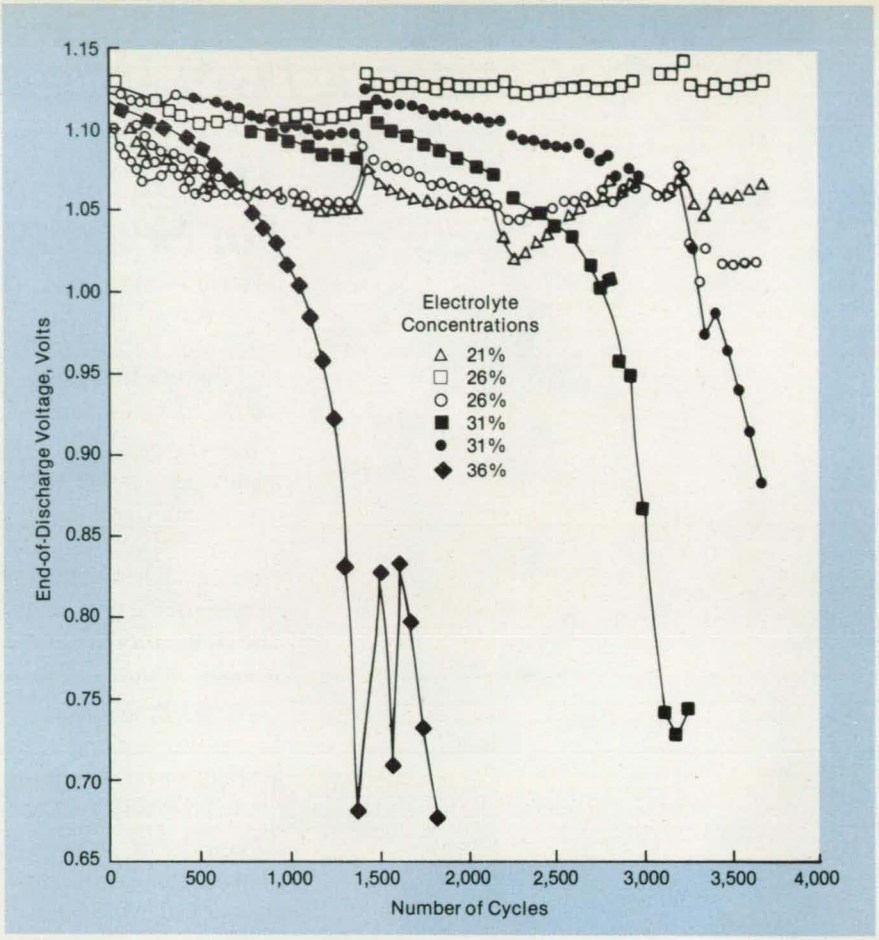


Figure 1. The **End-of-Discharge Voltages** were measured after repeated charge/discharge

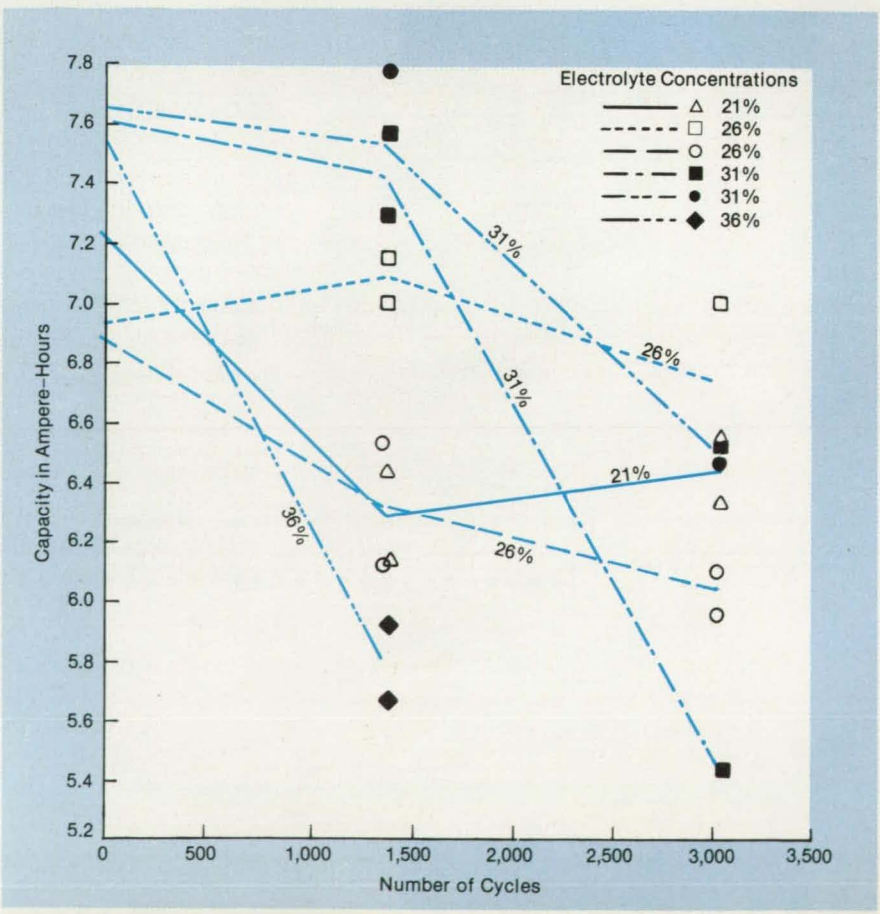


Figure 2. The **Charge Capacities** of cells were measured after repeated charge/discharge cycles. The electrolyte concentrations are the same as those of Figure 1.

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6,000 cycles are typically required per year. The high cycle life can also be traded into low battery weight by operating the battery at an increased depth of discharge. High cycle life is also important for such terrestrial applications as electrical vehicles and aircraft.

This work was done by H. S. Lim and S. A. Verzwyvelt of Hughes Aircraft Co. for **Lewis Research Center**. *Further information may be found in A86-24802, "KOH Concentration Effect on the Cycle Life of Nickel-Hydrogen Cells."*

Copies may be purchased [prepayment required] from AIAA Technical Information Service Library 555 West 57th Street, New York, New York 10019 Telephone No. (212) 247-6500. LEW-14301

Reliable Wiring Harness

Materials and design are changed for immunity to vibration and corrosion.

Marshall Space Flight Center, Alabama

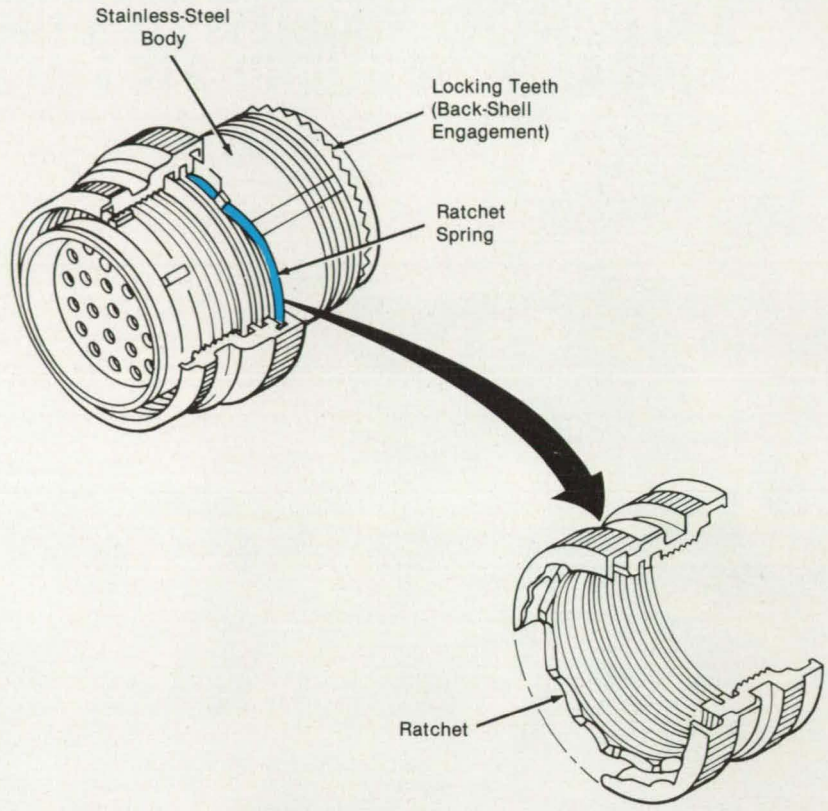
A new harness for electrical wiring includes plugs that do not loosen from vibration. In addition, the ground braids are prevented from detaching from connectors and are constrained so that the braids do not open into swollen "birdcage" sections.

To prevent loosening, self-locking connectors (see figure) are used. Even if they are screwed on one turn loose, the connectors tighten under vibration. The connectors are made of stainless steel instead of the corrosion-prone aluminum used previously.

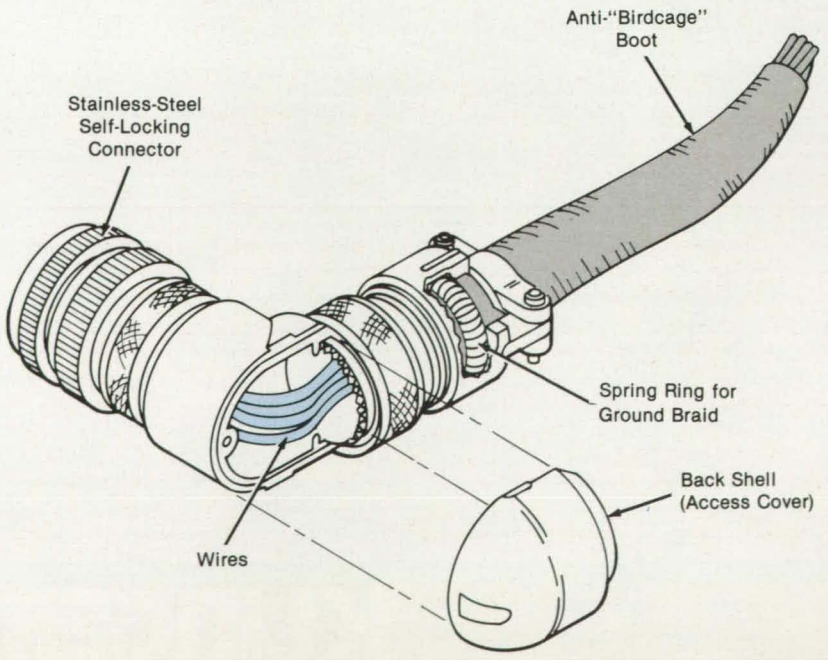
The ground braid is held securely by a ring of stainless-steel spring. The resistance of the ground-braid termination is low enough to protect the cable from lightning. A boot sheathing the cable prevents the "birdcages" from forming. A removable back shell provides access for maintenance.

This work was done by Kenneth C. Gaspar of Rockwell International Corp. 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 20]. Refer to MFS-29192.



SELF-LOCKING-CONNECTOR VIEW ROTATED 180°



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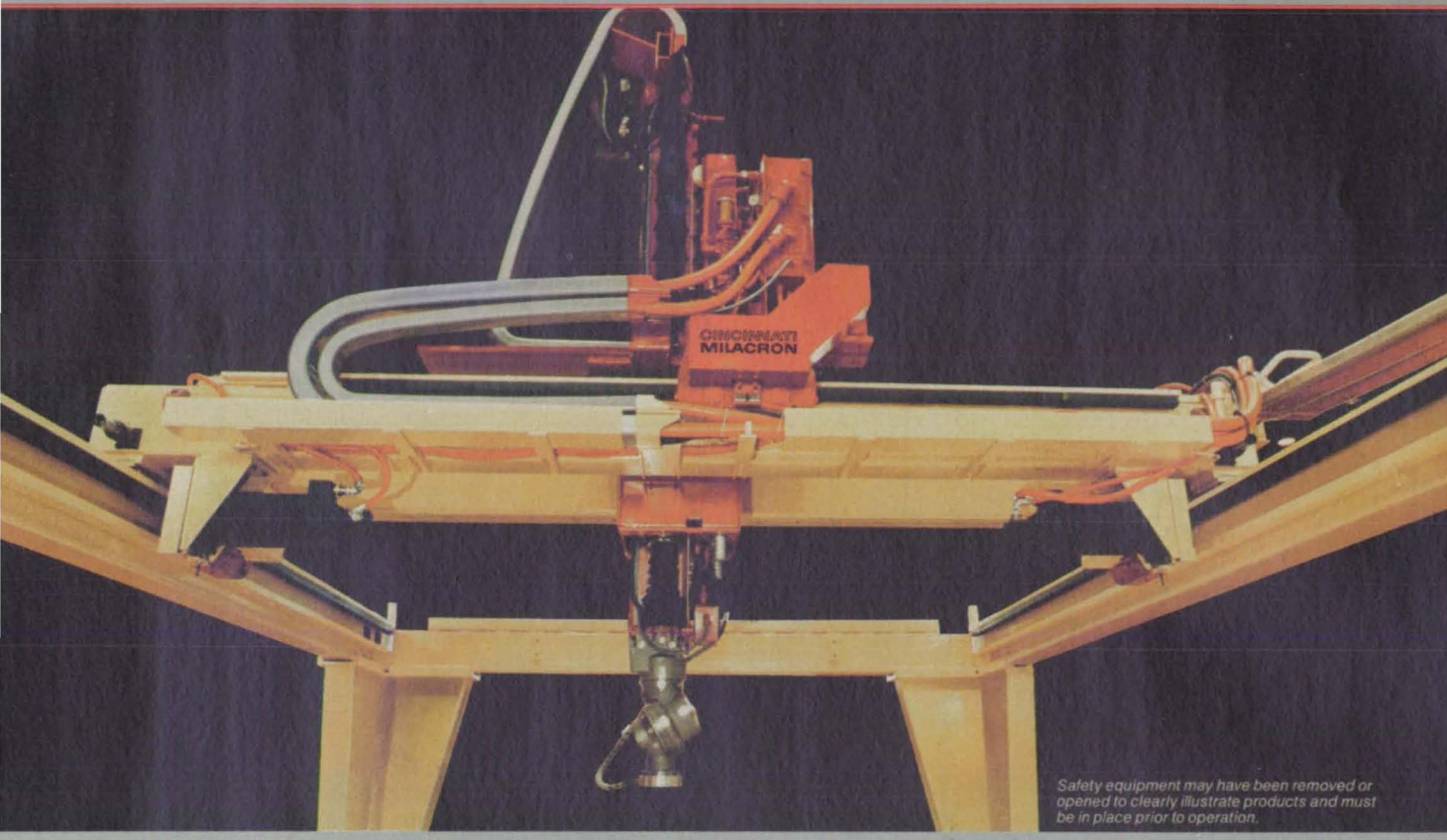

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Circle Reader Action No. 349

Extension of Subreflector Increases Antenna Efficiency

The subreflector is widened up to about 1 wavelength beyond the optical limit.

NASA's Jet Propulsion Laboratory, Pasadena, California

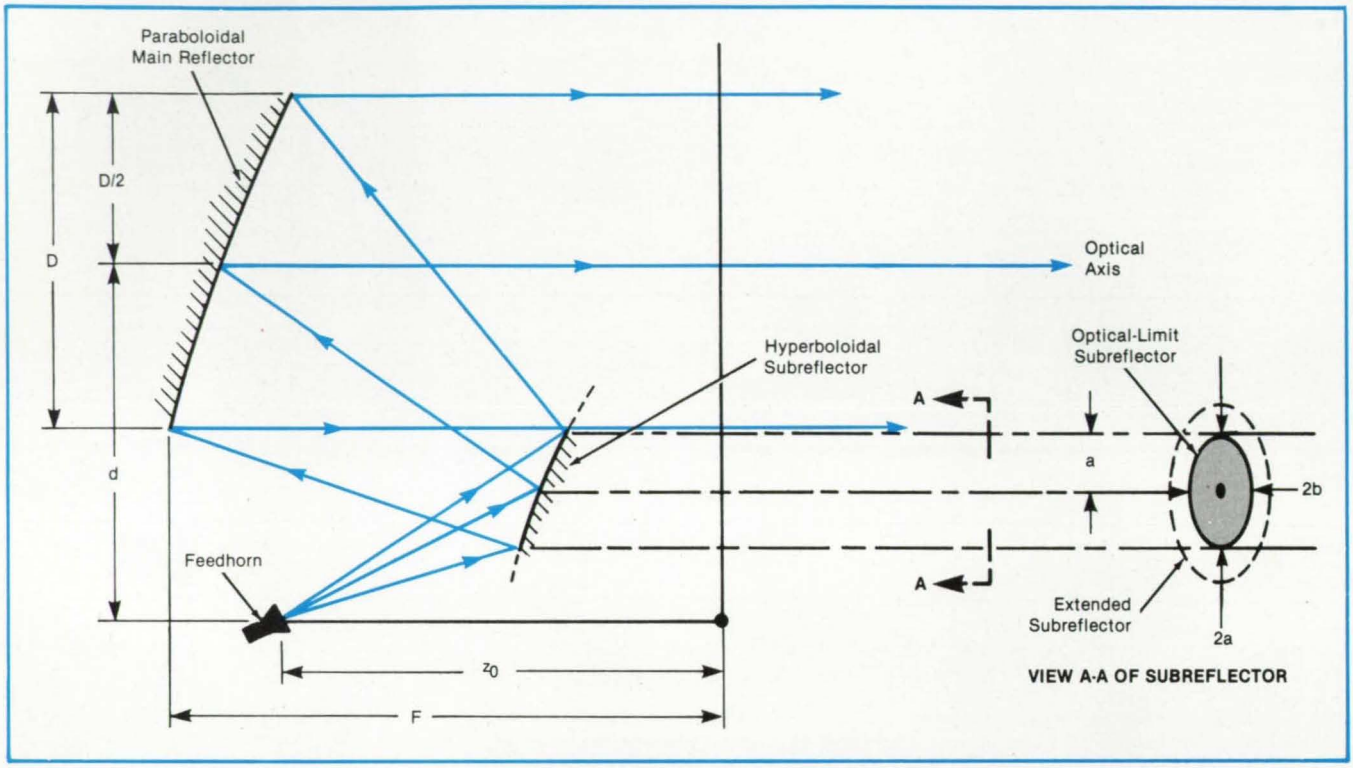

Figure 1. The **Offset Subreflector** is extended beyond the geometrical optical limit by extending the hyperbolic surface until it meets an elliptical cylinder that is parallel to the optical axis and has major axes larger than 2a and 2b, respectively.

According to calculations, the efficiency of an offset Cassegrain reflector antenna can be increased by about 8 percent by extending the edge of the subreflector outward about 1 wavelength beyond the optical limit. Even though the main reflector may then be partially shadowed by the subreflector, the partial aperture blockage is more than offset by the consequent reduction of diffraction on the subreflector. Similar conclusions apply to symmetric Cassegrain antennas.

The analysis was based on a parabolic main reflector with a hyperbolic subreflector (see Figure 1). In a typical prior design, the subreflector was placed so that its rim just touched the imaginary cylinder extending parallel to the optical axis from the rim of the main reflector; thus, by geometrical optics, the subreflector was an optical-limit subreflector.

The aperture efficiency of the antenna is the product of the spillover, illumination, polarization, and subreflector-diffraction efficiencies. These quantities were evaluated, using the geometric theory of diffraction to calculate the field scattered from the subreflector, and physical optics with the aid of the Jacobi-Bessel expansion to calculate the far field of the main reflector. To provide a comparison to show the effect of edge diffraction at the subreflector, the aperture efficiency was also calculated using geometrical optical scattering from the subreflector, with no subreflector edge diffraction included.

The analysis was conducted parametri-

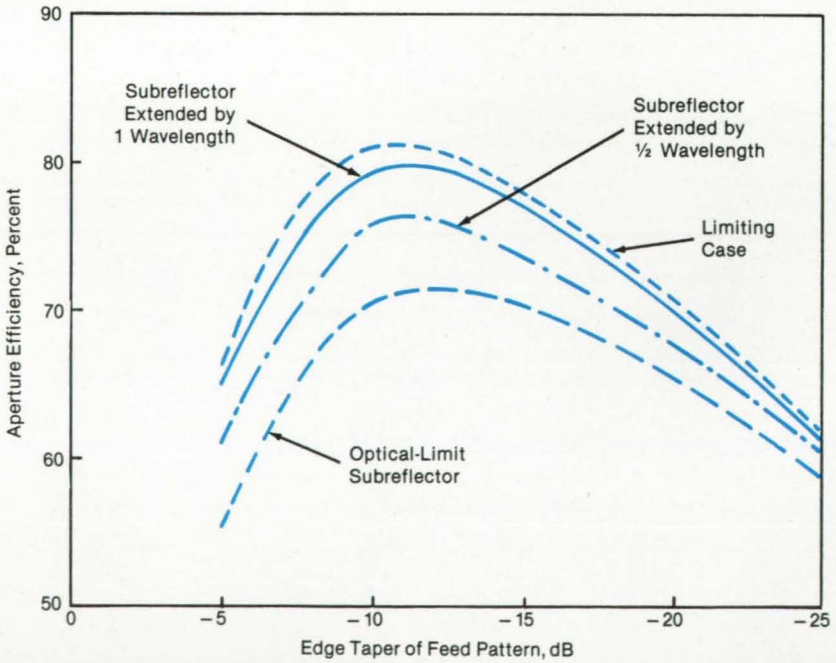

Figure 2. The **Aperture Efficiencies** for an antenna with an extended subreflector were calculated for various illumination tapers and two different subreflector extensions. Some of the antenna dimensions are D = 100 λ, a = 7.40 λ, b = 6.08 λ, d = 70 λ, F = 96 λ, and z_0 = 25 λ (where λ = 1 wavelength).

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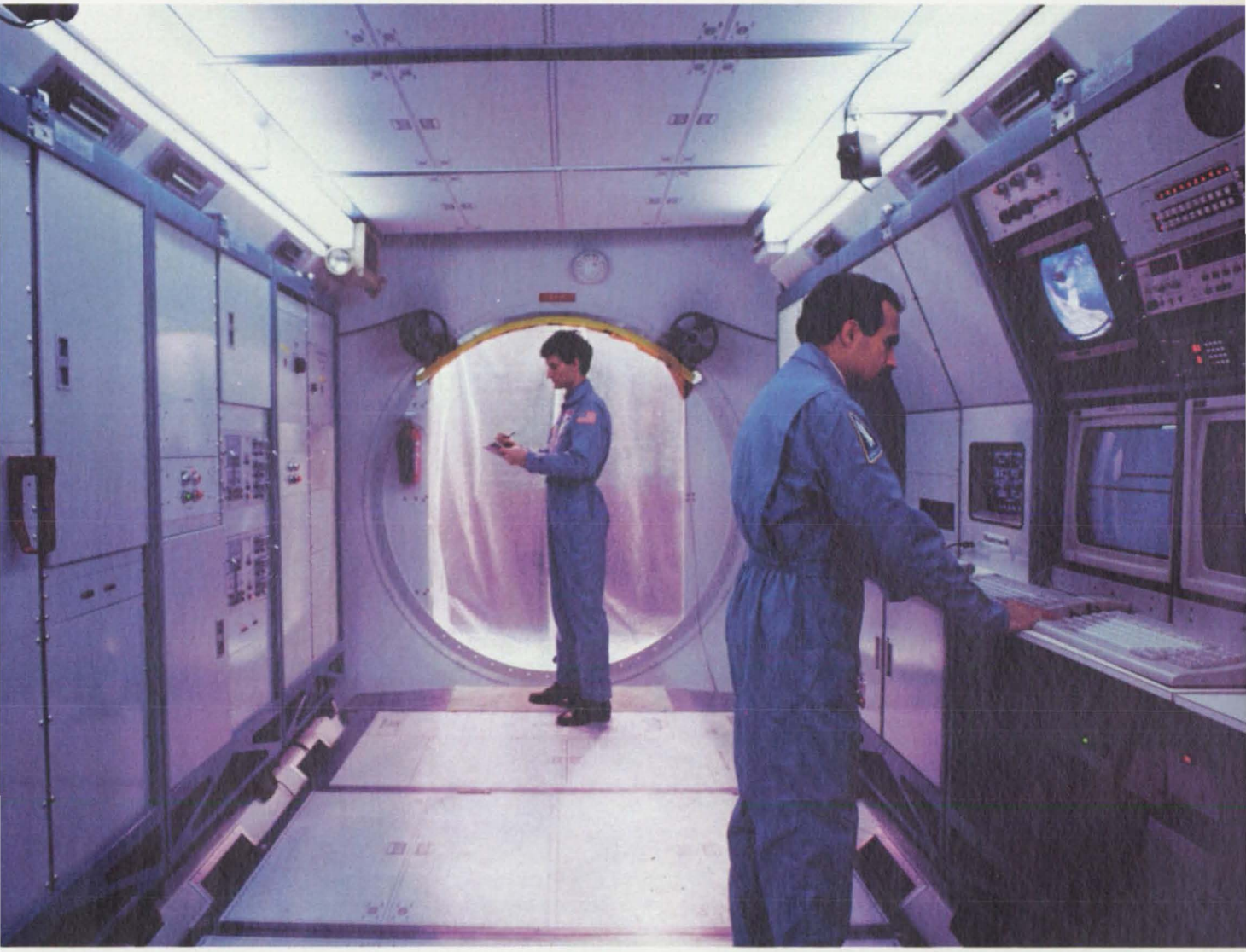

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Circle Reader Action No. 226

cally using various subreflector extensions and subreflector illumination tapers. Figure 2 shows the result of a representative case. Because significant improvements are not achieved by extensions beyond 1 wavelength, plots are not shown for those cases. (The dotted curve shows the limiting case for which no subreflector diffraction was included.)

This work was done by Y. Rahmat-Samii of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 134 on the TSP Request Card.*
NPO-16872

Dual-Energy X-Radiography With Gadolinium Filter

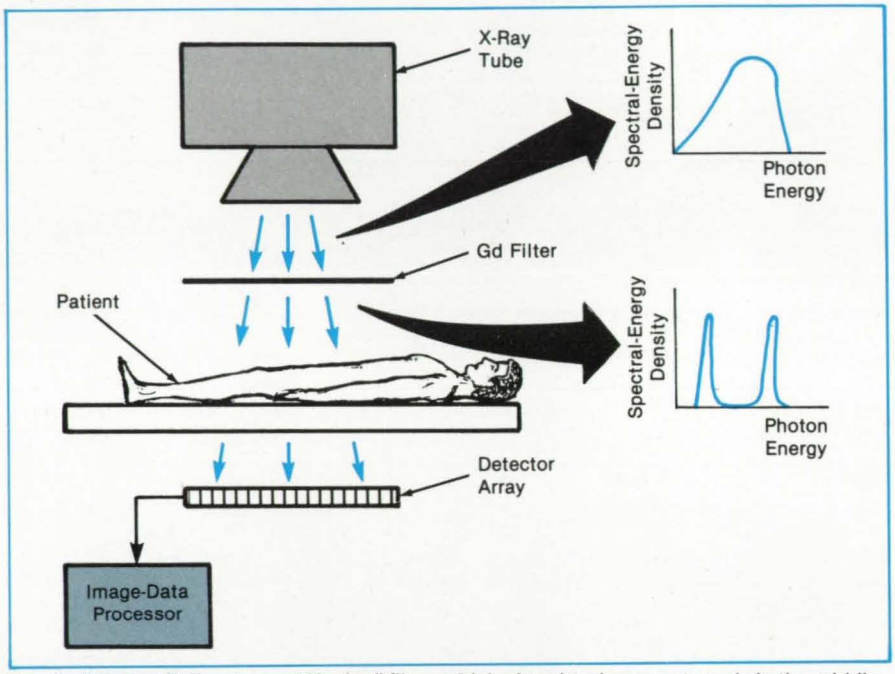
The image resolution would be increased, and the cost would be reduced.

NASA's Jet Propulsion Laboratory. Pasadena, California

In a proposed dual-energy x-ray imaging system, the continuous bremsstrahlung spectrum from an x-ray tube would be filtered by a foil of nonradioactive gadolinium or another rare-earth metal to form a two-peaked energy spectrum. After passing through the patient or object under examination, the filtered radiation would be detected by an array of energy-discriminating, photon-counting detectors (see figure). The detector outputs would be processed to form the x-ray image for each peak and possibly an enhanced image based on the data taken at both peaks.

Dual-energy x-radiography exploits the variation of x-ray attenuation with energy. By forming images at different energies and therefore different attenuations, one can enhance the radiographic contrast between different tissues. For example, dual-energy imaging has been used to reduce the effects of variable soft-tissue and fat content when measuring the density of bone. Prior methods of forming dual-energy spectra include alternately applying two voltages to the x-ray tube, filtering one bremsstrahlung spectrum with two different materials, using back-to-back detectors, and irradiating the patient with 45- and 100-keV x rays from a radioactive Gd^{153} source.

The latter method is often preferred because the photon energies of Gd^{153} are optimal for quantitative bone-mineral determination. However, to be sufficiently intense, a Gd^{153} source has to be large enough (typically forming a focal spot with an area of 5 mm^2) to limit image resolution seriously. Futhermore, the radioactive decay of the source necessitates annual replacement at a cost of about $10,000 to $20,000.



The **Gadolinium Foil** acts as a "K-edge" filter, which absorbs photons strongly in the middle portion of the spectrum above the K-edge energy. When illuminated with the continuous spectrum from an x-ray tube, the foil therefore produces a double-peaked spectrum. The images formed at the two peaks reveal more than does a single image.

Because the new system would use an x-ray tube with a source only 1/20 as large, it could achieve higher resolution. The radiation intensity available from the tube is 50 times that from a typical Gd^{153} source. When the continuous x-ray-tube spectrum is filtered by the nonradioactive gadolinium foil, the output spectrum has two peaks separated by 40 keV and nearly identical to the Gd^{153} peaks. The radiation dose to the patient would be about the same as with Gd^{153}. The x-ray image would be formed on a linear array of 15 to 24 detector elements etched 2 mm apart onto a single crystal of highly pure germanium. The detector array would be moved across the scene in a line-scanning mode.

This work was done by Brian Rutt of the University of California at San Francisco for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 124 on the TSP Request Card.* *NPO-16773*

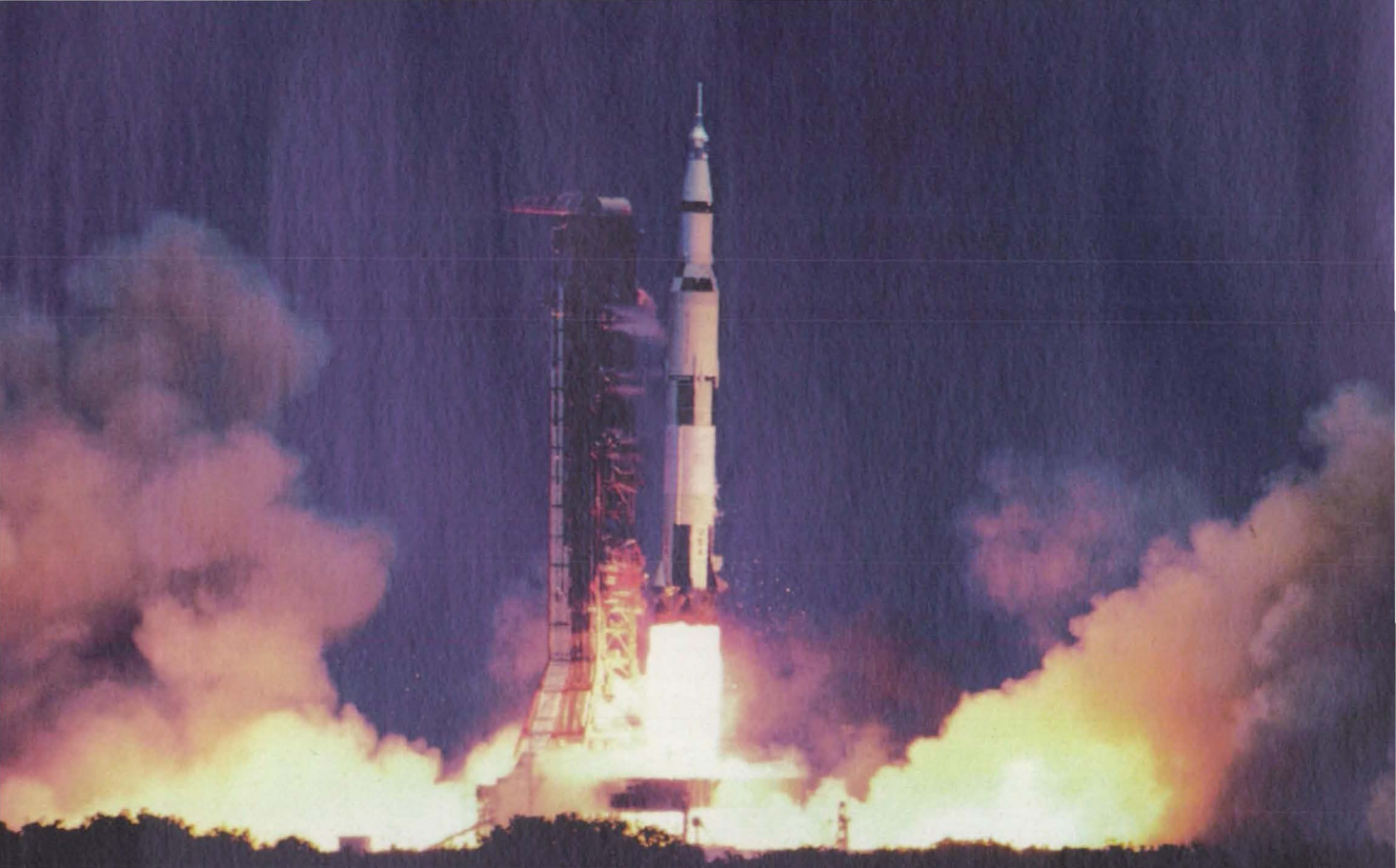
Tunable Dual Semiconductor Laser

Parallel lasers interact in shared space to alter output wavelength.

NASA's Jet Propulsion Laboratory, Pasadena, California

The light produced by a near-infrared semiconductor laser can be tuned over a range of 3 nm by a parallel laser directly below it in the same chip. The tunable laser will be useful in optical communication, in which narrow-band interference filters are used widely. The passband of such filters tends to change with age, and the fixed wavelength of light generated by a laser may no longer precisely match the wavelength of light transmitted by the filter. As much as 60 percent of the output power of the laser may be lost on account of mismatch with the filter. With the new tunable device, the output wavelength may be changed to match the changing wavelength of peak filter response. Such tunable sources can also be useful in optical communications systems employing wavelength-division multiplexing.

The new device consists of two stripe lasers in an aluminum gallium arsenide chip (see figure). The parallel stripes are close enough so that light from the lower laser is coupled into the upper laser and vice versa. The lasers are operated by low-duty-cycle current pulses. The lasing



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Circle Reader Action No. 527

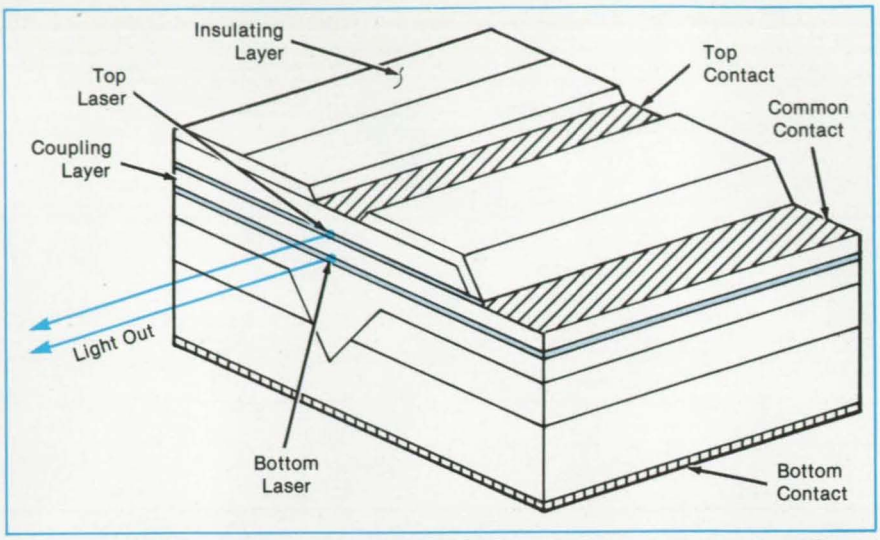
threshold of each is about 100 mA. The currents are controlled independently.

The current in the top laser is adjusted so that it is above the threshold value, and the laser produces a beam of coherent light at about 880 nm. The current in the bottom laser is kept below the threshold. As the current in the bottom laser is increased, the wavelength of the light from the top laser decreases. Moreover, the output is single-mode light rather than the usual multimode radiation and has a narrower spectrum than light from single semiconductor lasers.

Changing the current in the bottom laser apparently changes the complex dielectric constant of that device. This change in turn alters the resonance condition of the combined cavities of the two lasers and thereby alters the output wavelength.

When the current in the bottom laser is increased above the threshold level, that device also starts lasing. The chip then produces two laser beams at different wavelengths.

The chip is made by a process that includes two stages of liquid-phase epitaxial growth. First, an n^+ gallium arsenide layer is grown on a p^+-type, zinc-doped gallium arsenide substrate. A groove is etched through the layer and into the substrate. In the second epitaxial step, five layers of differing composition are grown to delineate the two layers. Top, common, and bottom electrical contacts are then deposited on the chip.



The **Top Laser Emits Light**, the wavelength of which is controlled by the bottom laser. Current to the top laser is applied through the top and common contacts, and current to the bottom laser is applied through the common and bottom contacts.

This work was done by Seiji Mukai, Eli Kapon, Joseph Katz, Shlomo Margalit, and Amnon Yariv of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 53 on the TSP Request Card.*

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

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

Refer to NPO-16374, volume and number of this NASA Tech Briefs *issue, and the page number.*

New Products

Tartan Laboratories (Pittsburgh, PA) has released Tartan Ada VMS and Tartan Ada VMS/1750A, a development and execution environment for the Ada language. Tartan Ada combines advanced code generation technology with Ada language expertise, providing Ada compilers unsurpassed in quality and performance. The compilers are validated to ANSI/MIL-STD-1815A and are ideally suited for Ada language applications where small, fast object code is of major concern. **Circle Reader Action Number 599.**

A new lightweight, reusable clamp for difficult-to-secure flat cables is offered by **TA Manufacturing Co.** (Los Angeles, CA). The clamp's cushion design isolates the cable from abrasion and relative motion and prevents breakage by relieving strain. The clamps come in 1, 2 and 3 inch widths, and the metal portion can be either aluminum or stainless steel. **Circle Reader Action Number 594.**

MathSoft Inc., Cambridge, MA has announced numerous new features, performance and ease-of-use enhancements for MathCAD, their PC-based calculation software package. MathCAD is an "electronic scratchpad" that allows users to write calculations on a PC using standard math notation. The program allows text, formulas and graphics to be entered with the same free-form ease as a blackboard, but the computer performs the actual calculations. Version 2.0 includes, among other improvements, the ability to solve simultaneous equations, full matrix capabilities, autoscaling plot, and new histogram plot types. For more information **Circle Reader Action Number 593.**

Melles Griot Gas Laser Products (Irvine, CA) announces a new 10 milliwatt, 632.8 nanometer helium neon plasma tube. Both randomly polarized and linearly polarized will be useful in applications requiring higher outputs such as laser printers, particle measuring systems and high speed character readers. "Zero-leak" hard seals assure long, trouble-free operating life. The rotationally symmetrical cathode design and unique bore support provide mechanical and thermal stability for pointing accuracy and stable operation. **Circle Reader Action Number 595.**

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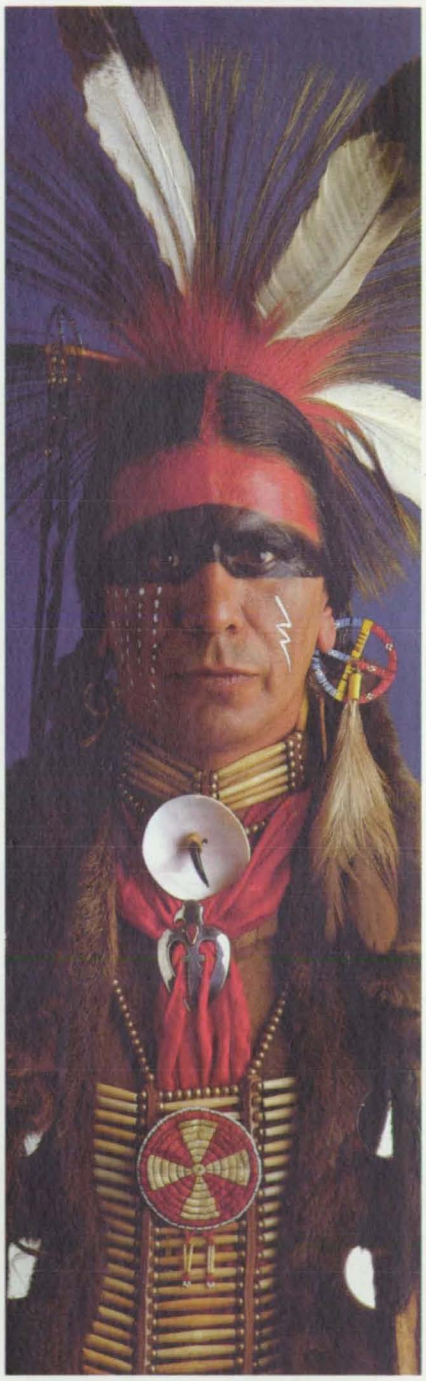

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Circle Reader Action No. 319

Electronic Systems

Hardware, Techniques, and Processes

Optoelectronic Proximity Sensor Finds Edges

Seams are tracked for automatic control of welding.

NASA's Jet Propulsion Laboratory, Pasadena, California

An optoelectronic system based on a relatively simple array of optical proximity sensors locates the edge of a plate. The system can be used to control automatic production machinery — for example, to locate spot welds at the correct lateral position with respect to the seam between two overlapping metal plates or sheets. The system follows curved seams as well as straight ones, and neither special control programming nor precise initial positioning of a workpiece is necessary for accurate tracking of a seam.

Facing the workpiece is an array of optoelectronic proximity sensors (see Figure 1) in a line across the seam. Each proximity sensor is calibrated for use with the particular workpiece material and configuration, so that the output of each sensor can be used to determine the distance to the workpiece surface.

Each sensor is sampled in turn. The light-emitting diode is turned on, and the output of the detecting photodiode is measured. The digitized measurements are used to locate the exposed edge of the workpiece: the system computer finds the lateral position that corresponds to a previously calibrated sensor-output value between the values for the flat surfaces on either side of the edge. In effect, this amounts to a crude form of image analysis, in which the field of view of each sensor constitutes a picture element. For high definition of the position of the edge (high resolution), the sensor array should be dense and the fields of view should abut or overlap slightly.

Although the light-emitting diodes and detecting photodiodes could be mounted in the sensing head as in Figure 1, it would be better to remove them from the vicinity of the weld to reduce electromagnetic interference. Therefore, in a practical system, the diode pairs are mounted on circuit cards with other electronic circuits and connected through glass optical fibers to the lens array in the sensing head. This arrangement also facilitates tracking by reducing the size and mass of the sensing head.

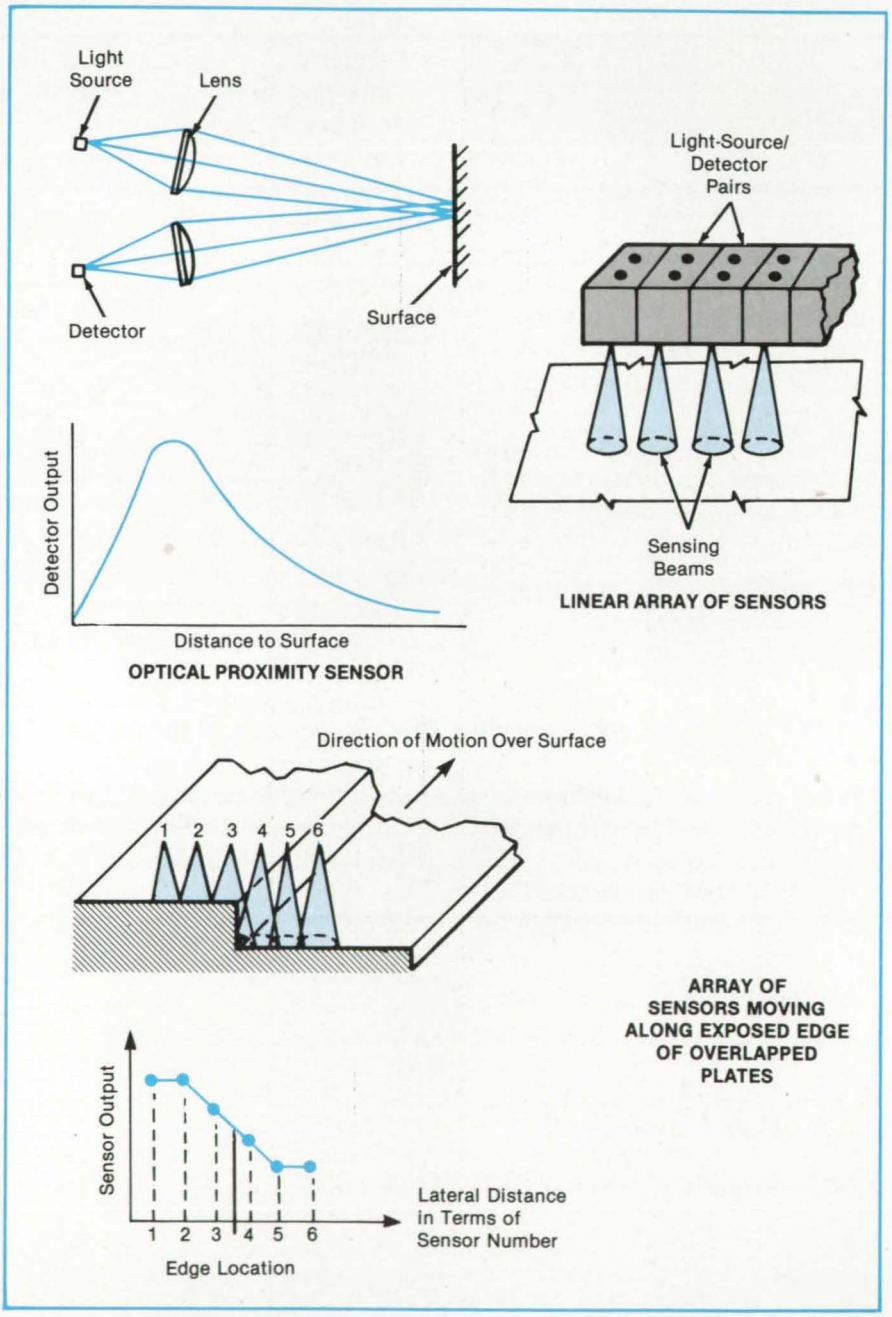

Figure 1. In an **Optoelectronic Proximity Sensor**, the signal from a light-emitting diode is reflected by a surface and detected by a photodiode. For a given surface viewed perpendicularly or at a fixed angle, the known dependence of the photodiode output with distance can be used to determine the instantaneous distance to the surface. A linear array of such sensors can thus be used to obtain a rough profile of the surface along the axis of the array.

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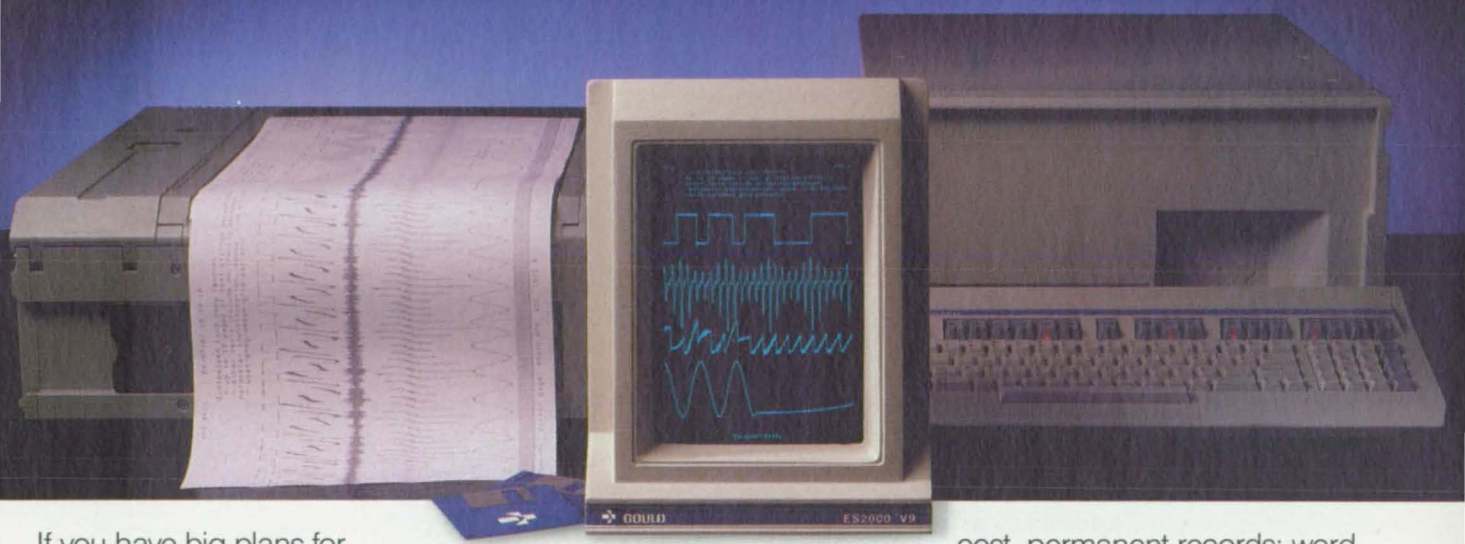

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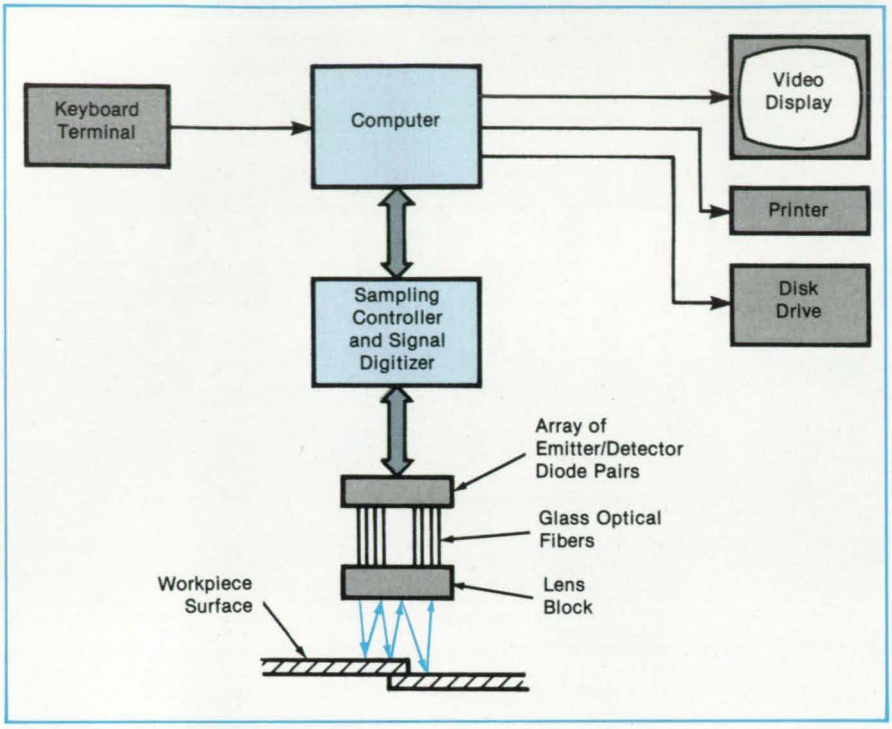

Figure 2. The **Optoelectronic System** processes the outputs of the linear array of sensors to locate the exposed edge. In this configuration, the sensing head is separated from the diode pairs and optically reconnected to them through fiber optics.

Other subsystems and the overall system configuration are shown in Figure 2. Through a standard keyboard, the operator instructs the computer in the specifics of the task. The computer controls the sampling of the proximity sensors and displays the processed outputs in sequence on a video screen. The results of the sensor scans can also be sent to a printer or saved on a magnetic disk.

This work was done by Antal K. Bejczy of Caltech for ***NASA's Jet Propulsion Laboratory****. For further information, Circle 52 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 of this invention should be addressed to

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1201 East California Boulevard
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Refer to NPO-16697, volume and number of this NASA Tech Briefs *issue, and the page number.*

Distress Transmitter and Receiver

Identifying distress signals are sent and received automatically.

Goddard Space Flight Center, Greenbelt, Maryland

A radio transmitter and receiver are designed to be used together for the location and identification of persons, aircraft, or ships in distress. The modulation of the transmitted signal is characterized by a unique combination of frequencies, repetition rates, and duty cycles, so that the type or identity of the vehicle or person in distress can be ascertained from the signal. The receiver can be operated manually and monitored aurally in the conventional manner, but also includes automatic tuning and monitoring features to assist the operator in measuring the modulation characteristics and in detecting weak signals.

In the transmitter (see Figure 1) an oscillator generates a carrier signal at a frequency of 121.5 MHz. The carrier is fed to an output amplifier through a gate, which is opened or closed repeatedly to obtain full carrier, zero carrier, or 100-percent amplitude modulation. Because the output amplifier is nonlinear, it feeds the gated signal to the antenna at the two international distress frequences of 121.5 and 243 MHz.

Under the control of an electronic switch, the gate is opened or closed by a combination of timing pulses, by fixed-frequency audio oscillations, and by the output of a multivibrator, the frequency of which is repeatedly swept downward in the range of 1,600 to 300 Hz, 2 to 4 times per second (the present standard international distress signal). For example, a modulation scheme might call for a period (e.g., 0.5 s) of unmodulated carrier, followed by a period of the international distress signal, followed by a period of steady 200-Hz tone, and then by a repetition of the foregoing sequence.

In addition to the standard superhetero-

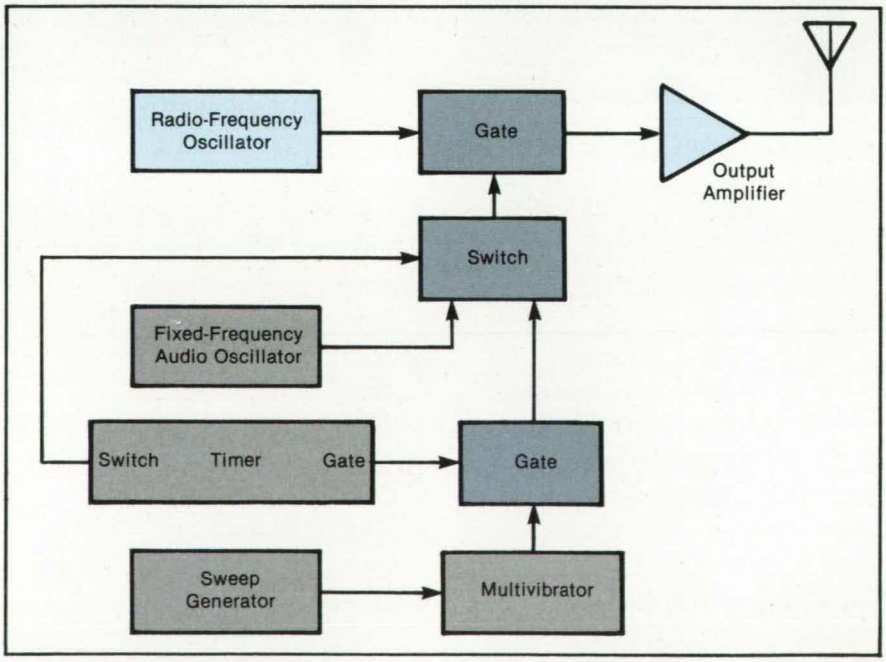

Figure 1. The **Transmitter** generates a signal characterized by a timed sequence of modulating pulses.

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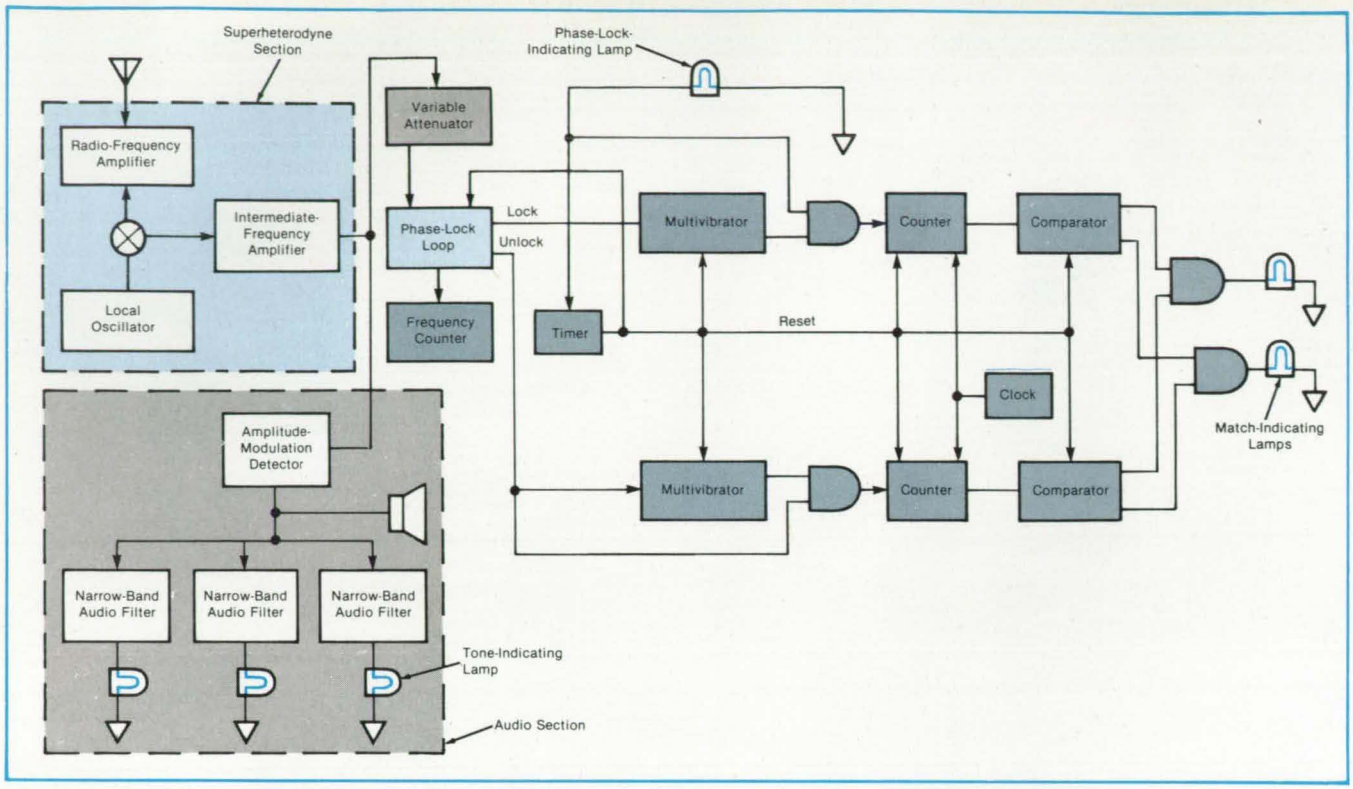


Figure 2. The **Receiver** automatically locks onto the signal and identifies it according to its modulation characteristics. The operator can also listen to the receiver and tune it manually. Together, the transmitter and receiver constitute a distress radio system.

dyne input and audio output sections, the receiver (see Figure 2) includes narrow-band audio filters connected to lamps. The filters are set to the frequencies of the steady audio tones of known transmitters, to give visual indications of the reception of signals from those transmitters.

The receiver also includes a phase-lock loop that locks onto the carrier signal when it is unmodulated. Exploiting the fact that phase lock is lost during the modulation periods, the receiver is equipped with counters to measure the periods of lock and unlock. These periods are compared with stored values; if a match is found, the comparators cause lamps to light, thereby indicating that the signal is that of a known transmitter.

The output of the phase-lock loop is also fed to a frequency counter to assist the operator in identifying the signal source. The phase-lock loop repeatedly sweeps through a narrow frequency range until it locks on a signal. A timing circuit prevents the resumption of the sweep during the short modulation periods of the signal to which the receiver is locked. This feature prevents the receiver from attempting to lock onto other distress signals in the event that more than one is present. The phase-lock loop can also be unlocked and tuned manually.

A variable attenuator enables the operator to prevent false locking during the modulation period by adjusting the amplitude until the signal is below the loop threshold during modulation but above the threshold during no modulation. The correct adjustment of the attenuator is indicated by the repeated, regular flashing of the phase-lock-indicating lamp as the loop goes into and out of lock.

This work was done by Paul E. Wren of **Goddard Space Flight Center**. *For further information, Circle 101 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Goddard Space Flight Center [see page 20]. Refer to GSC-12821.

Solar-Powered Sensor Module

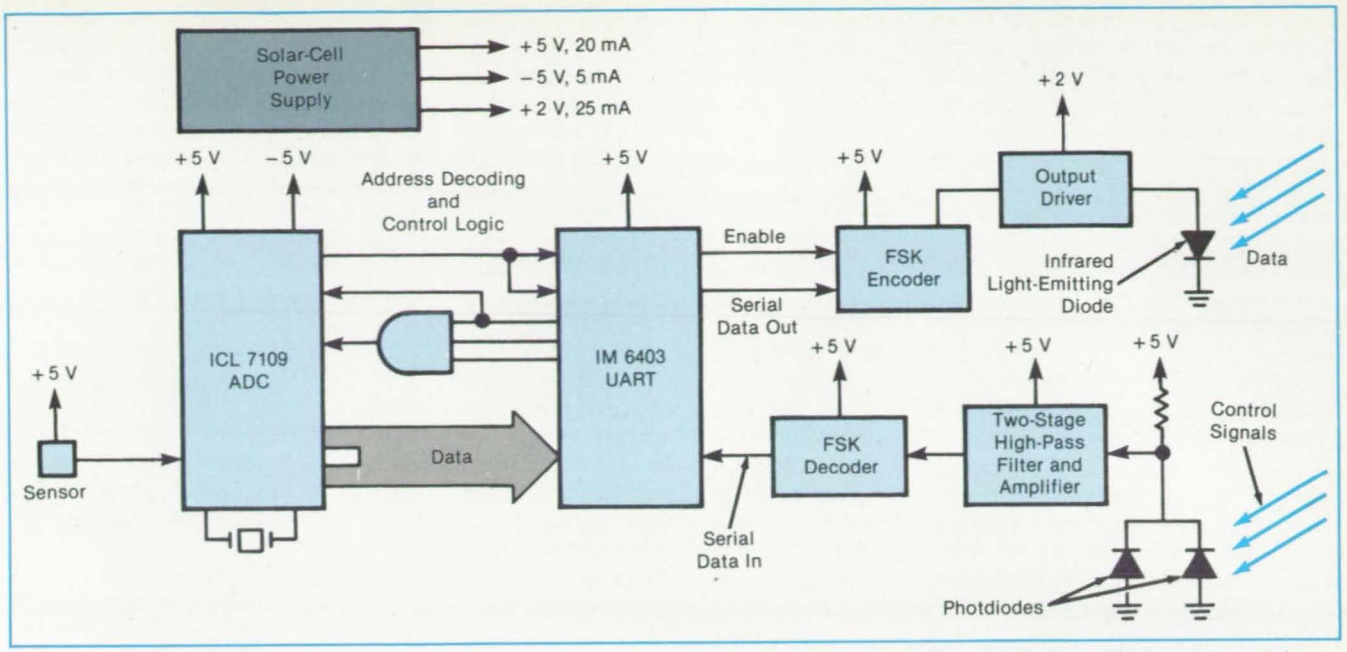
A hybrid sensor module with no external electrical interconnections includes an optical data link.

Langley Research Center, Hampton, Virginia

Geo-orbital systems of the near future will require more-sophisticated monitoring and control systems than do current satellite systems, with an emphasis on the electronic density and autonomy of the subsystem components. Hybrids that have typically served as components in spacecraft electronics will have to assume the roles of subsystems and systems. A solar-powered hybrid sensor module (see figure) has been designed to combine low-power CMOS electronics, GaAs solar cells, a crystal oscillator, standard universal asynchronous receiver/transmitter (UART) data format, and a bidirectional optical data link into a single 1.25- by 1.25- by 0.25-in. (3.18- by 3.18- by 0.64-cm) hybrid package that has no need for electrical input or output. Sensor modules with optical data links could also be useful on Earth in hazardous environments; for example, in explosive atmospheres or high-voltage equipment.

The module is made up of four general subsystems: (1) the power supply, (2) the data-acquisition section, (3) the control section, and (4) the communication section. The power supply is an array of solar cells attached to the hybrid package. The data-acquisition section includes the sensors or transducers and the analog-to-digital converter (ADC). The control section coordinates the functions of the other sections. The communication section receives and transmits information and forms the link between the control computer and any remote sensors under its control.

Data are transmitted serially over a bidirectional optical data link that offers the option of operation without wires or cables connecting the data source to the receiver. In addition, the optical data transmission is



The **Hybrid Sensor Module** measures such parameters as temperature, acceleration, and strain. The module transmits measurement data to a central unit and receives control signals via light beams.

considered preferable to more-conventional radio-frequency or microwave transmission systems because it will not interfere with the spacecraft electronics. The modulation method chosen for this application was frequency-shift keying (FSK) because of its high immunity to noise.

Three self-contained solar-powered hybrid sensor modules that were built and tested met the design goals of minimal module weight and no electrical interconnections. For the most part, standard fabrication processes were used. Nonstandard techniques that were developed were compatible with standard hybrid processing. The hybrid module functioned to a large extent as a separate system, and the use of a free-space optical data link between the hybrid and the controlling computer was successfully demonstrated. Initial results are very promising, and the potential applications of such a system, from data gathering to systems control, are numerous.

This work was done by J. Michael Johnson of Hughes Aircraft Co. for **Langley Research Center**. *Further information may be found in NASA CR-172495 [N87-11343/NSP], "Solar Powered Hybrid Sensor Module 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.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Langley Research Center [see page 20]. Refer to LAR-13454.

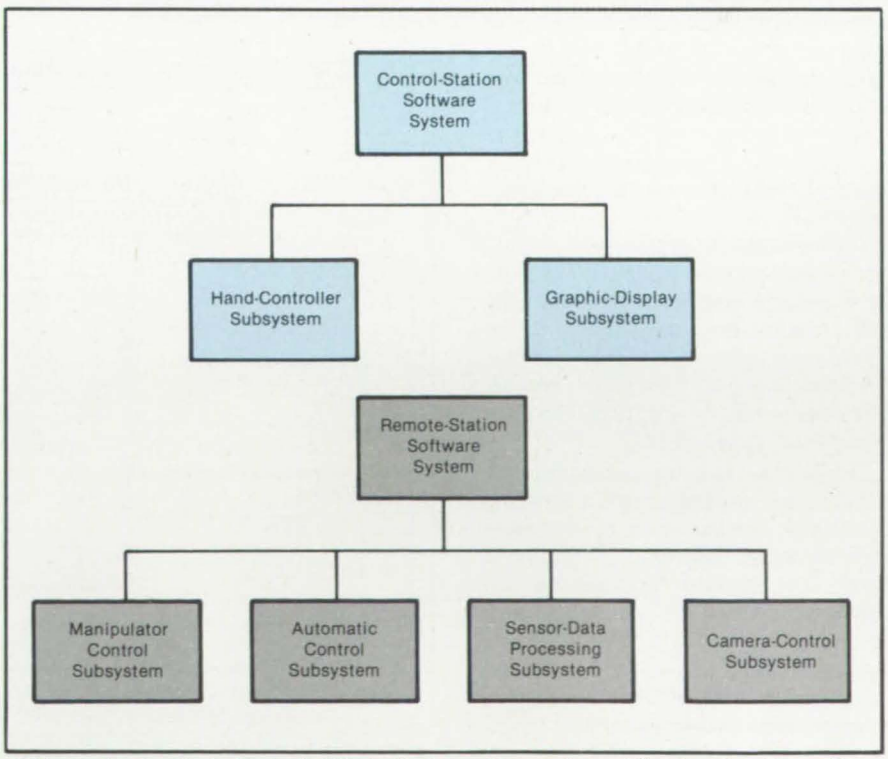
Digital Control for Remote Manipulators

Multiple microprocessors enable large separations between controllers and manipulators.

NASA's Jet Propulsion Laboratory, Pasadena, California

A controller for a remote manipulator requires no direct mechanical connection between the slave arm and the master arm moved by the human operator. The controller employs two-way digital data transmission rather than a mechanical linkage between the master and the slave. The manipulator can therefore be a considerable distance from the operator — perhaps thousands of kilometers away.

The microprocessor-based controller sends commands to the slave according to the operator's hand and arm movements; it returns signals to the master to give the operator visual and kinesthetic feedback. The master and slave arms need not be kinematically and dynamically identical:



Software for the Controller is distributed between the master and the slave locations. It is organized into modules, as indicated by the blocks. Hardware and software for the system, still under development, have been demonstrated in a laboratory model.

the master arm can be designed to suit the needs of the operator and the control station, whereas the slave arm can be designed to suit the remote environment. Microprocessors at the master and slave locations make the necessary transformations of positions, orientations, forces, and torques to adapt the two units to each other. The microprocessors are modular and expandable and control such auxiliary functions as television cameras and displays.

Four central-processing units (CPU's) are used so that the large computation burden can be handled in real time. Each CPU includes a 32000-series microprocessor; 128 kbytes of random-access memory; floating-point, timing-control, interrupt-control, and memory-management units; serial and parallel ports; and an expansion connector. Two CPU's are grouped together on a multibus chassis at each location. Each CPU pair can thus readily share information and memory space for coordinating robot control and sensor-data display.

In a demonstration model of the controller, the master manipulator is a general-purpose, 6-degree-of-freedom, back-drivable joystick. A dedicated 32016 microprocessor translates the joint-angle potentiometer values of the master into position instructions for transmission to the slave. The microprocessor accepts data on the orientation, position, forces, and torques at the remote end effector and combines the data to back-drive six torque motors on the master. It thus conveys to the operator a sense of the inertia of the remote manipulator and a feel for the compliance of objects in the remote workspace.

An 8086B microprocessor on the end effector reads and normalizes sensor data for transmission to the control station. This microprocessor also controls the servomechanism that closes the robot hand as instructed by the control station.

The controller software is organized in a modular structure that increases versatility and reliability and makes duplication of programs unnecessary (see figure). The software modularity also makes software-error detection and correction easier and faster.

This work was done by Antal K. Bejczy and Ronald S. Dotson of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 133 on the TSP Request Card.*
NPO-16879

Interface for Color-Video Monitor

A wide range of video signals can be accommodated.

Goddard Space Flight Center, Greenbelt, Maryland

A commercially produced color-video monitor is modified by the addition of an interface circuit to accommodate a wider-than-usual range of scanning rates and resolutions. The monitor displays a properly adjusted picture as long as the input video signal conforms to one of several industry standards and has a horizontal-synchronization frequency of 15.0 to 37.5 kHz, a vertical-synchronization frequency of 43 to 65 Hz, a horizontal resolution up to 1,280 elements, and a vertical resolution up to 1,024 elements. With little or no intervention by the operator and without having to be turned off for adjustments, the interface adapts the monitor within 1 second to changes in rates or resolutions, as long as those parameters remain within the specified ranges.

The interface design relies on the fact that standard video signals having the same vertical- and horizontal-synchronization frequencies usually require similar aspect ratios and other monitor settings. The interface adjusts the monitor identically for video signals for which those frequencies are sufficiently close.

The vertical- and horizontal-synchronization pulses are taken from a sampling point in the monitor after these pulses have been separated from the incoming video signal. The interface measures the two pulse frequencies and processes them, according to a transfer function, into eight outputs that adjust the width, height, centering, geometric distortion, and other characteristics of the picture (see Figure 1).

The transfer function is contained in electronic memory in the form of two

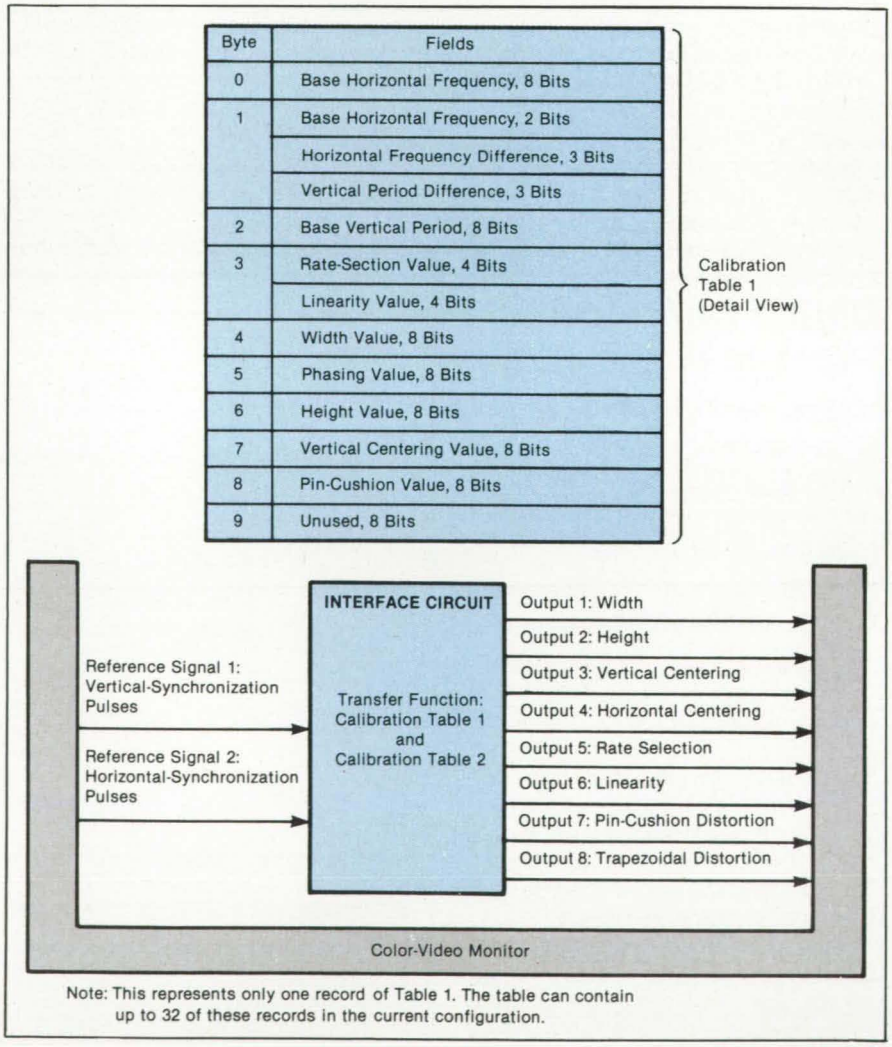


Figure 1. The **Interface Circuit** measures the frequencies of the horizontal- and vertical-synchronizing pulses. When these frequencies fall within a combination of preset ranges, the interface generates an associated preset combination of eight picture-adjusting signals.

"lookup" tables that specify the outputs for input frequencies in various combinations of nonoverlapping ranges. Table 1 contains the adjustment records, which are defined by the operator during the initial calibration. Table 2 contains fixed calibration values that are used when Table 1 does not contain an entry for a particular video signal. An important feature is that the contents of Table 1 are maintained in nonvolatile memory.

The interface repeatedly measures the two pulse frequencies. A match is found when each frequency lies within the range specified in a particular adjustment record, and the two most recent consecutive readings of the frequencies differ by no more than one count. When a match is found, the values in the adjustment record are used to control the monitor. When a match is not found, the interface uses arbitrary values from Table 2 that keep the monitor in a safe operating condition and that might accidentally provide a correctly adjusted picture with some input video signals.

The adjustment records are made during an initial calibration, which is conducted with the help of a computer connected to the monitor (see Figure 2). A video generator is set to one of the anticipated combinations of signal parameters. For each combination, the interface is allowed to adjust the monitor from Table 2. The operator then makes fine adjustments manually for the best picture. The optimized adjustment values, along with the horizontal and vertical frequency range for that combination, is then stored in Table 1. The procedure is repeated for each different combination.

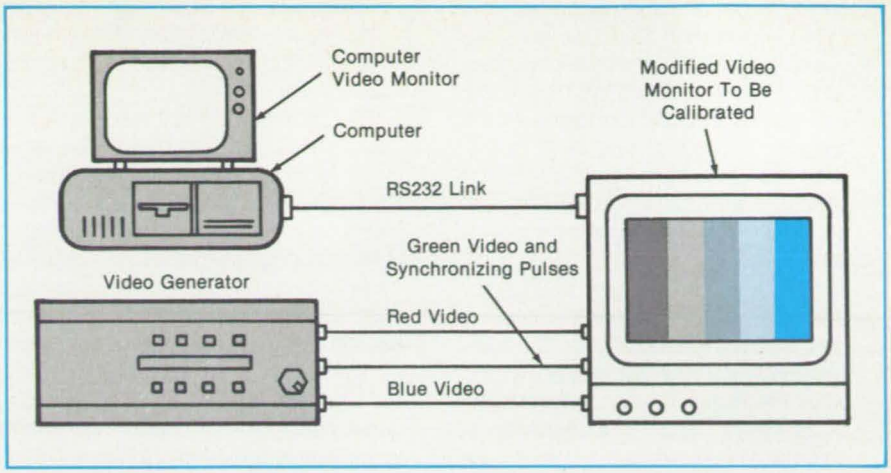


Figure 2. The **Video Monitor Is "Trained"** by a computer that helps to control the calibration procedure and inserts the values in the calibration tables.

This work was done by Eric Rodriguez of **Goddard Space Flight Center**. *For further information, Circle 55 on the TSP Request Card.*
GSC-13076

Self-Identifying Emergency Radio Beacons

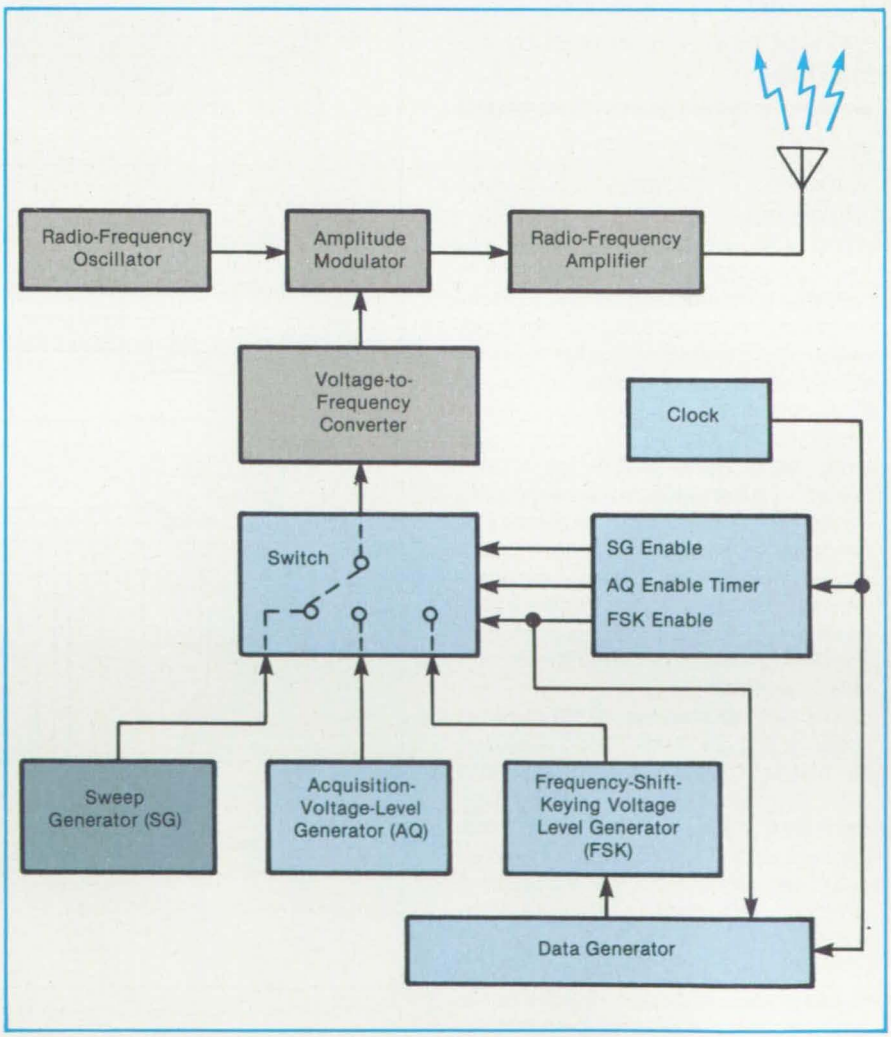
Rescue teams are aided by knowledge of the vehicle in distress.

Goddard Space Flight Center, Greenbelt, Maryland

An emergency radio transmitter gives information about the identity and/or type of vehicle in distress. Thus, it not only guides rescue workers to a downed airplane or sinking ship but also alerts them to the approximate number of people to be rescued and the nature of the rescue operation. It is similar to conventional emergency transmitters except that it contains additional timing and modulating circuits.

In the transmitter (see figure), a radio-frequency (RF) oscillator produces the 121.5-MHz sinusoidal carrier signal assigned by the FCC. The transmitter also contains a voltage-to-frequency converter with a range of 0 to 1,600 Hz. An amplitude modulator impresses the sinusoidal output of the voltage-to-frequency converter on the carrier, producing an amplitude-modulated RF signal. A nonlinear RF amplifier boosts the modulated carrier signal, providing a frequency-doubled output at 243 MHz as well as an amplified 121.5-MHz output.

Under control of a timer and switch, the transmitter broadcasts three signals in a predetermined sequence:



Additions to a Standard Emergency Transmitter, depicted in color, enable the transmitter to send rescuers an identifying signal in addition to the conventional distress signal created by the sweep generator. The data generator contains the identifying code.

1. An RF carrier amplitude-modulated at a typical frequency of 100 Hz serves as acquisition signal. When an Earthbound or orbiting station receives this tone, it recognizes that an information signal will follow and prepares to receive it. To produce the acquisition signal, the switch connects an acquisition-voltage-level generator to the voltage-to-frequency converter.
2. An RF carrier is amplitude-modulated by a series of tones of two distinct frequencies, typically 150 and 250 Hz. The lower frequency tone represents binary "zero," while the higher frequency tone represents binary "one." The sequence of zeros and ones provides a unique code that identifies the transmitter and its vehicle to the rescuers.
3. A conventional RF carrier is amplitude-modulated by a tone that repeatedly descends from about 1,600 to 800 Hz. This is the conventional distress signal, and when demodulated by the rescuers' receiver, it sounds like a siren. The switch connects a sweep generator to the voltage-to-frequency converter to produce this signal.

The pattern of binary zeros and ones from the data generator may be the identification number of the vessel or aircraft. A 30-to 128-bit field is adequate for this type of identification and can convey such additional information as the type of emergency and the latitude and longitude. A low pulse repetition rate — on the order of 32 pulses per second — ensures accurate transmission without error-correcting codes.

To produce the identifying signal, a frequency-shift-keying voltage-level generator generates two distinct voltages in direct response to the voltages of the binary outputs of a data generator. One voltage sets the output of the voltage-to-frequency converter to 150 Hz; and the other, to 250 Hz. The frequencies are sufficiently different from the acquisition signal and the conventional distress signal to ensure reliable demodulation.

The conventional sirenlike distress signal should last fairly long to maximize the probability of its detection by local aircraft and search parties. The acquisition signal merely indicates that an identification signal is coming; both the acquisition and data signals can be short. For 128 bits transmitted at 32 bits per second, the identification signal would last 4 seconds. The acquisition signal would be of equal duration. The siren signal would last 52 seconds, giving a 1-minute cycle.

This work was done by Morton L. Friedman of **Goddard Space Flight Center**. *For further information, Circle 94 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Goddard Space Flight Center [see page 20]. Refer to GSC-13089.

Cavity-Modulation Autotuner for Hydrogen Maser

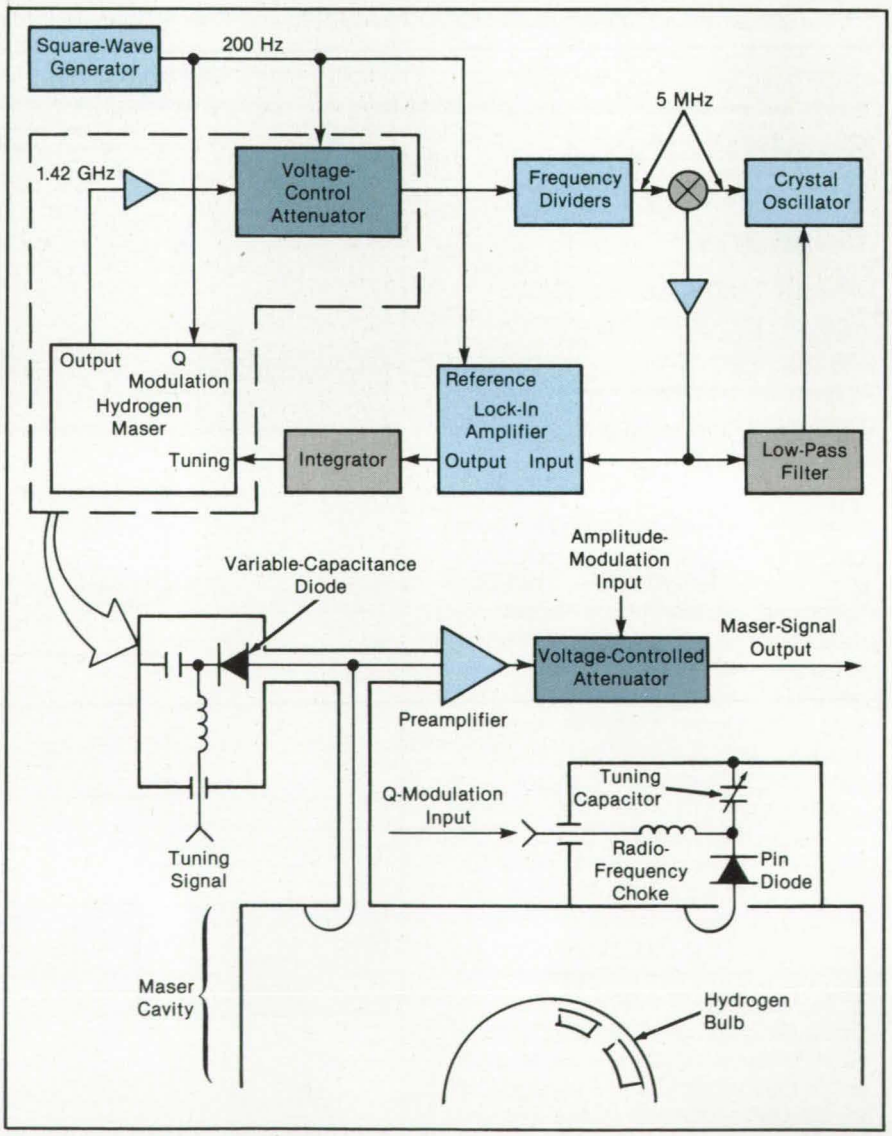
Resonance is maintained without incidental frequency modulation.

NASA's Jet Propulsion Laboratory, Pasadena, California

A cavity-modulation tuning system maintains the resonance of a hydrogen-maser cavity automatically, thereby stabilizing the maser frequency, without introducing the undesirable frequency modulation caused by other tuning systems. As its name implies, the system tunes the maser cavity rapidly by modulating one of the physical characteristics of the cavity that affect the resonant frequency. According to calculations, the long-term frequency stability of a maser equipped with the autotuner could be as good as $3 \times 10^{-13} \tau^{-1/2}$ (where τ is the observation time in seconds).

In cavity-modulation autotuning, a phase or amplitude modulation is caused by, and is proportional to, a deliberate periodic mistuning, in which the cavity resonance is dithered about a nominal adjustment point. The modulation is detected by a phase-sensitive amplifier, the output of which is used to derive a slow modulation (tuning signal) that corrects the frequency error of the adjustment point.

The modulator portion of the tuner is made of a few electronic components mounted on the maser cavity (see figure). The dithering signal — a 200-Hz square



The **Frequency-Controlling Components** of the tuning system are placed at the maser cavity, within the maser vacuum. The thermal environment is well controlled, and the device is insensitive to the driving signal: these features contribute to the stability of the maser frequency.

wave — is applied to a positive/intrinsic/negative (PIN) diode. The tuning signal is applied to a variable-capacitance diode.

By a suitable choice of the parameters of the PIN diode and the components with which it is mounted and coupled to the cavity, the effective diode-circuit capacitance can be made to remain constant when the current through the diode is varied. In that case, the diode-resistance variation due to the modulating signal affects only the ratio of reactance to resistance (Q) of the circuit. Although the Q of the maser and, therefore, the phase of the maser output are modulated, the frequency of the maser output remains the same. The circuit can therefore be operated in a low-Q condition without adversely affecting the frequency stability.

In experiments, the tuner compensated for variations in the maser-cavity frequency with a loop gain greater than 1,000. Amplitude modulation incidental to the Q modulation was also compensated by applying the 200-Hz square wave to a voltage-controlled attenuator. The tuner should be of interest to those concerned with precise measurements of time and frequency.

This work was done by G. J. Dick and T. K. Tucker of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 79 on the TSP Request Card.*
NPO-16906

Portable Test and Monitoring System for Wind-Tunnel Models

Model instrumentation can be tested in or out of the wind tunnel.

Langley Research Center, Hampton, Virginia

A portable system has been developed to test and monitor the instrumentation used in wind-tunnel models. The system is currently in use at the Langley Research Center 16-ft (4.9-m) wind tunnel.

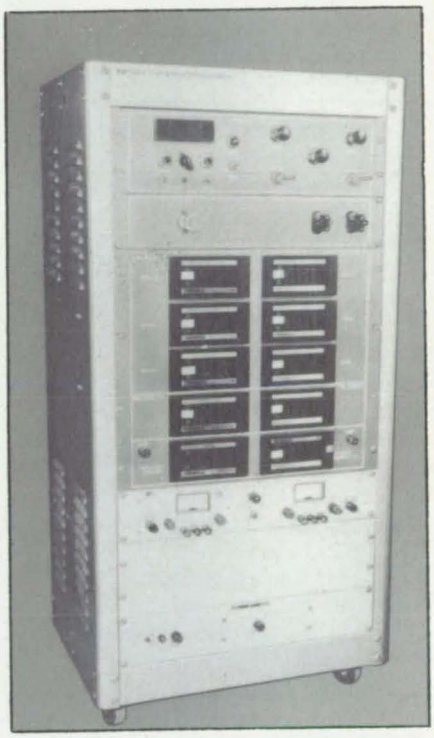
This system has the capability of monitoring balance readouts on all six wind-tunnel model components: normal, axial, pitch, roll, yaw, and side. It can be used for checking thermocouples and electrical leads for continuity and for leak-checking pressure transducers. It was developed as a completely portable and self-contained unit that can be moved to the location where the work is being performed.

The primary benefits realized with the portable test and monitoring system are associated with a saving of time. The models used in this major wind-tunnel facility are very complex. Previously, about 30 percent of the facility occupancy time was devoted to model calibration and buildup. Without this system, a large portion of the pretest buildup of a wind-tunnel model cannot be conducted until the model is inserted into the tunnel and connected to the data-acquisition system, wasting valuable tunnel time.

With the full utilization of this portable equipment, a portion of the calibration and checkout work can be accomplished outside of the facility, shortening the time required for model installation. Because of these features, this system can be used for checkout during model buildup before the model is installed in the wind tunnel or for trouble-shooting model-instrumentation problems after the model is installed in the tunnel.

This work was done by Charles A. Poupard 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 20]. Refer to LAR-13405.



The **Portable System Is Self-Contained** and can be moved easily to the model, either before or after the model is installed in the wind tunnel. The system is 44½ in. (113 cm) high, 22 in. (56 cm) wide, and 17 in. (43 cm) deep and weighs 100 lb (45 kg).

New Products

Powerex, Inc. (Youngwood, PA) has released a full-color brochure on their new FET-MOD and MOSBIP isolated power modules. The products were created specifically to address problems in circuit design for high-frequency applications up to 100 kHz. The brochure presents relevant technical information including dimensional drawings, circuit diagrams and charts delineating ratings and electrical characteristics. For a copy of the brochure, **Circle Reader Action Number 598.**

Netzsch Inc. Exton PA has expanded its line of thermal expansion instruments. The Model 402E/7 2000 Dilatometer features a water cooled graphite furnace, graphite sample support and W-Re Thermocouple for sample temperature. A ceramic system is easily substituted for operation in oxidizing atmospheres up to 1700 degrees C. Computer based data analysis is available. **Circle Reader Action Number 597.**

Design Components, Inc., Franklin, MA, has introduced Smart Slide, an integrated, single axis positioning system that includes a precision linear table, a microprocessor-based motion controller, and a high performance motor drive. Users can tailor the system to exact operating conditions without any previous motion control knowledge. **Circle Reader Action Number 589.**

New high frequency oscilloscopes from **Philips Test & Measurement** (Everett, WA) offer a bandwidth that breaks the 400 MHz barrier. The PM 3295A and PM 3296A series oscilloscopes have an autoset function that automatically selects channels, sets the amplitude range, timebase speed, trigger functions and screen position for any input signal with a single button. Both models can be supplied with a nonvolatile memory for 75 complete front-panel settings. An infrared remote control unit allows instant recall of the settings. **Circle Reader Action Number 588.**

Amoco Laser Company has introduced the ALC 1064-50 Laser Diode Pumped Solid State Infrared Microlaser. The 1¾ inch diameter, 4 inch long laser head produces 50 mW of TEM_{∞} 1064 mm light. Designed for testing optical coatings and nonlinear materials, alignment of high power YAG systems, and general research and development use, the new microlaser has a stability of ± 2% and a noise level of less than 0.2% RMS. **Circle Reader Action Number 586.**

NCR Microelectronics Division has announced the availability of fully qualified plastic packages in both pin-grid arrays and quad flat packs for high-pin count products including application specific integrated circuits. The plastic lidded pin-grid array package has a single layer epoxy glass substrate with a nickel/gold plated routed cavity. Leads are solder plated, phosphor bronze with a .100 inch pitch and support through-hole assembly. **Circle Reader Action Number 585.**

Physical Sciences

Numerical Simulation of Silicon-Ribbon Growth

A mathematical model includes nonlinear effects.

NASA's Jet Propulsion Laboratory, Pasadena, California

A mathematical model in development will simulate the growth of a silicon ribbon from a melt. Unlike previous models, this one takes account of the entire temperature and stress history of the ribbon. The material history is important because it strongly affects the achievable quality and growth rate of the product. Numerical simulations performed with the new model will help in the search for the temperature distribution, pulling speed, and other conditions that favor the growth of wide, flat, relatively defect-free silicon ribbons for solar photovoltaic cells at economically attractive, high production rates. The model is also applicable to materials other than silicon.

Silicon ribbons can be grown in widths of up to 2 cm and at speeds of up to 1 cm/s. At greater widths or speeds, ribbon growth tends to become unstable at the ribbon/melt interface, ribbons tend to buckle transversely to the direction of growth, and residual stresses cause both shattering during cutting and dislocations in crystal structure that degrade electrical efficiency. For realistic numerical simulations, the model takes account of the accumulation of thermal and mechanical changes that cause these deleterious effects.

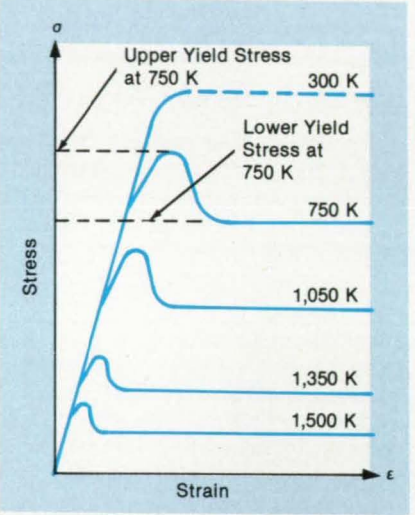
The ribbon is treated as a plane membrane so that the problem can be simplified to two dimensions. The two-dimensional stress/strain equations include the effects of elastic, plastic, and creep strains; total displacements; thermal expansion; and gravitation (see figure). In practice, the gravitational stress is negligible. The thermal components of strain are expressed in terms of the temperature distribution and the coefficients of thermal expansion. The tendency toward buckling is evaluated in the usual way, by seeking the solution for ribbon bending in the presence of in-plane stresses only.

To simulate the highly nonlinear effects of plasticity, the model must include the following:

- A criterion to determine whether the material has yielded;
- A flow rule to compute the incremental plastic strain;
- A hardening rule to follow the stress-included changes of the yield surface;
- A rule for the temperature dependence of the yield stress (see figure) to follow the changes of the yield surface with temperature; and
- A rule for the annealing mechanism to compute the dissipation of accumulated plastic strains.

The creep loading is related to the viscous behavior of silicon at high temperatures. The simulation incorporates the Sumino model of silicon viscosity, which expresses the creep rate in terms of the temperature, the dislocation density, and other parameters dependent on the material.

The combined equations for the stresses, strains, displacements, and temperature distribution are placed in finite-spatial-element form, with spatial and temporal thermal boundary conditions. At each time step, the position of the ribbon (and consequently the boundary and solution domain) is incremented to simulate the ribbon motion, and the spatial solutions are obtained. For the history-dependent quantities, the increments at each time step are accumulated.



The **Stress-vs.-Strain** relationship of silicon is highly nonlinear and temperature-dependent in the high-temperature, plastic-flow region.

This work was done by Ben K. Woda, Chin-Po Kuo, Senol Utku, and Sujit Kumar Ray of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 122 on the TSP Request Card.*
NPO-16805

Books and Reports

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

Convective Evaporation of Sprayed Liquid

The behavior of clusters of drops is analyzed.

A theoretical model has been developed to analyze the behavior of both dense and dilute clusters of evaporating liquid drops in gas flows. The model is particularly useful in the search for methods of controlling the evaporation, ignition, and combustion of fuel sprays.

The analysis is based on a cluster of drops, all of the same size, uniformly distributed in a cluster volume, V_c, which is embedded in a gaseous control volume, V. The drops are treated as moving with respect to the gas, but not with respect to each other. Each drop is considered to be surrounded by an imaginary sphere of influence, the radius of which is half the distance between adjacent drops; the ensemble of the spheres of influence and the spaces between them constitute V_c.

The quiescent evaporation of each drop within its sphere of influence is modeled by

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Circle Reader Action No. 540

quasi-steady convective/diffusive differential equations for species and heat. These equations are coupled to the equations for the nonuniform temperature within the drop through the boundary conditions at the drop surface. The solutions of these equations are used in an integral set of equations that describe heat, mass, and species conservation over the entire V_c, and the global equation of state completes the formulation for the quiescent condition. Convective evaporation is described with the help of a previously developed correlation between the quiescent evaporation rate, the evaporation rate in convective flow, and the Reynolds number. In this case, the Reynolds number is based on the drop radius and the relative velocity between the cluster of drops and the gas.

The equation for the conservation of momentum in V treats the drop cluster and the gas as two interpenetrating fluids. The transfer of momentum between the drops and the gas is assumed to occur through evaporation, fluid-flow interaction that can be expressed in the form of a drag coefficient, and small pressure gradients: this splitting enables the model to yield the correct limits in the case of no evaporation, no slip (zero relative velocity), or quiescent ambient gas.

Calculations for a spray of n-decane in air revealed several distinctive evaporation regimes at different fuel/air ratios. Very dense clusters were found to evaporate in a diffusion-controlled regime, while very dilute clusters were found to evaporate in a convection-controlled regime. Between these extremes is a convection/diffusion regime where both phenomena influence the lifetime of the drop cluster. These results are insensitive to the drag model: three different drag models showed less than 10-percent variation in the evaporation time.

The effects of important parameters were investigated in the various evaporation regimes. The initial relative velocity was found to be a weak control parameter for both dense and dilute clusters. The variation of the evaporation time with the initial ambient temperature is basically the same for both dense and dilute clusters. For both dense and dilute clusters the internal drop temperature relaxes quickly to a nearly uniform condition, but transients persist throughout the drop lifetime.

The drop lifetime in a dilute cluster depends weakly on the initial drop temperature, while for dense clusters the dependence is weak in the higher-temperature regime and strong in the lower-temperature regime. For a given air/fuel mass ratio, the evaporation time of a dilute cluster is very insensitive to the fraction of the fuel mass that is initially in vapor form, but the evaporation time of a dense cluster decreases linearly with an increase in the initial fuel-vapor fraction.

This work was done by Josette Bellan and Kenneth G. Harstad of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Analysis of the Convective Evaporation of Dense and Dilute Sprays," Circle 36 on the TSP Request Card. NPO-16955*

Predicting Visible Range of an Object

The relative angles of light sources and object orientation are taken into account.

A report and supplementary materials present a method for estimating the maximum distance at which the Spartan free flyer can be seen by star trackers on the Space Shuttle. The ability to detect the Spartan, or another object, depends on the brightness of the object relative to that of other visible sources. The brightness, and consequently the visible range, is calculated by using a simplified model of the object as a reflector, taking into consideration the orientation of the object and the predicted relative positions of the Shuttle and the Sun.

The Spartan reflector model is a rectangular parallelepiped having a diffuse reflectance of 0.05 on one of the end faces

and 0.82 on all of the other faces. The model is considered to be illuminated by solar radiation and by light reflected from the Earth. A conservative average Earth albedo of 0.30 is adopted, and the illumination of the Spartan by the reflected light is approximated by summing the reflections toward the Spartan from finite Sun-illuminated surface elements of the Earth visible from the Spartan.

Illuminated by the combined direct and Earth-reflected solar radiations, the Spartan reflector model becomes, via its own reflectivity, a model light source itself. The intensity of this Spartan source varies with direction of observation, and its intensity in the Shuttle direction determines the desired visible range. The light reflected into the Shuttle star trackers from each Spartan face visible from the Shuttle is calculated from the intensity of its combined illumination, its reflectivity, and its angle to the Shuttle/Spartan line.

The angles for the photometric calculations are obtained from the fundamental geometric relationships among the positions of the Sun, Earth, Shuttle, and Spartan, and from the orientation of the Spartan. The inputs for the angle calculations are obtained from the ephemerides of the Sun and the Shuttle, and from the anticipated schedule of Spartan maneuvers.

The working range is defined as the distance at which the Spartan brightness is at least third stellar magnitude, the level needed for reliable detection by the star trackers. Because of the uncertainties in predicting actual Spartan/Shuttle distances, the visibility-prediction problem is formulated to compute the working range from the other variables. In practical applications, a series of computed ranges covering all or a part of a Spartan free flight can be plotted against time and compared to actual range values or limits to determine the usefulness of optical tracking during the flight.

This work was done by Joseph C. King of **Goddard Space Flight Center**. *To obtain a copy of the report, "Continuous Prediction of Spartan Visibility from Orbiter Over Modeled Free-Flight Mission" and the summaries "Optical Tracking" and "Method for Predicting Free-Flyer Visibility from Shuttle," Circle 54 on the TSP Request Card. GSC-13078*

Testing Long-Term Exposure to Vacuum

A laboratory facility enables storage of materials under controlled vacuum conditions.

A facility for studying the long-term effects of vacuum on materials is described in a report. The facility was built for testing specimens of materials used in solid-rocket motors, including propellants, castings, insulators, and liners.

The vacuum storage system maintains specimens at constant temperature and high vacuum. It enables the specimens to be removed easily and safely for analysis. It includes six canisters connected to a vacuum manifold. Samples of outgassing products from the specimens are collected on salt plates cooled to 50 °F (10 °C).

A nitrogen storage system maintains specimens at 77 °F (25 °C) in pure, dry nitrogen gas under a gauge pressure of 2 to 4 psi (14 to 28 kPa). It enables the comparison of control specimens with specimens exposed to the vacuum. It, too, consists of a set of canisters.

The canisters are maintained at the constant temperature of 77 ± 5 °F (25 ± 3 °C) by circulating heated water that flows through jackets on the canisters. An instrumentation-and-control system measures and records the operating parameters and generates control signals and alarm indications as necessary.

This work was done by D. L. Clark, Charles E. Forsyth, Thomas L. Rerucha, and William J. Arbegast, Jr., of Martin Marietta Corp. for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "In-Situ Vacuum Effects Testing of Solid Rocket Motor Materials," Circle 24 on the TSP Request Card. NPO-16944*

Materials

Thermosetting Fluoropolymer Foams

Uses include coatings, electrical insulation, and structural parts.

Goddard Space Flight Center, Greenbelt, Maryland

A new process makes fluoropolymer foams with controllable amounts of inert-gas fillings in the foam cells. Unlike foamed thermoplastic fluoropolymers, the thermosetting fluoropolymers do not require foaming additives that leave undesirable residues and do not have to be molded and sintered at temperatures of about 240 to 400 °C. Consequently, the thermosetting polymers may be better for use with electronic or other parts that are sensitive to high temperatures or residues.

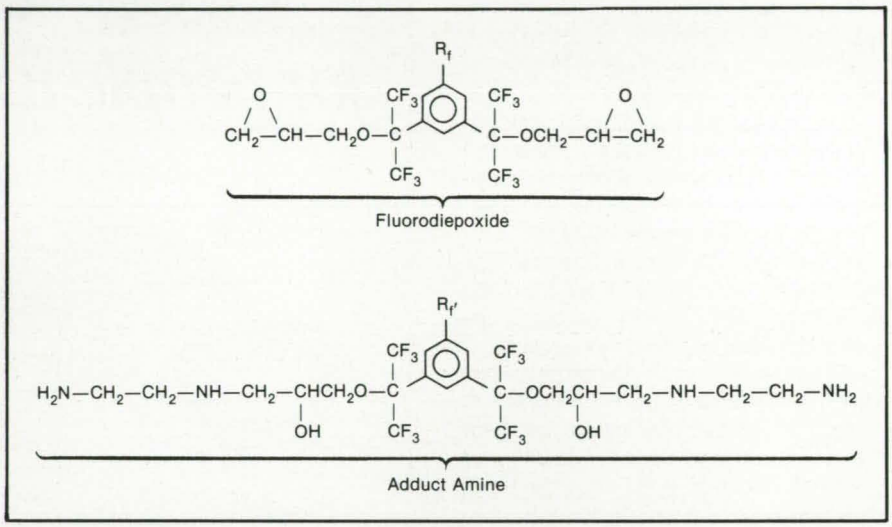
A typical thermosetting polymer is made from a fluorodiepoxide and a curing agent that is usually an adduct amine (see figure). These ingredients are liquid at or near room temperature. First, they are mixed in stoichiometric or other suitable amounts. After deaeration in a vacuum, the mixture is placed in a chamber, which is then pressurized with the desired filling gas at a pressure of several atmospheres.

The filling gas can be air, oxygen, nitrogen, or any of a variety of elements and compounds that do not react chemically with the mixture. Experiments have shown that the gas reacts physically with the mixture in a controlled way and that the gas can be squeezed into the mixture as long as the fluorine content of the mixture is at least 30 to 40 percent by weight.

The mixture is allowed to cure partially at room temperature. Once the mixture has gelled, the gas is trapped in the polymer.

The partially cured polymer is removed from the pressure chamber and heated to complete the cure. While the polymer is being cured, the trapped gas causes it to foam by heating. The depth of foaming depends on the type of gas and can be increased by increasing the pressure during the gas-trapping/partial-curing stage.

The type and amount of gas can be selected to impart a desired mass density. For example, the material might be foamed to the maximum possible extent to reduce the cost. (Fluoropolymers are relatively expensive.) A gas filling — possibly sulfur hexafluoride — might be chosen to enhance the dielectric properties of a foam to be used as electrical insulation. Another gas [oxygen or Freon (or equivalent)] might be chosen to support or retard combustion or to perform other specific functions.



These Ingredients are mixed at or near room temperature to form a thermosetting fluoropolymer. The fluorine content varies with the sizes of the perfluoroalkyl groups, R_f and R_f'.

This work was done by Sheng Yen Lee of **Goddard Space Flight Center**. *For further information, Circle 131 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Goddard Space Flight Center [see page 20]. Refer to GSC-13008.

Polyphenylquinoxalines Containing Alkylenedioxy Groups

Better processability is achieved through the lowering of glass-transition and melt temperatures.

Langley Research Center, Hampton, Virginia

New polyphenylquinoxalines (PPQ's) have been prepared from the reaction of novel bis(alpha-diketones) with aromatic bis(*o*-diamines). These PPQ's contain alkylenedioxy groups in their repeating units. They have lower glass-transition temperatures and melt viscosities and, consequently, better processability than the all-aromatic PPQ's. The tensile strength, modulus, elongation, adhesive strength, fracture energy, and solvent resistance of the new polymers are comparable with the properties of known PPQ's.

The incorporation of a flexibilizing segment such as an aliphatic or an alkylene-

dioxy group into the repeating unit of an aromatic/heterocyclic polymer is an effective way of reducing the glass-transition temperature and improving the processability. In this case, the flexibilizing alkylenedioxy unit was incorporated into the bis(alpha-diketone) portion of the PPQ repeating unit.

The PPQ's containing alkylenedioxy units of two to six carbon atoms within the backbone were prepared in high-molecular-weight forms. Their glass-transition temperatures ranged from 203 to 241 °C, decreasing with the increasing lengths of the alkylenedioxy groups. Solution-cast films had tensile strengths, tensile moduli, and elongations at room temperature as high as 14,400 psi (99 MPa), 378,000 psi (2.61 GPa), and 8.1 percent, respectively. The PPQ's were readily compression-molded to provide compact tension specimens that had fracture energies as high as 10.5 in.-lb/in.^{2} (1.84 kJ/m^2). Titanium-to-titanium tensile shear specimens provided average strengths of 4,400 psi (30 MPa) at 26 °C, 3,100 psi (21 MPa) at 177 °C, and 2,010 psi (13.9 MPa) at 203 °C. The PPQ's were resistant to normal aircraft fluids but were soluble in chlorinated solvents. These polymers are potentially useful as adhesives, coatings, films, and molded products, particularly for aerospace applications.

This work was done by Paul M. Hergenrother of **Langley Research Center**, *Stephen J. Havens of PRC Kentron, Inc., and Frank W. Harris of the University of Akron. For further information, Circle 3 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Langley Research Center [see page 20]. Refer to LAR-13601.

Books and Reports

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

Degradation of Reflectors and Dielectrics

Terrestrial and orbital effects are described.

A report describes the important degrading effects of the atmosphere and outer-space environments on reflective surfaces and dielectrics. For reflective surfaces, the terrestrial effects include soiling on glass surfaces and their changes with time. The space effects include the ultraviolet enhancement of contamination and possible surface erosion due to solar radiation, the impact of debris, and interactions with atomic oxygen. Dielectrics are similarly affected in both environments.

It is known from solar-energy programs that the primary agents of the degradation of reflectors in terrestrial applications are natural aerosols from vegetation, dust, ozone, and such industrial pollutants as sulfur. The main degradation effects in terrestrial applications are caused by water vapor coupled with airborne dust. In certain geographical regions, surfaces are damaged by hail. In low orbits around the Earth, the degrading agents are space debris, contaminating volatile materials emitted by adjacent equipment, and atomic oxygen. Damage by micrometeorites and photolysis of surface contaminants by ultraviolet or particulate radiation is also important.

Insulators that perform well in terrestrial applications may perform poorly in satellite applications. On the Earth, factors that degrade insulators are the same as those that degrade reflective surfaces. However, for insulators the primary concern regards the buildup of contamination surface layers that provide electrical-discharge paths over the surfaces. It has been found that water vapor, coupled with dust and temperature cycles due to weather, causes the most damage. In desert areas, insulation does not require frequent washing except near industrial pollution sources. In coastal areas, the presence of humidity and contamination necessitates frequent washing.

The effects of the orbital environment upon insulators are more complex than originally thought. The response of an insulator to postulated radiation, atomic oxygen, and contamination needs to be known for success in an intended application. Orbital altitudes, radiation-resistant materials, and low-outgassing adjacent materials may have to be chosen with a view toward the minimization of degrading effects.

This work was done by Frank L. Bouquet, Edward F. Cuddihy, and Carl R. Maag, Jr., of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Terrestrial and Space Effects on Reflective Surfaces and Dielectrics," Circle 86 on the TSP Request Card.*
NPO-16711

Advances in Thermoelectric Materials

Rare-earth chalcogenides and boron-rich borides show promise.

A report discusses the search for materials that will perform more efficiently in high-temperature thermoelectric conversion. It begins with a summary of developments during the past three decades. This is followed by a brief introduction to the theory of thermoelectric energy conversion, then by experimental findings and by some additional theory on specific materials.

The efficiency of conversion of heat to electrical energy in a thermoelectric couple increases with the difference between the squares of the Seebeck coefficients of the two materials and is reduced by heat conduction and Joule heating. These effects are summarized in a figure of merit, Z, which appears in the equation for the conversion efficiency and has the dimensions of the reciprocal of temperature. As Z increases, so does the efficiency. It is also common to use a modified definition of Z for a single material and then to compare different materials in terms of the dimensionless parameter ZT (where T = absolute temperature.)

Early theoretical work explained the transport properties of and guided the development of materials with high conversion efficiencies. In general, it has been found that the Seebeck coefficients of metals are too low, while the electrical resistivities of insulators are too high. Good compromises (the highest Z values) are made by choosing highly doped semiconductors that have intermediate Seebeck and resistivity values. The more significant developments have involved the estimation of optimum doping concentrations, the reduction of thermal conductivities by solid-solution doping, and the development of a variety of materials with ZT ≈ 1 in the temperature range of 300 to 1,200 K.

It would be a breakthrough to find materials with ZT ⩾1, that can withstand large hot-junction temperatures. The search has led to two classes of candidate materials: (1) the rare-earth chalcogenides, which have high vacancy concentrations, behave as conventional, highly degenerate n-type semiconductors at room temperature, and become partially degenerate at higher temperatures; and (2) the boron-rich borides, which exhibit hopping p-type conduction. In the interest of the compatibility of materials, it would be desirable to fabricate a thermocouple from n- and p-legs of the same compound. However, it appears extremely difficult to dope rare-earth chalcogenides p-type or boron-rich borides n-type.

This work was done by Charles Wood of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "High Temperature Thermoelectric Energy Conversion," Circle 89 on the TSP Request Card.* *NPO-16885*

Computer Programs

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Computer Programs

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Electronic Components and Circuits

Designing Rectangular RHCP Microstrip Antennas

A program calculates the configuration and the impedance.

RHCP, the Right-Handed, Circularly Polarized Microstrip Antenna program, aids in the design of a rectangular microstrip-antenna element, given the desired frequency of operation and characteristics of the substrate. RHCP begins the design calculations on the basis of a square element with linear polarization. The effective dielectric constant and changes in electrical length due to fringing at the edges of the radiating element are taken into account. A coaxial feed is inset with 50 ohms input impedance. By placement of the feed such that two orthonormal modes are produced in the antenna cavity, right- or left-handed circular polarization is obtained.

The input to RHCP consists of the desired frequency, the dielectric constant, and the thickness of the substrate. The output consists of the final rectangular configuration, the proposed placement of the feed inset, and the actual input impedance.

RHCP has been used successfully for frequencies between 2 and 15 GHz for thin substrates. This program was used to design antenna elements for the S-band quad antennas on board the Space Shuttle and is a part of the design project for the S-band phased-array-antenna radiating aperture.

RHCP is written in FORTRAN 77 for interactive execution and has been implemented on a DEC VAX-series computer operating under VMS. The program was developed in 1985.

This program was written by Shayla E. Davidson of **Johnson Space Center**. *For further information, Circle 51 on the TSP Request Card. MSC-21180*

PCACE — Personal-Computer-Aided Cabling Engineering

Routine aspects of the design of wiring harnesses are automated.

The PCACE computer program has been developed to provide an inexpensive, interactive system for learning and using an engineering approach to interconnection systems. PCACE is basically a database system that stores information as files of individual connectors and handles wiring information in circuit groups stored as records. This directly emulates the typical manual engineering methods of handling data, thus making the interface between the user and the program very natural.

Data files can be created, viewed, manipulated, or printed in real time. The printed output is in a form ready for use by fabrication and engineering personnel. PCACE also contains a wide variety of error-checking routines, including checks of connector contacts during printing.

The user can edit existing files of data on wiring harnesses or create new files. In creating a new file, the user is given the opportunity to insert all the connector and harness "boilerplate" data that would be part of a normal connector wiring diagram. These data include connector reference designator, connector part number, backshell part number, cable reference designator, cable part number, drawing revision, relevant notes, standard wire gauge (in the Apple version only), and maximum circuit count. Any item except the maximum circuit count may be left blank, and any item may be changed later.

Once a file is created and organized, the user is directed to the main menu and has access to the file boilerplate, the circuit-wiring records, and the wiring-records index list. The organization of a file is such that record zero contains the connector/cable boilerplate, and all other records contain circuit-wiring data.

Each wiring record handles a circuit with as many as nine wires in the interface. The record stores the circuit name and wire count and the following data for each wire: wire identifier, contact, splice, wire gauge, wire/group type, wire destination, and note number. The PCACE record structure provides for a wide variety of wiring forms using splices and shields, yet retains sufficient structure to maintain ease of use.

PCACE is available in two versions. The Apple version is written in P-Code Pascal and has been implemented on an Apple II computer with a memory of 64K of 8-bit bytes, two 5¼-inch floppy-disk drives, and an Epson MX-series printer. It was developed in 1983. The IBM PC version of PCACE is written in TURBO Pascal 3.0 and has been implemented on IBM PC, XT, and

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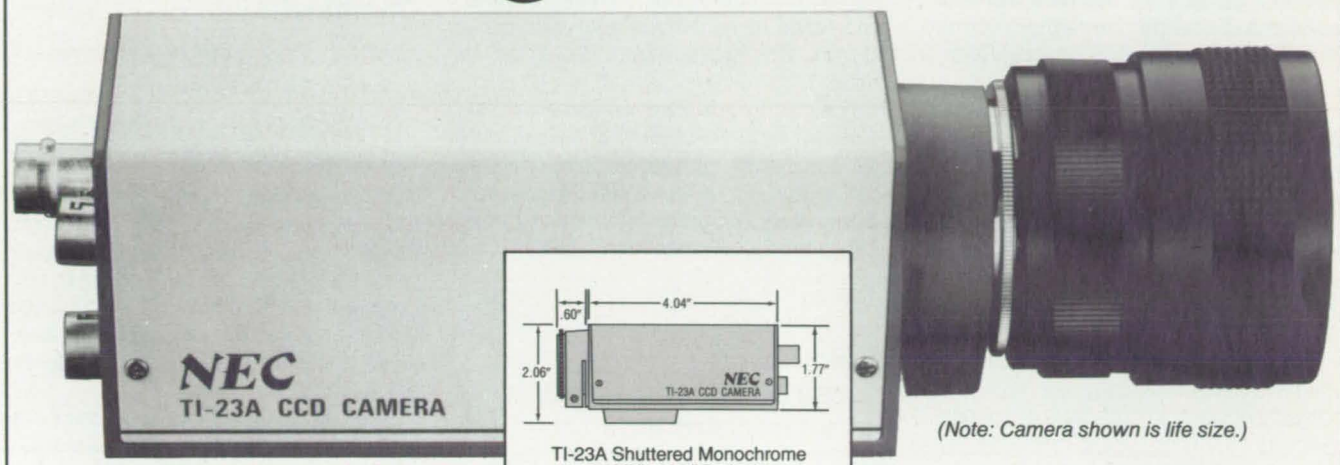

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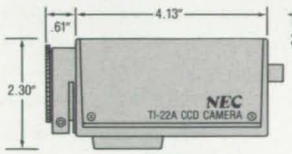

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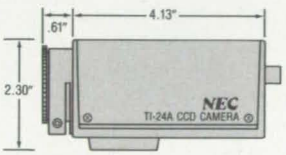

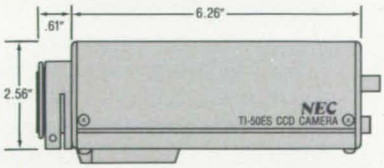

TI-50ES High-Speed
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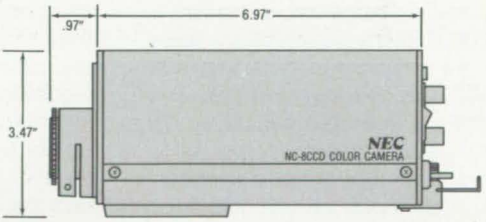

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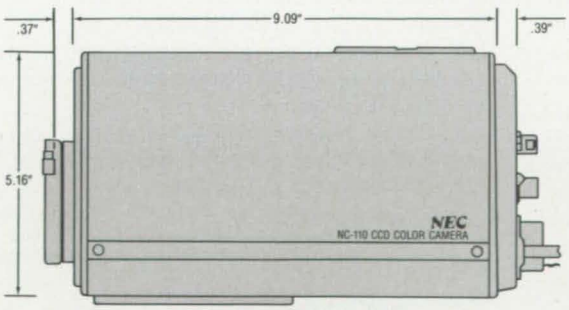

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652-041

Circle Reader Action No. 369

AT systems under DOS 3.1 with a memory of 512K of 8-bit bytes, two floppy-disk drives, an RGB monitor, and a printer with ASCII control characters. The IBM PCACE was developed in 1986.

This program was written by Joseph W. Billitti of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 58 on the TSP Request Card.*
NPO-17006

Assessment of Advanced Concentrator Photovoltaic Modules

Many designs are analyzed in terms of cost and efficiency.

A computer program was developed to estimate probabilistically the total and component costs to end users of concentrating photovoltaic arrays in the 1990's. The program is based on a modified version of the SIMRAND program (SIMRAND — Simulation of Research and Development projects — is available separately from COSMIC) to estimate the total cost of a system for a large number of module designs. The module design that yields the minimum cost for the total system is then chosen as the preferred design. To obtain a distribution of expected module costs, a simulation is performed. The component estimates made by SIMRAND include the efficiency of a module and the costs of a cell, an assembly of cells, an assembly of lenses, and an assembly of modules.

The program includes 120 possible module designs representing concentrators of 200×, 500×, and 1000×. These 120 designs are put through 500 trials with SIMRAND. A second program is then used to examine a selected subset of the SIMRAND cases; for example, only 200× concentrators or only concentrators contained in plastic housings with heat sinks. The input variables include the efficiency of the lenses, the time value of money, and the costs of the substrate, heat sink, packaging, interconnections, optical elements, and antireflective lens coatings. These variables are used to produce 34 distributions, such as the baseline cost of silicon, the advanced cost of silicon, the efficiencies of compression-molded lenses, the efficiencies of injection-molded lenses, the costs of plastic housings, and the costs of aluminum housings.

The documentation contains instructions on how to alter the number of designs, the number of distributions, and the probability of failure and the associated cost of failure for each distribution. The ouput includes the mean and standard deviation for each cost equation, a cumulative histogram for each cost equation, and a histogram of how many trials each module design won.

This program is written in FORTRAN 77 for batch execution and has been implemented on the IBM PC computer series under DOS (2.0 or higher) with a minimum central-memory requirement of 256K of 8-bit bytes. Two double-sided, double-density flexible-disk drives, or one megabyte of hard-disk space is also required. This program was developed in 1986.

This program was written by C. S. Borden and D. L. Schwartz of Caltech, and M. C. Davisson of Apogee Computer Designs, Inc., for **NASA's Jet Propulsion Laboratory** *For further information, Circle 98 on the TSP Request Card. NPO-17042*

Calculating Electromagnetic Fields of a Loop Antenna

Approximate field values are computed rapidly.

The MODEL computer program was developed to calculate the electromagnetic-field values of a large loop antenna at all distances to an observation point. The antenna is assumed to be in an x-y plane with its center at the origin of the coordinate system. MODEL calculates the field values in both rectangular and spherical components. It also solves for the wave impedance.

MODEL is not intended to give extremely accurate answers but to give acceptable answers very quickly. MODEL has been used to investigate the electromagnetic fields the Space Shuttle may encounter from some of the planned payloads that will emit low-frequency radiation. The program is a simple and fairly accurate tool for finding approximate field values in the near field of a large loop antenna.

MODEL is a quick interactive program. The user is prompted for the radius of the loop antenna, the starting frequency, the stopping frequency, the change in frequency, and information on the observation point. The output includes the coordinates of the observation point, the frequency, magnetic-field values, electric-field values, and the wave impedance.

MODEL is written in MicroSoft FORTRAN 77 for interactive execution and has been implemented on an IBM PC with a memory requirement of approximately 120K of 8-bit bytes. MODEL was developed in 1985.

This program was written by Mitchell B. Schieffer of McDonnell Douglas Corp. for **Johnson Space Center**. *For further information, Circle 108 on the TSP Request Card.*
MSC-21110

Physical Sciences

Improved General Chemical-Kinetics Program

More computational power is brought to bear on complicated, homogeneous ideal-gas reactions.

A new general chemical-kinetics code, GCKP84, has been developed to compute the progress of many types of complex gas-phase chemical reactions. This new code replaces the original GCKP code and offers greatly improved efficiency, additional capabilities, and greater convenience.

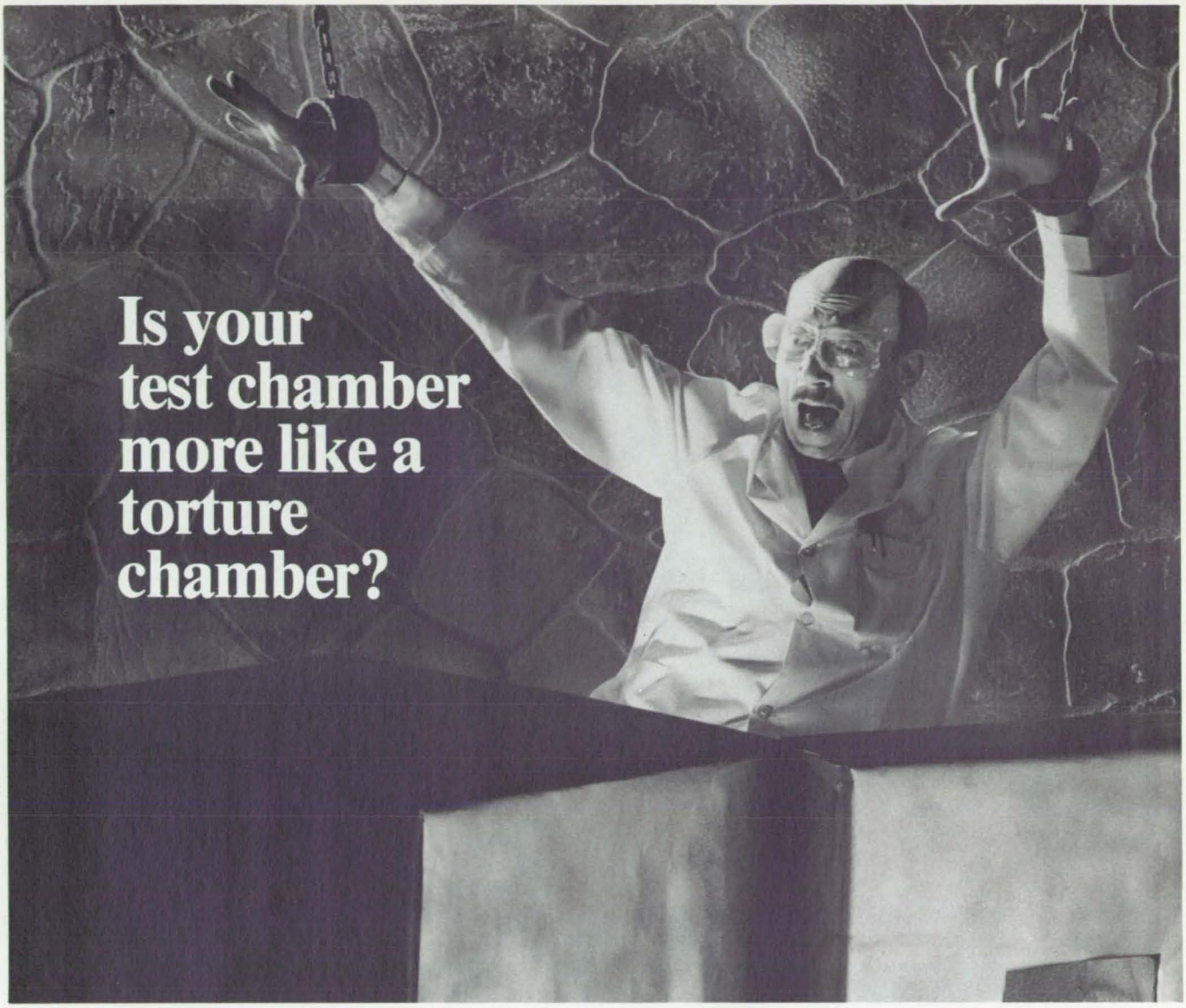
The original GCKP computed the progress of a general complex, homogeneous, gas-phase reacting system. The system was assumed to be adiabatic, and the reaction could be in a batch or in one-dimensional frictionless flow. Shock-tube kinetics and equilibrium combustion models were also included in the code. Any chemical system could be used if thermodynamic data for the species and the chemical-reaction mechanism (including rate constants) were known.

The new code, GCKP84, has the following seven new capabilities and convenient features:

1. Heat transfer between any reacting system and its surroundings can now be considered.
2. The well-stirred-reactor model is included.
3. A new implicit numerical-integration technique is used for greatly increased speed in integrating "stiff" differential equations. The speed of integration is increased by a factor of 10 to 20 over that of GCKP, while maintaining the same accuracy.
4. The new code can use several additional types of reaction processes, including photochemical reactions and reactions of activated species.
5. The input for combustion problems is simplified.
6. Rocket-performance parameters can be computed for any flow-expansion problem.
7. A well-stirred reactor followed by a normal flow reaction can be computed as a single case.

The new code is written in FORTRAN IV and was developed on the IBM 370/3033 computer.

This program was written by David A. Bittker and Vincent J. Scullin of **Lewis Research Center**. *For further information, Circle 18 on the TSP Request Card.*
LEW-14216



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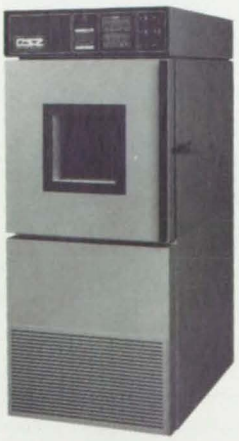

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Calculating Thermodynamic and Transport Properties of Fluids

A computer program incorporates a van der Waals equation and correction tables.

The accurate computation of the thermodynamic and transport properties of fluids is a necessity for many engineering calculations. The FLUID program was developed to calculate the thermodynamic and transport properties of pure fluids in both the liquid and gas phases. Properties are calculated by use of a simple gas model, empirical corrections, and an efficient numerical interpolation scheme. FLUID produces results that agree very well with measured values. FLUID is much faster than older, more complex programs developed for the same purpose.

A van der Waals equation of state is used to obtain approximate state values. These values are corrected for the effects of real gases by model correction factors obtained from tables based on experimental data. These tables also compensate accurately for the special circumstances that arise from phase transitions. Values of viscosity and thermal conductivity are computed directly from tables. Interpolation within tables is based on Lagrange's three-point formula. A set of tables must be generated for each fluid.

FLUID currently contains tables for nine fluids, including dry air and steam. The user can add tables for any fluid for which adequate data on thermal properties are available. The FLUID routine is structured so that it can be incorporated easily into engineering programs.

The IBM-360 version of FLUID was developed in 1977. It is written in FORTRAN IV and had been implemented on an IBM 360 with a central memory of approximately 500K bytes. The IBM-PC version of FLUID is written in Microsoft FORTRAN 77 and has been implemented on an IBM PC with a memory of 256K bytes. The IBM-PC version of FLUID was developed in 1986.

This program was written by Margaret P. Proctor of **Lewis Research Center** *and Mark D. Klem of the U.S. Air Force. For further information, Circle 93 on the TSP Request Card. LEW-14418*

Star-Tracker Computer Program

Image-analyzing pointing systems can be aimed to high precision.

The star-tracker program, STRACKER, was developed to solve algorithm-design problems for area-array tracking and pointing systems operating at accuracies of 0.001 to 0.01 picture element (pixel). Trackers and pointers of this accuracy are primarily required for the pointing of astronomical instruments. STRACKER includes auxiliary programs for reformatting point-spread data from the commercial ACCOS V lens-design program. Other optical-analysis program data can be reformatted by use of the utility routines included in the STRACKER package.

STRACKER calculates a simple centroid estimation of an arbitrary point-spread function supplied by the user. It then calculates a set of correction polynomials to best-fit the calculated centroid to the actual centroid as the actual centroid is moved over a pixel. Maximum and root-mean-square errors are calculated for all polynomials.

STRACKER displays the polynomial values and a pixel-error map showing, in two dimensions, the deviations from perfect pointing. STRACKER can also calculate the field variation of a set of point-spread functions, and local corrections thereof, distributed in an image field. The program is menu-driven and prompts the user for all required input. Options include the calculation, storage, and recall of sets of polynomials and the generation of plots of zones, full-field errors, and individual field-point errors.

STRACKER is written in FORTRAN 77 for interactive execution and has been implemented on a PRIME 550 computer operating under PRIMOS 19.1.6 with a central-memory requirement of approximately 250K bytes. STRACKER supports Tektronix 4025 and 4107 graphics terminals. The program was developed in 1986.

This program was written by Thomas Glavich of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 61 on the TSP Request Card. NPO-16862*

Materials

Calculating Transport of Moisture Through Honeycomb Panels

Diffusion equations are solved for steady-state and transient conditions.

HUMID is a computer program for predicting the moisture gradients and internal bursting pressure in composite honeycomb-sandwich panels. Advanced multilayer composite structures are usually degraded by absorbed moisture when subjected to high temperatures. HUMID was designed to monitor the ebb and flow of moisture in the Space Shuttle Orbiter payload bay doors, but is applicable for general use.

A sandwich panel consists of many layers of different materials with adhesives and facesheets surrounding a ribbon of honeycomb core. Absorbed moisture causes swelling and may alter the mechanical properties of a material. Moisture is transported to the core from the surface skin via rapid diffusion through trapped air. This phenomenon can be satisfactorily modeled by Fick's diffusion laws for both steady-state and transient conditions.

The diffusion response of each layer of different material to boundary humidities is represented in HUMID by a linear partial differential equation. The equations of all the layers are solved simultaneously with the ideal-gas law to yield structural moisture levels as a function of the environment.

The input to HUMID consists of such sandwich-layer parameters as thicknesses, densities, permeabilities, break temperatures, water solubilities, etc., and such environmental factors as the initial humidity of the layers; the duration of the flight; and the temperatures of the core and outer skin during ascent, re-entry, and cool-down. Typical HUMID results include the average moisture content of each layer of material. The contribution of water-vapor pressure to the honeycomb-sandwich internal pressure as a consequence of heating is also calculated. The internal bursting pressure and structural margins of safety can also be determined. HUMID produces plots of the moisture content against time, the temperature against time, and the margin of safety against time.

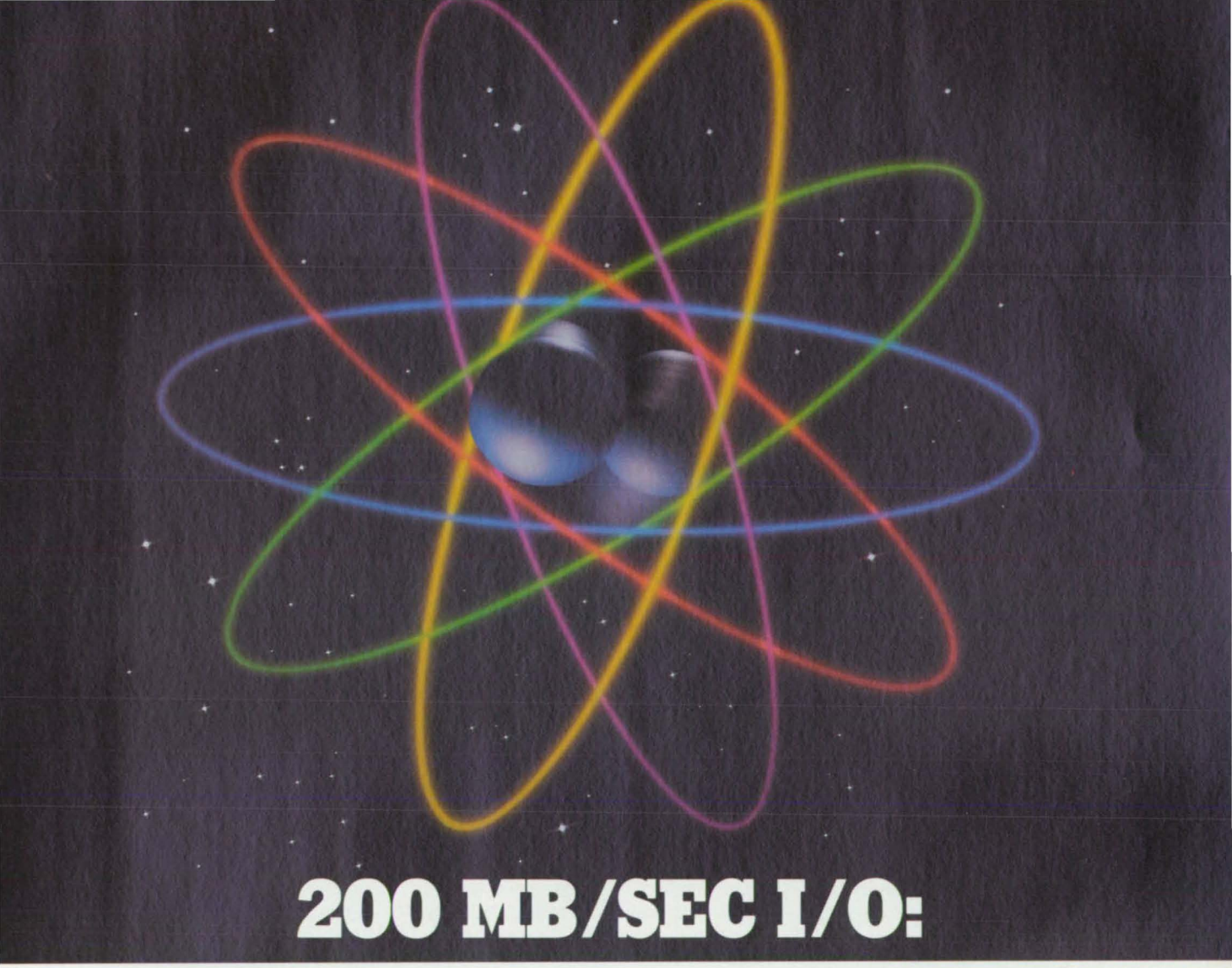
HUMID is written in FORTRAN for batch execution and has been implemented on an IBM 360-series computer operating under OS with a central-memory requirement of approximately 501K of 8-bit bytes. This program was developed in 1985.

This program was written by R. T. Martin and D. J. Zigrang of Rockwell International Corp. for **Johnson Space Center**. *For further information, Circle 159 on the TSP Request Card. MSC-21144*

Laminate-Moisture-Analysis Computer Program

The diffusion and the deleterious effects of moisture can be predicted.

The General One-Dimensional, One Material Moisture Analysis computer program was developed to predict the moisture gradient across a composite laminate where moisture enters two surfaces and flows in the direction between these surfaces. The mechanical properties of composites, especially matrix/fiber combinations, are adversely affected by moisture when subjected to high temperatures. This program was designed to monitor the flow



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of moisture in the Space Shuttle Orbiter payload bay doors but is applicable for general use.

Advanced composite structures are usually degraded by absorbed moisture. The resin in a composite part absorbs water, which slowly diffuses across the material. If the material is not chemically changed by this absorption, the detrimental effect on such properties as shear, plate buckling, and ply delamination can be reversed. At high temperatures, the resin may change from a glassy to rubbery state, and the thermal properties are altered drastically.

This program solves Fick's law of diffusion with the user's choice of finite-difference solution: Crank-Nicholson or backward-difference method. Diffusivity is allowed to be a function of moisture concentration and temperature, and the external surfaces can be exposed to transient-relative-humidity environments.

The input to the program consists of such laminate parameters as diffusivity, glass-transition temperature, and solubility and of such environmental factors as the initial humidity and the temperature history. Typical results include temperature and moisture levels at node points and the average moisture content of the laminate. The program produces plots of the moisture content against time, the temperature against time, and the margin of safety against time.

This program is written in FORTRAN IV (IBM Level H extended) for batch execution and has been implemented on an IBM 360 computer operating under OS/MVS with a central-memory requirement of approximately 152K of 8-bit bytes. This program was developed in 1982.

This program was written by Ronald T. Martin of Rockwell International Corp. for **Johnson Space Center**. *For further information, Circle 156 on the TSP Request Card. MSC-21143*

ICAN: Integrated Composites Analyzer

This program calculates macromechanical, micromechanical, and related environmental effects.

The importance of, and need for, multilevel analysis in the design of structural components made of multilayered fiber composites is well documented. As a result, the computer code ICAN has been developed to carry out comprehensive linear analyses of multilayered fiber composites. The program contains the essential features required to design structural components made from fiber composites. The program is an outgrowth of two in-house computer codes: MFCA (multilayered filamentary composite analysis) and INHYD (intraply hybrid composite design).

MFCA provides (1) micromechanical theories for the thermoelastic properties and the stress-level limit of a single ply or as functions of the properties of constituent materials and the particular fabrication process, (2) the combined stress/strength criterion for a single ply, and (3) analysis of the response of a single ply or of an entire multilayered composite structure, where the effects of interply layers are taken into account.

INHYD is the result of recent theoretical and experimental investigations of the mechanical behavior of intraply hybrids. The theoretical methods and equations, together with those for hygrothermal effects, have been integrated to form this computer code, which predicts hygral, thermal, and mechanical properties of intraply hybrid composites.

The synergy of MFCA and INHYD, together with several significant enhancements, has produced ICAN, which utilizes the micromechanical design of INHYD and the laminate analysis of MFCA to build a capability for comprehensive analyses of structural composites. One enhancement is a data base of material properties for commonly used fibers and matrices. The program searches and selects the appropriate properties from its library.

The inputs to the code are the properties of the constituent materials, factors that reflect the fabrication process, and the size and shape of the composite structure. The code performs micromechanics, macromechanics, and analysis of laminates, including the hygrothermal responses of fiber composites. The code outputs are the properties of the various plies and composites, the responses of composite structures, and results of analyses of stresses in composite structures, including detailed information about failures.

The code is in FORTRAN IV and can be used efficiently as a package in complex structural analysis programs. In addition, ICAN has been tested on the UNIVAC 1108, IBM 370, and CRAY 1 operating computer systems.

This program was written by Christos C. Chamis of **Lewis Research Center** *and Pappu L. N. Murthy of the National Research Council. For further information, Circle 144 on the TSP Request Card. LEW-14468*

Mechanics

Steady-State Thermal-Analysis Program for Microcomputers

A nodal-network model of heat flow is implemented by a computer program.

The Steady State Thermal Analysis Program (STEADY) provides the thermal designer with a quick and convenient method for the calculation of heat loads and temperatures. STEADY can be used on small nodal networks for conceptual or preliminary thermal design and analysis. STEADY will accept up to 20 nodes of fixed or variable temperatures, with constant or temperature-dependent thermal conductivities, and any set of consistent units.

In a steady-state thermal network, the heat balance on each variable-temperature node must sum to zero. The general heat-transfer equations are solved with a Newton-Raphson technique and refined by a fourth-order quartic solution. The input data include the number of nodes, the number of boundary nodes, the fixed temperatures at all boundary nodes, the initial guesses of the temperatures at the variable-temperature nodes, impressed heat loads, conduction and radiation coefficients, and such control parameters as convergence criteria, the maximum number of iterations, and damping factors. The output is stored in a print file, which tabulates final temperatures and heat flows for all nodes. STEADY is menu-driven and allows the user to save files for future modification.

STEADY is written in FORTRAN 77 (Ryan McFarland's RMFORTRAN) for interactive execution and has been implemented on the IBM PC computer series under DOS with a central-memory requirement of approximately 92K of 8-bit bytes with a math coprocessor, and 103K bytes without the coprocessor. This program was developed in 1986.

This program was written by S. W. Petrick and C. L. Cagle of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 99 on the TSP Request Card. NPO-17179*

Aerodynamic-Analysis Programs for Microcomputers

Lifts, drags, and moments can be calculated for subsonic and supersonic speeds.

A series of computer programs used for aerodynamic analysis at the NASA Langley Research Center has been modified for use on a microcomputer. The programs include an aerodynamic-analysis program for low-speed wing and flap systems (SUBAERF), a supersonic-wave-drag-analysis program (WDRAG2), and a supersonic-lifting-surface program (Lift Analysis). The programs are set up to run from a common geometry format with appropriate additional input data for each particular program.

SUBAERF provides estimates of the performances of wings, including the effects of attainable thrust and vortex lift, and analysis of simple leading- and trailing-

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edge flap systems. This low-speed wing/flap aerodynamic analysis is based on a lifting-surface solution from linearized theory.

WDRAG2 can be used to determine the wave drag of a configuration that may include a wing, a fuselage, and various combinations of nacelles, canards, horizontal tails, and vertical tails. The program uses the supersonic-area rule to determine the equivalent body-area distributions from which the wave drag is calculated. An optimization feature is included.

The Lift Analysis program determines distributions of lifting pressures, drag due to lift, pitching moment, and trimmed drag of a fuselage and wings with canard and/or horizontal tail configurations. The program employs modified methods of linearized theory to calculate lifting-surface pressures, both far-field and near-field methods to calculate forces due to configuration volume, and turbulent-flat-plate theory to calculate skin friction.

This package is written in FORTRAN 77 for interactive execution and has been implemented on the IBM PC series of computers operating under DOS with a central-memory requirement of approximately 256K of 8-bit bytes. The Lift Analysis program requires a hard disk. The SUBAERF and Lift Analysis programs require a math coprocessor and the commercial Lahey F77L compiler and Phoenix PLINK linker. (A Microsoft compiler and linker are not sufficient.) The package includes source, object, executable (except for Lift Analysis), and sample input/output files for each program. This collection of microcomputer programs was made available in 1986. The mainframe versions of these programs are available separately from COSMIC.

This program was written by Marie L. Knapp of PRC Kentron, Inc., for **Langley Research Center**. *For further information, Circle 96 on the TSP Request Card.*
LAR-13666

Computing Long-Term Orbital Motions

Drifts and lifetimes can be predicted.

The Long-term Orbit Predictor (LOP) is a trajectory-propagation computer program intended to be used as an analysis tool for studies of the lifetimes of orbiting spacecraft. It can be used for any planetary orbiting missions. Sample usages are included for studies of the drift cycle of an inclined geosynchronous station, of a Venus radar mapper, of the orbit of an Earth-ocean topography spacecraft, and for a frozen orbit about Mars.

LOP uses the variation-of-parameters method in the formulation of equations of motion. Terms involving the mean anomaly are removed from the numerical integration so that large step sizes, on the order of days, are possible. Consequently, LOP executes much faster than programs based on Cowell's method, such as the companion program ASAP. (The Artificial Satellite Analysis Program, ASAP, is available separately from COSMIC.)

Both programs use identical force models; i.e., with gravity fields of up to 21 by 21, lunisolar perturbation, drag, and solar-radiation pressure. The input includes classical orbital elements (either mean or osculating), orbital elements of the Sun relative to the planet, reference time and dates, drag coefficients, gravitational constants, planet radius, and rotation rate. The printed output contains the classical elements for each time step and such additional orbital data as true anomaly, eccentric anomaly, latitude, longitude, periapsis altitude, and the rates of change per day of certain elements. Selected output is additionally written to a plot file for postprocessing by the user.

LOP is written in FORTRAN 77 and can be compiled and linked by any F77 compiler. The IBM-PC version uses the Lahey F77 V2.0 compiler and Microsoft Linker under DOS and requires a minimum of 256K 8-bit bytes. The LOP package includes examples that use LOTUS 1-2-3 for graphical displays, but any graphics software package should be able to handle the ASCII data file. The LOP program was written in 1986.

This program was written by J. H. Kwok of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 91 on the TSP Request Card.*
NPO-17052

Numerical Simulation for Supersonic Inlets

Flows are calculated for realistic engine-inlet conditions.

The analytical study of large-scale transient flows in supersonic inlets and interactions of inlet flows with engine flows is of primary importance to the design and control of inlets. The optimum design of an inlet, its associated auxiliary air systems, and the inlet-control system is based on an understanding of the effects of flow transients on the history of the inlet flow and the attendant effect on the control and performance of the inlet. The computer code LAPIN (large-perturbation inlet) was developed to analyze the large-perturbation, transient-flow fields in supersonic inlets.

LAPIN is a robust, quick-running code capable of solving unsteady quasi-one-dimensional, inviscid-flow problems in mixed subsonic and supersonic regimes for inlets. Its approach is based upon a quasi-one-dimensional, inviscid, unsteady formulation that includes engineering models of unstart/restart, bleed, bypass, and geometrical effects. The numerical solution of the governing time-dependent equations of motion is accomplished through a shock-capturing, finite-difference algorithm. A few of the important numerical features included in the code are the following:

- Implicit Solution Algorithms — The Beam and Warming and the MacCormack implicit methods have been included to provide fast solutions under slow transients or under time-asymptotic conditions.
- Explicit Solution Algorithms — The MacCormack explicit method has been incorporated in the code to yield efficient solutions for highly transient flows.
- Split-Flux Schemes — To provide robust solutions for highly transient flows with moving shocks, split-flux schemes were applied to both the MacCormack and the Beam and Warming algorithms.

To model inlet flows accurately, the code uses precise inlet- and exit-plane boundary conditions. For the exit plane, these include specified exit-plane pressures and corrected mass flow as a function of time. For the inflow boundary, these include a specified mach number for the fully started inlet and code adaptability to model inlet unstart. LAPIN utilizes both explicit and totally-implicit boundary conditions in the inlet code to provide totally-compatible numerical schemes.

The code includes a number of sophisticated engineering features for treating such real inlet phenomena as translating center bodies, throat bleed, moving ramps, and variable engine-bypass flow — all with real-time variation. The code, designed by use of the top-down modular approach, is highly interactive with the user. It has been verified against data from unsteady tests of axisymmetric and two-dimensional engine inlets over a wide range of free-stream and geometric conditions.

The program is written in FORTRAN IV for execution on the IBM 370 or the VAX-11/780 and contains approximately 6,100 lines of source code.

This program was written by M. O. Varner, W. R. Martindale, W. J. Phares, K. R. Kneile, and J. C. Adams, Jr., of Sverdrup Technology, Inc., for **Lewis Research Center**. *For further information, Circle 95 on the TSP Request Card.*
LEW-14324

Machinery

Computing Aerodynamics of Propfans

The cost and duration of wind-tunnel tests could be reduced.

High-speed turboprops (propfans) have the potential to reduce significantly the fuel consumption of current transport aircraft. The propfans also offer higher installed

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propulsive efficiency at high subsonic cruise speeds. The integration of the propfan/nacelle with the airframe is the key factor in determining the efficiency of the propfan propulsion system under installed conditions. A computer program was developed to predict the interference of the slipstream of a propfan on a supercritical wing at subsonic speeds. The use of this program could reduce the cost and time involved in the wind-tunnel testing of newly-designed wing/nacelle configurations.

For the computer program, a subsonic-flow panel code was modified to handle the effects of a propeller wake. The effects of the propeller slipstream are increased axial velocity, a new tangential velocity, and a total-pressure rise in the wake of the propeller. Principles based on blade-performance theory, momentum theory, and vortex theory are used to evaluate the slipstream characteristics. The slipstream effects are superimposed on Neumann boundary conditions to predict the installation aerodynamics of the powered propellers mounted on overwing or underwing nacelles integrated with supercritical wings. The inclusion of viscous-flow modeling enhances the accuracy of the prediction.

The input to the program includes the free-stream mach number, the propeller angle of attack, the propeller geometry, the propeller location, the propeller rotation, the thrust coefficient, the root-cutout position of the propeller blade, and the control parameters of the solution technique. The output includes the panel-induced velocities, the pressure increases, the final velocity distribution, and the pressure-coefficient distribution.

This program is written in FORTRAN V for batch execution and has been implemented on a CDC CYBER 800-series computer operating under NOS with a central-memory requirement of approximately 74K (octal) of 60-bit words. The program was developed in 1986.

This program was written by B. Chandrasekaran of Vigyan Research Associates, Inc., for **Langley Research Center**. *For further information, Circle 92 on the TSP Request Card.*
LAR-13623

Simulation of the Internal-Combustion Engine

This program adapts to the available information about a particular engine.

A mathematical model of the internal-combustion engine has been constructed and implemented as a computer program suitable for use on large digital computer systems. The ZMOTTO program calculates Otto-cycle performance parameters as well as working-fluid compositions and properties throughout the cycle for a number of consecutive cycles and for a variety of input parameters.

The model strikes a balance among three competing factors: (1) the desire for physical realism, (2) the extent of experimental information on the physical processes occurring in the engine, and (3) the capabilities of the present generation of computers. The result is a flexible and computationally economical model based on a system of ordinary differential equations for cylinder-averaged properties.

The computer program is capable of multicycle calculations, with some parameters varying from cycle to cycle, and has restart capabilities that enable the continuation of a sequence of cycle calculations or the recalculation of earlier cycles with altered assumptions. It can accommodate a broad spectrum of reactants, permit changes in physical properties, and offer a wide selection of alternative modeling functions without any reprogramming.

The program readily adapts to the amount of information available in a particular case because the model is actually a hierarchy of five models of differing complexity. The models range from simple, requiring only thermodynamic properties, to very complex, demanding full combustion kinetics, transport properties, and the flow characteristics of poppet valves.

The cycle calculations are based on the premise that heat transfer is expressible in terms of a heat-transfer coefficient and that the cylinder average of kinetic plus potential energies remains constant. Furthermore, during combustion the pressures of the burned and unburned gases are assumed to be equal and their heat-transfer areas are assumed to be proportional to their respective mass fractions. Although the model cannot resolve spatial gradients, it does not assume spatial uniformity.

The computer program ZMOTTO contains over 70 routines. It is written in standard FORTRAN IV and was tested on the IBM 370/3033, the IBM 360/67, and the Cray 1S computers.

This program was written by Frank J. Zeleznik and Bonnie J. McBride for **Lewis Research Center**. *For further information, Circle 19 on the TSP Request Card.*
LEW-14313

Fabrication Technology

Calculation of Multicomponent Convective Diffusion Deposition

A computer program calculates rates of deposition by vapor or by small particles.

A wide variety of engineering concerns, including the chemical coating of metals, solid-state electronics, filtration, icing of aircraft, and the corrosion and fouling of gas-turbine blades and heat exchangers, involves the capture of vapor and particles. A computer program that embodies a comprehensive but tractable theory of rates of convective diffusion deposition has been developed on the basis of the assumption of a multicomponent, chemically-frozen boundary layer.

The theory makes full use of the available information on transport coefficients and properties. It is not only applicable under conditions of transport of multicomponent vapors (e.g., chemical-vapor deposition) but is also capable of simultaneously calculating the transport of particles, provided that the particles are small enough to be considered heavy molecules. The code is being used to interpret experiments in the deposition of sodium sulfate as related to hot corrosion.

The program is written in FORTRAN IV for use on an IBM computer.

This program was written by Suleyman A. Gokoglu of Analex Corp. and Daniel E. Rosner and Bor-Kuan Chen of Yale University for **Lewis Research Center**. *For further information, Circle 143 on the TSP Request Card.*
LEW-14366

Mathematics and Information Sciences

Allocating Spare Parts in Complicated Systems

Assortments are analyzed for cost effectiveness and effects on system functionality.

The Eisenberger-Maiocco algorithm (EMA) is an efficient Markov algorithm to aid in the provision of spare parts. Two calculations are performed by EMA: (1) forecasting the availability of a system with a given pool of spare parts and (2) determining the most cost-effective assortment of spares. EMA was used in NASA's Deep Space Network project to calculate the probability that a system would continue to function with the spares available at each location.

The system to be analyzed is defined in terms of modules, which are any pieces of equipment that may fail, be repaired, or be replaced. A module can be in one of three states: (1) working, (2) spare, or (3) failed

and waiting for repair. For each module type in the system configuration, there is an actual number in use by the system and a minimum number for the system to function. A module type is considered "down" (that is, failed) when there are fewer than the required minimum number working, and there are no spares in the stockpile.

The input to EMA includes such module data as the mean time between failures, the mean time to repair, the number of spares, and the cost of each item. EMA determines the overall system availability, or uptime ratio, as the probability that the system will function during a given time. EMA can also calculate the most cost-effective assortment of spares for a given range of uptime ratios.

EMA is written in interpreter PC-BASIC and is for interactive execution. It has been implemented on an IBM PC-series computer operating under DOS 2.0 with a central-memory requirement of approximately 64K of 8-bit bytes. This program was developed in 1978.

This program was written by I. Eisenberger, G. Lorden, Fredric Kajikawa, F. Maiocco, Jodie Gunn, and Ethel Kameyama of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 142 on the TSP Request Card. NPO-16973*

Simulation of Research and Development Projects

Measures of preference for alternative project plans can be calculated.

The Simulation of Research and Development Projects (SIMRAND) program aids in the optimal allocation of research and development resources needed to achieve project goals. SIMRAND models the system subsets or project tasks as various network paths to a final goal. Each path is described in terms of such task variables as the cost per hour, the cost per unit, and the availability of resources. Uncertainty is incorporated by treating task variables as probabilistic random variables.

SIMRAND calculates the measure of preference for each alternative network. The networks yielding the highest utility function (or certainty equivalence) are then ranked as the optimal network paths. SIMRAND has been used in several economic-potential studies at NASA's Jet Propulsion Laboratory, involving solar-dish power systems and the construction of photovoltaic arrays. However, any project having tasks that can be reduced to equations and related by measures of preference can be modeled.

SIMRAND analysis consists of three phases: (1) reduction, (2) simulation, and (3) evaluation. In the reduction phase, analytical techniques from probability theory as well as simulation techniques are used to reduce the complexity of the alternative networks. In the simulation phase, a Monte Carlo simulation is used to derive statistics on the variables of interest for each alternative network path. In the evaluation phase, the simulation statistics are compared, and the networks are ranked in preference by a selected decision rule. The user must supply information on project subsystems in terms of equations based on variables (for example, parallel and series assembly-line tasks in terms of the number of items, cost factors, time limits, and the like). The associated cumulative distribution functions and utility functions for each variable must also be provided (for example, allowable upper and lower limits and group-decision factors).

SIMRAND is written in Microsoft FORTRAN 77 for batch execution and has been implemented on an IBM PC-series computer operating under DOS. This program was developed in 1986.

This program was written by Ralph F. Miles of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 41 on the TSP Request Card.*
NPO-16937

Optimal Network-Topology Design

Candidate network designs are tested for acceptability and cost.

The Optimal Network Topology Design computer program was developed as part of a study on the topology design and the analysis of performance of the Space Station Information System (SSIS) network. The program uses an efficient algorithm to generate candidate network designs (consisting of subsets of the set of all network components) in increasing order of their total costs and checks each design to see whether it forms an acceptable network. This technique gives the true cost-optimal network and is particularly useful when the network has many constraints and not too many components.

It is intended that this new design technique consider all important performance measures explicitly and take into account the constraints due to various technical feasibilities. In the current program, the user inserts the technical constraints by properly forming the starting set of candidate components (e.g., nonfeasible links are not included). As subsets are generated, they are tested to see whether they form an acceptable network by checking that all requirements are satisfied. Thus, the first acceptable subset encountered gives the cost-optimal topology satisfying all given constraints.

The user must sort the set of "feasible" link elements in increasing order of their costs. The program prompts the user for the following information for each link: cost, connectivity (number of stations connected by the link), and the identities of stations connected by that link. Unless instructed to stop, the program generates all possible acceptable networks in increasing order of their total costs. The program is written only to generate topologies that are simply connected. Tests of reliability, delay, and other performance measures are discussed in the documentation but have not been incorporated into the program.

This program is written in PASCAL for interactive execution and has been implemented on an IBM PC-series computer operating under PC DOS. This program was developed in 1985.

This program was written by Victor O. K. Li, Joseph H. Yuen, Ting-Chao Hou, and Yuen Fung Lam of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 162 on the TSP Request Card.*
NPO-16809

Fast-Polynomial-Transform Program

A modular approach saves computational resources.

A computer program uses a fast-polynomial-transformation (FPT) algorithm applicable to two-dimensional mathematical convolutions. Two-dimensional convolutions have many applications, particularly in image processing. Two-dimensional cyclic convolutions can be converted to one-dimensional convolutions in polynomial rings. Traditional FPT methods decompose one-dimensional cyclic polynomials into polynomial convolutions of different lengths. This program decomposes cyclic polynomials into polynomial convolutions of the same length. Thus, only FPT's and fast Fourier transforms of the same length are required. This modular approach can save computational resources. To enhance its appeal further, the program is written in the transportable C language.

The five steps in the algorithm are the following:

1. Formulate the modulus-reduction equations.
2. Calculate the polynomial transforms.
3. Multiply the transforms by use of a generalized fast Fourier transformation.
4. Compute the inverse polynomial transforms.
5. Reconstruct the final matrices by use of the Chinese remainder theorem.

The input to this program comprises the row and column dimensions and the initial two matrices. The matrices are printed out

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at all steps, ending with the final reconstruction.

This program is written in C for batch execution and has been implemented on the IBM PC series of computers under DOS with a central-memory requirement of approximately 18K of 8-bit bytes. The program was developed in 1986.

This program was written by T. K. Truong, I. S. Hsu, and Y. F. Chu of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 60 on the TSP Request Card.*
NPO-17030

Mathematical Routines for Engineers and Scientists

Programs for frequently-used mathematical procedures save time.

A package of computer programs provides the scientific and engineering community with the means to perform routine mathematical manipulations. This collection will enable scientists to concentrate on their work without having to write their own programs to solve common problems, thus saving considerable amounts of time.

The package contains 16 subroutines. Each is separately documented with descriptions of the invoking subroutine call, its required parameters, and a sample test program. The functions available include the following:

- Maximums, minimums, and sorting of vectors;
- Factorials;
- The generation of random numbers with uniform or Gaussian distribution;
- Complementary error function;
- Fast Fourier transformation;
- Integration by Simpson's rule;
- Determinants and inverses of matrices;
- Bessel function for any order and modified Bessel function for zero order;
- Roots of a polynomial;
- Roots of a nonlinear equation; and
- The solution of first-order ordinary differential equations using Hamming's predictor-corrector method.

There is also a subroutine for using a dot-matrix printer to plot a given set of *y* values for a uniformly-increasing *x* value.

This package is written in FORTRAN 77 (Super Soft Small System FORTRAN compiler) for batch execution and has been implemented on the IBM PC series under MS-DOS with a central-memory requirement of approximately 28K of 8-bit bytes for all subroutines. The program was developed in 1986.

This program was written by A. V. Kantak and F. Davarian of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 77 on the TSP Request Card.*
NPO-17165

Algorithm Sorts Groups of Data

Sets are sorted quickly according to weighted sums of elements.

An algorithm sorts sets of data into an ascending or descending order. Such sorting can become difficult for grouped data; i.e., multiple sets of data, where each set of data involves several measurements or related elements. The sorting becomes increasingly cumbersome as more elements are added to each set.

For efficient sorting, the algorithm finds the set that contains the minimum or maximum most significant data. The sets of data are then sorted as desired. The algorithm has been implemented in a computer program that handles the daily temperature readings of the Voyager spacecraft; in particular, those related to the special telecommunications-tracking requirements of Voyager 2.

The sorting process is simplified by the reduction of each multielement set of data to a single representative number. First, each set of data is expressed as a polynomial with a suitably chosen base, using the elements of the set as coefficients. The most significant element would be placed in the term containing the largest exponent. The base is selected by examining the range in value of the data elements. The resulting series is then summed to yield a single representative number. These numbers are then easily sorted, and each such number is converted back to its original set of data by successive division.

The computer program includes a sample data file containing 500 sets of data. Each set contains five elements. The program sorts the sets in ascending order in 3 to 5 seconds on an IBM PC-AT (or equivalent) computer equipped with a hard disk; on a similarly equipped PC-XT (or equivalent), the time is still less than 10 seconds. Operating instructions are included.

This program is written in BASIC (specifically the Microsoft QuickBASIC compiler) for interactive execution and has been implemented on the IBM PC computer series operating under PC-DOS with a central-memory requirement of approximately 40K of 8-bit bytes. (Note: The bulk of this memory space is occupied by the run-time support modules; the program is executable directly from DOS.) A hard disk is desirable for speed, but is not required. The program was developed in 1986.

This program was written by J. D. Evans of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 76 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 20]. Refer to NPO-17077.

Computer Program for Linear Algebra

A collection of routines is provided for basic vector operations.

The Basic Linear Algebra Subprogram (BLAS) library is a collection of FORTRAN-callable routines for employing standard techniques to perform the basic operations of numerical linear algebra. The BLAS library was developed to provide a portable and efficient source of basic operations for designers of programs involving linear-algebraic computations. The subprograms available in the library cover the operations of dot product, multiplication of a scalar and a vector, vector plus a scalar times a vector, Givens transformation, modified Givens transformation, copy, swap, Euclidean norm, sum of magnitudes, and location of the element of largest magnitude. Since these subprograms are to be used in an ANSI FORTRAN context, provisions are made for the case of single precision, double precision, and complex data. All of the subprograms have been thoroughly tested and produce consistent results even when transported from machine to machine.

The BLAS library is supplied as a machine-independent ANSI FORTRAN-77 version and assembler-code versions. The assembler versions offer extra efficiency in operations involving large vectors. The mainframe BLAS has been implemented on IBM-370, UNIVAC-1100, and CDC-6000 series computers. The PC BLAS FORTRAN version requires one of the following compilers: Lahey F77L, IBM-PC Professional FORTRAN, or Microsoft FORTRAN. The PC BLAS assembler version requires the Microsoft Macro assembler and a math coprocessor. The PC implementation allows individual arrays of over 64K. The BLAS library was developed in 1979, and the PC version was made available in 1986.

This program was written by F. T. Krogh and R. J. Hanson of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 57 on the TSP Request Card.*
NPO-17121

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Atlas/Centaur launches FleetSatCom from Cape Canaveral.

NASA's PC Programs

Software-hungry computer mavens can feast on COSMIC's library of computer programs. NASA's Computer Software Management and Information Center, a non-profit organization run by the University of Georgia, currently has 1,161 programs available for industry, government agencies and academic institutions. An increasing number of programs run on personal computers, according to John Gibson, COSMIC's Director. He explains: "Most engineers at NASA centers have PCs. They're creating more microcomputer-based programs." Gibson anticipates that within a year nearly ⅓ of COSMIC's library will consist of microcomputer programs. Many, he said, will be PC versions of programs developed for engineering workstations.

The following list describes PC programs developed by and for NASA. Circle the reader action number for a Technical Support Package. □

Mathematical Routines for Engineers and Scientists (Cal Tech/JPL) This package provides the scientific and engineering community with a library of 16 programs useful for performing routine mathematical manipulations. The library also includes a subroutine for using a dot matrix printer to plot a given set of y values for a uniformly increasing x value. **Circle 165 on the TSP Request Card.**

OAP-Office Automation Pilot Graphics Database System (NASA Goddard Space Flight Center) The Office Automation Pilot (OAP) Graphics Database system assists the IBM PC user in producing a wide variety of graphs and charts. OAP uses a convenient database system, called a chartbase, for creating and maintaining data associated with the charts. Twelve different graphics packages are available to the OAP user. **Circle 164 on the TSP Request Card.**

AIPE-Apple Image Processing Educator (Computer Sciences Corp.) The Apple Image Processing Educator (AIPE) was developed to explore the concept of using microcomputers to provide personalized computer-assisted instruction (CAI) in the digital image processing of remotely sensed images. AIPE is intended to be a "proof-of-concept" system and is not a polished production system. **Circle 163 on the TSP Request Card.**

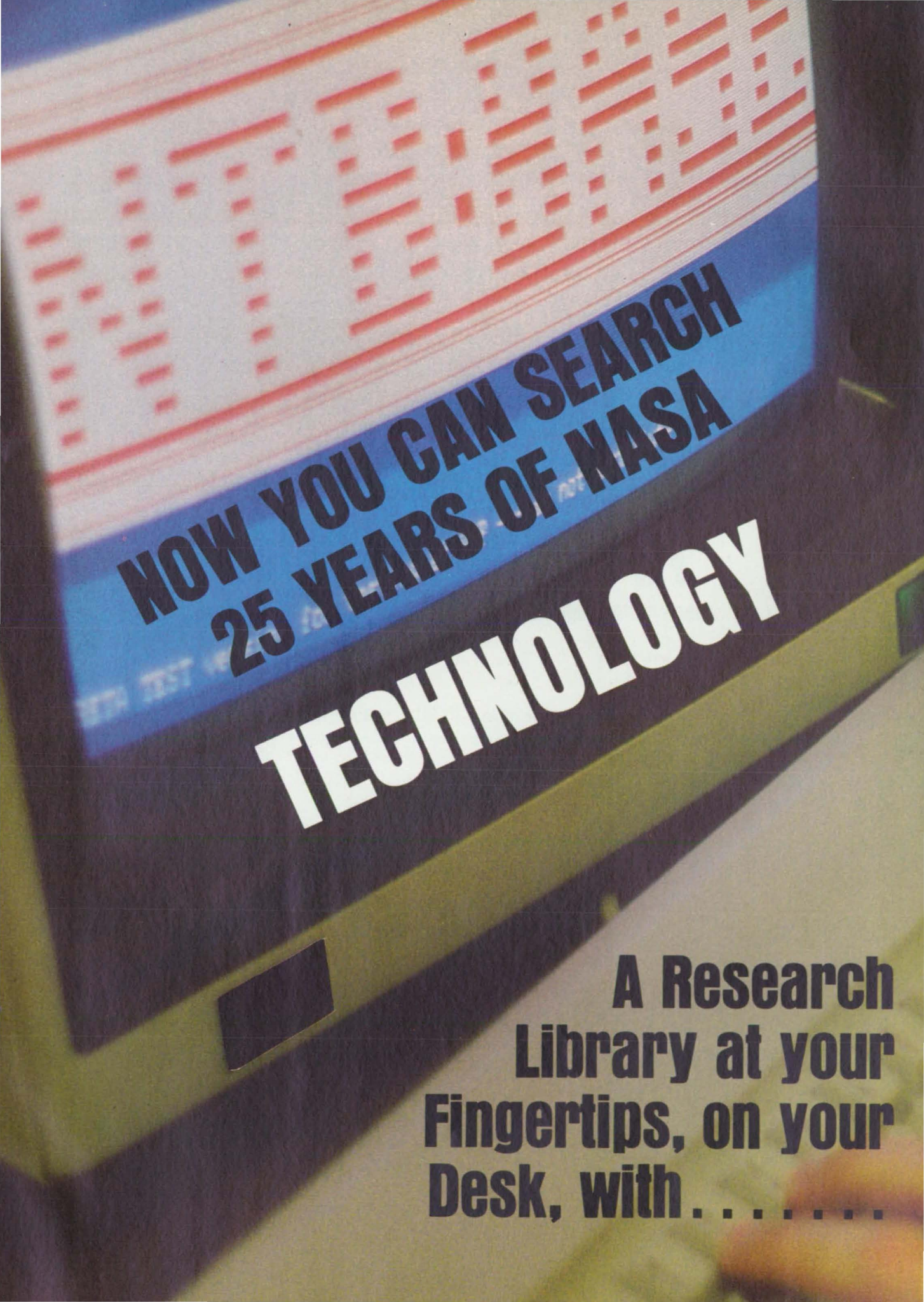
OWL-1200 Video Terminal Emulator For The IBM Personal Computer (Boeing Services International) An OWL-1200 video terminal emulator has been written for the IBM Personal Computer. Even those features which are implemented in hardware on the OWL-1200 are fully provided by the emulator software. **Circle 160 on the TSP Request Card.**

ARCEM-Arinc Research Concept Evaluation Methodology Program (Arinc Research Corp.) The Arinc Research Concept Evaluation Methodology (ARCEM) program was developed to assist in the rank-ordering of research concepts in terms of their potential benefit-to-cost ratios. **Circle 100 on the TSP Request Card.**

Subsonic-Supersonic Aerodynamic Analysis Programs For The Microcomputer (PRC Kentron) A series of computer programs used for aerodynamic analysis at the NASA Langley Research Center have been modified for use on a microcomputer. **Circle 158 on the TSP Request Card.**

EXADS-Expert System For Automated Design Synthesis (NASA Langley Research Center) The expert system called EXADS was developed to aid users of the Automated Design Synthesis (ADS) general purpose optimization program. **Circle 157 on the TSP Request Card.**

FLUID-Thermodynamic And Transport Properties Of Fluids (NASA Lewis Research Center) The FLUID program was developed to calculate the thermodynamic and transport properties of pure fluids in both the liquid and gas phases. FLUID produces results that are in very good agreement with measured values, while being much faster than older, more complex programs developed for the same purpose. **Circle 155 on the TSP Request Card.**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BDMADS-Basic Data Manipulation And Display System (NASA Lewis Research Center) is a software package that runs on an Apple II + or IIe personal computer to provide a user-friendly environment in which to perform complex calculations on an array of numbers. **Circle 103 on the TSP Request Card.**

SDDL-Software Design And Documentation Language (Cal Tech/JPL.) The Software Design and Documentation Language (SDDL) provides an effective communication medium to support the design and documentation of complex software applications. SDDL supports communication between all the members of a software design team and provides for the production of informative documentation on the design effort. **Circle 102 on the TSP Request Card.**

Weld Heat Flow Model (NASA Marshall Space Flight Center) This program contains a numerical model of the temperature distribution in the vicinity of a weld. The model may be applied to gas tungsten arc, plasma arc, electron beam, and laser beam welds on wide plates under steady conditions. **Circle 154 on the TSP Request Card.**

CLIPS "C" Language Integrated Production System (NASA Johnson Space Flight Center) The C Language Integrated Production System (CLIPS) is a shell for developing expert systems. It was designed to allow artificial intelligence research, development, and delivery on conventional computers. (See also our feature story this month). **Circle 149 on the TSP Request Card.**

SOFTCOST-Deep Space Network Software Cost Estimation Model Program (Cal Tech/JPL.) The Software Cost Estimation Model Program, SOFTCOST, was developed to provide a consistent automated resource and schedule model which is more formalized than the often used guesswork model based on experience, intuition, and luck. It is basically a combination of several software cost models found in the open literature into one comprehensive set of algorithms that compensate for nearly fifty implementation factors relative to size of the task, inherited baseline, organizational and system environment, and difficulty of the task. **Circle 148 on the TSP Request Card.**

LCP-Lifetime Cost and Performance Model of Distributed Photovoltaic Systems (JPL) The Lifetime Cost and Performance (LCP) Model was developed to assist in the assessment of Photovoltaic (PV) system design options. LCP is a simulation of the performance, cost, and revenue streams associated with distributed PV power systems. **Circle 145 on the TSP Request Card.**

SAMIS-Standard Assembly-Line Manufacturing Industry Simulation (JPL) The Standard Assemble-Line Manufacturing Industry Simulation (SAMIS) program was originally developed to model a hypothetical U.S. industry which manufactures silicon solar modules for use in electricity generation. The SAMIS program has now been generalized to the extent that it should be useful for simulating many different production-line manufacturing industries and companies. **Circle 140 on the TSP Request Card.**

MMW-Mission Manager's Workstation (ABACUS Programming Corp.) The Mission Manager's Workstation (MMW) is a personal computer based system providing data management and reporting functions to assist Space Shuttle Mission Managers. MMW also acts as a general productivity aid by providing central data storage and word processing. **Circle 152 on the TSP Request Card.**

ASAP-Artificial Satellite Analysis Program (Cal Tech/JPL.) The Artificial Satellite Analysis Program (ASAP) is a general orbit prediction program which incorporates sufficient orbit modeling accuracy for mission design, maneuver analysis, and mission planning. **Circle 141 on the TSP Request Card.**

OMEGA-An Owner Dependent Methodology For Energy Generation Assessment (CalTech/JPL.) An Owner-Dependent Methodology of Energy Generation Assessment, OMEGA, has been developed to provide for the economic evaluation of energy generation systems. OMEGA can be used to find normative prices and break-even values of system parameters. **Circle 147 on the TSP Request Card.**

CRISP80-Software Design Analyzer System (Cal Tech/JPL.) The CRISP80 Software Design Analyzer System is a set of programs forming a software design and documentation tool which supports top-down, heirarchic, modular, structured design and programming methodologies. **Circle 146 on the TSP Request Card.**

MODEL-Electromagnetic Fields Induced By A Loop Antenna (McDonnell Douglas Corp.) The MODEL computer program was developed to calculate the electromagnetic field values of a large loop antenna at all distances to an observation point. The antenna is assumed to be in an X-Y plane with its center at the origin of the coordinate system. **Circle 151 on the TSP Request Card.**

General Thermal Analyzer (Rockwell International Corp.) The General Thermal Analyzer program solves transient and steady-state thermal problems using desktop computers. The user models the thermal problem in terms of a resistance and capacitance network. The program currently handles up to 400 nodes. **Circle 150 on the TSP Request Card.**

IPEG-Improved Price Estimation Guidelines (Cal Tech/JPL.) The Improved Price Estimation Guidelines (IPEG) program provides a simple yet accurate estimate of the price of a manufactured product. IPEG facilitates sensitivity studies of price estimates at considerably less expense than would be incurred by using the Standard Assembly-line Manufacturing Industry Simulation (SAMIS) program (COSMIC program NPO-16032). **Circle 105 on the TSP Request Card.**

LMSS Services Financial Report Program (Cal Tech/JPL) This Services Finance Report program provides a means for comparing alternative designs of LMSS systems or other services systems. This program is actually a Multiplan worksheet. **Circle 104 on the TSP Request Card.**

CES-Constant Elasticity of Substitution Production Function Simulation (Cal Tech/JPL.) This program simulates the constant elasticity of substitution (CES) production function. The user provides input parameters such as price of labor, price of capital, and dispersion levels. CES minimizes the expected cost to produce a capital-uncertainty pair. **Circle 106 on the TSP Request Card.**

LOOP-Simulation of the Automatic Frequency Control Subsystem of a Differential Minimum Shift Keying Receiver (Cal Tech/JPL) The LOOP computer program was written to simulate the Automatic Frequency Control (AFC) subsystem of a Differential Minimum Shift Keying (DMSK) receiver with a bit rate of 2400 baud. The AFC simulated by LOOP is a first order loop configuration with a first order R-C filter. **Circle 107 on the TSP Request Card.**

Optimal Network Topology Design (Cal Tech/JPL) This program was developed as part of a research study on the topology design and performance analysis for the Space Station Information System (SSIS) network. It uses an efficient algorithm to generate candidate network designs (consisting of subsets of the set of all network components) in increasing order of their total costs, and checks each design to see if it forms an acceptable network. **Circle 138 on the TSP Request Card.**

AKPLOT-A Plotter Routine for the IBM PC (Cal Tech/JPL) The AKPLOT routine was designed for engineers and scientists who use graphs as an integral part of their documentation. AKPLOT allows the user to generate a graph and edit its appearance on a CRT. **Circle 136 on the TSP Request Card.**

SMDOS-Shuttle Mission Design and Operations Software (Cal Tech/JPL) The Shuttle Mission Design and Operations Software (SMDOS) assists in the design and operation of missions involving low earth orbiting spacecraft by providing orbital and graphics information. **Circle 109 on the TSP Request Card.**

SIMRAND-Simulation of Research and Development Projects (Cal Tech/JPL) The Simulation of Research and Development Projects program (SIMRAND) aids in the optimal allocation of R&D resources needed to achieve project goals. SIMRAND models the system subsets or project tasks as various network paths to a final goal. Each path is described in terms of task variables such as cost per hour, cost per unit, availability of resources, etc. **Circle 110 on the TSP Request Card.**

EMA-Eisenberger-Malocco Algorithm for Spares Provisioning (Cal Tech/JPL) The Eisenberger-Maiocco algorithm (EMA) is an efficient Markov sparing algorithm to aid in the provisioning of spare parts. **Circle 132 on the TSP Request Card.**

PCACE-Personal Computer Aided Cabling Engineering (Cal Tech/JPL) A computerized interactive harness engineering program is developed to provide an inexpensive, interactive system designed for learning and using an engineering approach to interconnection systems. PCACE is a database system that stores information as files of individual connectors and handles wiring information in circuit groups stored as records. **Circle 130 on the TSP Request Card.**

NEW CAPABILITIES

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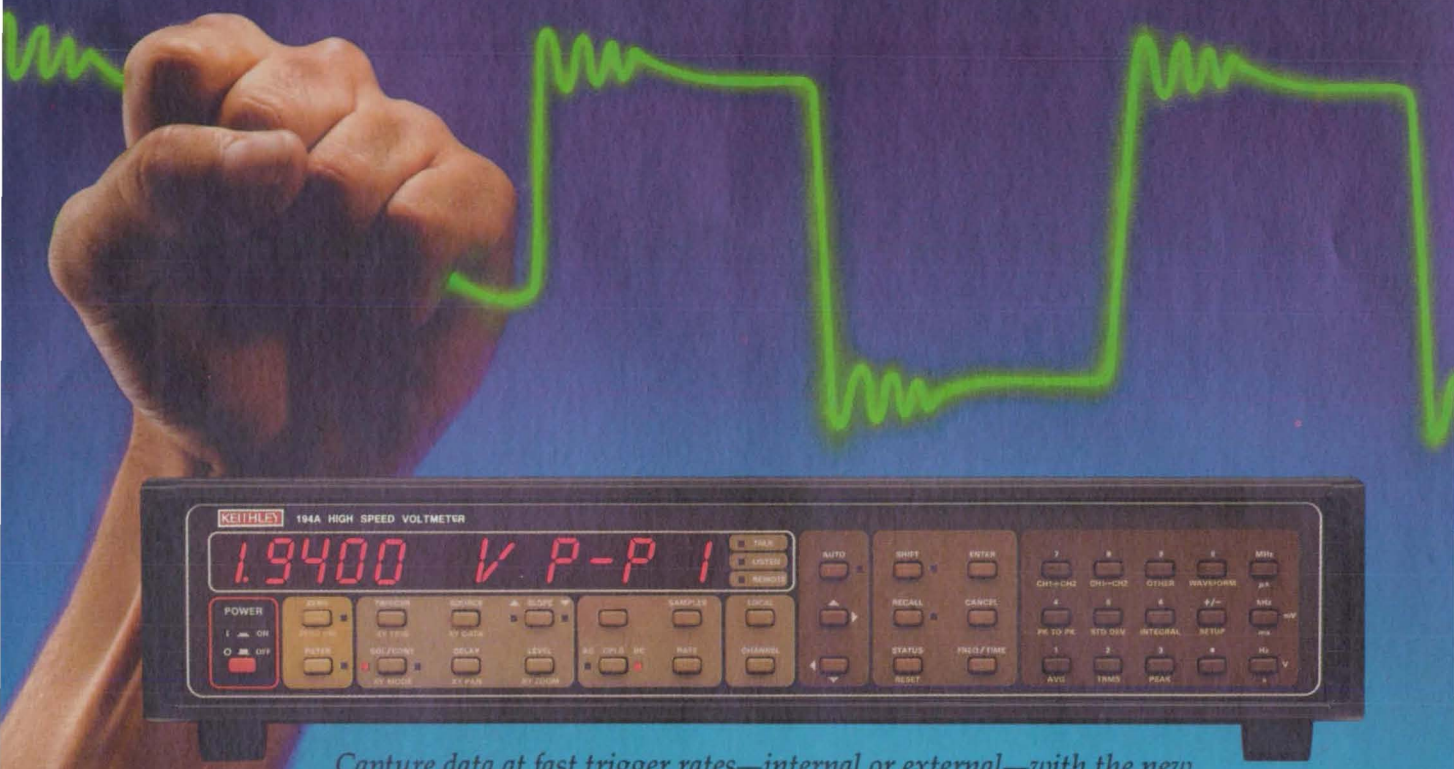

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KEITHLEY

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PITEST-Multiple Precision Arithmetic (Sterling) The PITEST program is a package of subroutines that perform arithmetic on floating-point numbers of arbitrarily high precision. PITEST can also work on very large integers by treating them as floating-point numbers with enough precision to exactly represent their integral values. **Circle 111 on the TSP Request Card.**

A Fast Polynomial Transform Program with a Modularized Structure (Cal Tech/JPL) This program uses a fast polynomial transformation (FPT) algorithm applicable to two-dimensional mathematical convolutions. The program is written in the transportable "C" language. **Circle 129 on the TSP Request Card.**

Assessment of Advanced Concentrator Photovoltaic Module Technologies (Cal Tech/JPL) This program was developed to probabilistically estimate the total and component costs to end users of concentrating photovoltaic arrays in the 1990's. This is accomplished by using a modified version of the SIMRAND program to estimate total system cost for a large number of module designs. The minimum system cost module design is then chosen as the preferred design. **Circle 128 on the TSP Request Card.**

LOP–Long-Term Orbit Predictor (Cal Tech/JPL) The Long-Term Orbit Predictor is a trajectory propagation program useful as an analysis tool in lifetime studies of orbiting spacecraft. LOP is suitable for studying planetary orbit missions with spacecraft trajectories of reconnaissance (flyby) and exploratory (mapping) nature. **Circle 127 on the TSP Request Card.**

Algorithm for Sorting Grouped Data (Cal Tech/JPL) It is often desirable to sort data sets in ascending or descending order. This becomes more difficult for grouped data. The sort becomes increasingly cumbersome when more than a few elements exist for each data set. In order to achieve an efficient sorting process, an algorithm has been devised in which the maximum most significant element is found, and then compared to each element in succession. **Circle 121 on the TSP Request Card.**

BLAS-Basic Linear Algebra Subprograms (Cal Tech/JPL) The Basic Linear Algebra Subprogram (BLAS) library is a collection of FORTRAN callable routines for employing techniques in performing the operations of numerical linear algebra. The BLAS library was developed to provide a portable and efficient source of basic operations for designers of programs involving linear algebraic computations. **Circle 120 on the TSP Request Card.**

STEADY-A Steady State Thermal Analysis Program for Microcomputers (Cal Tech/JPL) The Steady State Thermal Analysis Program (STEADY) provides the thermal designer with a quick and convenient method for calculating heat loads and temperatures. STEADY can be used on small nodal networks for conceptual or preliminary thermal design and analysis. STEADY will accept up to 20 nodes of fixed or variable temperature, with constant or temperature-dependent thermal conductivities, and any set of consistent units. **Circle 123 on the TSP Request Card.**

Pulsed and CW Power Sources For Diode Lasers

ILM

Pulser for MA/Com and Stantel bright arrays, 40 and 60A models, 20 to 200ns, operates from 15 to 28VDC, variable pulse width is standard.

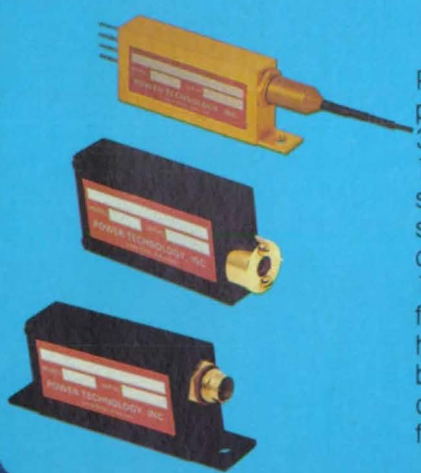
ILD and ILT

Pulser for .5 to 30A pulse current, two or three independently triggered pulses, pulse spacing can be reduced to -0-, pulse amplitude and width independently adjustable, operates from 10 to 28VDC.

ILC

Most popular pulser series, .5 to 100A, 7 to 500ns, 1 to 6 junctions, internal clock or external trigger, mounting options for a large variety of diodes, variable pulse width options, operates from 10 to 28VDC.

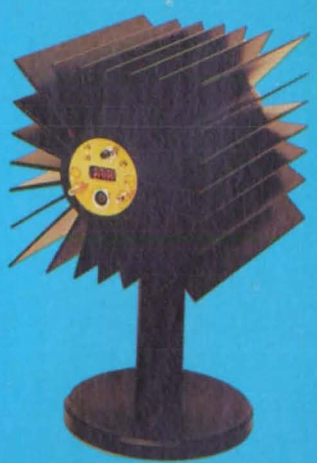
ILB



Pulser for .5 to 30A pulse current, 7 to 300ns pulse width, 1 to 3 junctions, separate power supply and head, compact size ½" x 1" x 2", total weight for power supply and head -35 gr., variable pulse width optional, operates from 10 to 28VDC.

ILE and ILN

A Temperature Controlled Diode Laser Mount, Thermoelectric cooling/heating provide a diode temperature range of -5° C to +70° C ± 0.1° C. The ILE pulsed version provides a current of 0.5A to 30A at a pulse width of 7 to 300ns. The ILN CW version provides a bias of 0 to 500mA and modulation from 0 to 500mA DC to 50 Mhz.



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with or without temperature control.

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Mechanics

Airplane Wings for Faster Climbing and Slower Landing

Reshaped airfoils improve performance.

Ames Research Center, Moffett Field, California

The performances of general-aviation airplanes can be improved by modifying airfoil shapes. An equation is used to determine a new contour for each type of wing. The calculations are straightforward enough to be done on a hand calculator; a computer is not necessary.

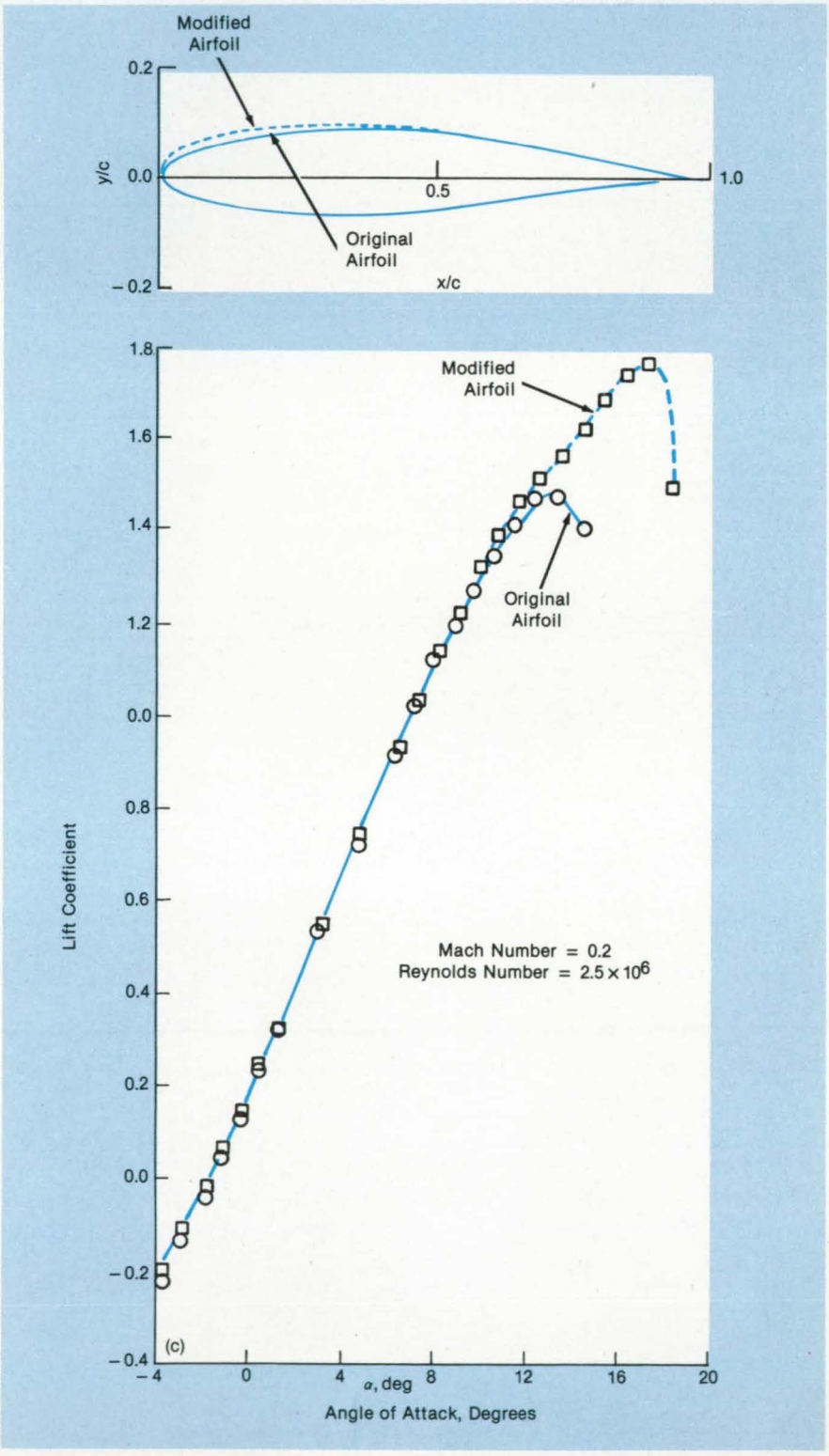
The equation applies to National Advisory Committee for Aeronautics (NACA) 63-, 64-, and 65-series airfoils with lift coefficients between 0 and 1 and maximum thickness-to-chord ratios between 0.06 and 0.18. These airfoils are used on a variety of general-aviation aircraft, including single-engine, propeller-driven airplanes and small passenger jet airplanes. The calculations determine new shapes for the upper surfaces of cambered airfoils or for both surfaces of uncambered airfoils.

The modification of an airfoil increases the bluntness of the leading edge and adds forward camber. It does so without introducing discontinuities in curvature anywhere, not even in the region where the modified shape blends with the original shape.

The increase in the forward thickness of the airfoil reduces the adverse pressure gradient near the leading edge of the upper surface at high angles of attack and results in a larger maximum coefficient of lift. Stalling characteristics are thereby improved, shorter and slower landings are possible, and the rate of climb is increased.

When it was used to modify a NACA 63-215 airfoil shape (see figure), the equation yielded a shape that gives approximately a 20-percent increase in the maximum lift coefficient. It also substantially increased the allowable angle of attack. The equation can be used to design new high-performance airfoils and to modify existing designs.

This work was done by Susan Cliff-Hovey of **Ames Research Center.** *No fur-*



The **New Shape** of a NACA 63-215 airfoil (above) increases the maximum coefficient of lift and angle of attack (below). The ratios y/c and x/c represent the thickness and chordwise dimensions, respectively, of a wing normalized to the chord, c.

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ther 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 20]. Refer to ARC-11598.

Books and Reports

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

Three-Axis Superconducting Gravity Gradiometer

Gravity gradients can be measured even on accelerating platforms.

A three-axis superconducting gravity gradiometer is based on flux quantization and the Meissner effect in superconductors and employs a superconducting quantum interference device as an amplifier. It incorporates several magnetically levitated proof masses, as described in the preceeding article, "Six-Axis Superconducting Accelerometer" (MFS-26040). The gradiometer design integrates the accelerometers for operation in a differential mode. The principal use is expected to be in commercial instruments for the measurement of Earth-gravity gradients in geophysical surveying and exploration for oil.

In the gravity gradiometer, the signals representing common-mode acceleration (due to motions of the instrument platform) are balanced out, leaving an apparent differential-acceleration reading for each axis proportional to the distance between two acceleration detectors along that axis and to the projection of the gravity gradient along that axis.

The gravity bias of the Earth is nulled by stable magnetic levitation using superconducting persistent currents. The levitation coils for the two proof masses for each axis are connected in series to stiffen the suspension springs against common-mode accelerations while keeping the differential-mode compliance unchanged. The common-mode resonance is damped by eddy-current dissipation; this improves the common-mode rejection. The stable magnetic field arising from persistent currents creates the effect of a negative spring, which increases the compliance of the differential mode and thereby increases the sensivity to gravity gradients.

Piezoelectric crystals are employed to align precisely the sensitive axes of the component accelerometers. This suppresses both the instrument errors associated with coupling to the cross-component linear accelerations and the modulation of the Earth-gravity bias caused by angular motions.

As in the accelerometer, force-rebalance feedback currents are applied to the proof masses for both the common and differential modes. In addition, cold damping feedback is applied to damp actively the differential mode. This reduces the nonlinearity error of the instrument and improves its dynamic range.

The instrument simultaneously reads out three in-line component gradients and three common-mode linear accelerations. The common-mode signals can be used to stabilize the platform, to compensate for errors, and to obtain the precise position of the instrument during a survey. The three gradient signals provide valuable cross-checks of the gravity data. The sum of these gradient signals reflects the attitude rate of the instrument and provides a cross-check of platform gyroscope readings.

A room-temperature gravity gradiometer developed by the Navy has a sensitivity limited to about 10 $s^{-3/2}$. The new superconducting gravity gradiometer has a sensitivity of $\sim 10^{-1}$ to $\sim 10^{-4}$ $s^{-3/2}$ and greater stability as well. The only serious limitation is the need for liquid helium to maintain the instrument at a temperature of ~2 to ~5 K.

This work was done by Ho Jung Paik of the University of Maryland for **Marshall Space Flight 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

Ho Jun Paik
Department of Physics and Astronomy
University of Maryland
College Park, MD 20742

Refer to MFS-26041, volume and number of this NASA Tech Briefs *issue, and the page number.*

Heat Shields for Transatmospheric Vehicles

Thermal-protection schemes are evaluated for space vehicles that bounce off the Earth atmosphere.

A report compares the performances of four conceptual heat shields for transatmospheric vehicles. These future spacecraft will operate above the atmosphere of the Earth but will dip into the atmosphere to exploit combinations of aerodynamic and propulsive forces for such major maneuvers as changing orbital planes. They will experience high rates of aerodynamic heating during such maneuvers.

Three of the concepts are based on insulating tile fastened to the skin of the vehicle. The fiber/fiber rigid composite insulation (FRCI) and the Tophat (ceramic/ceramic shell) insulation are bonded to a polyimide graphite skin with room-temperature-vulcanizing adhesive. The Tophat insulation includes a wall of FRCI around a layer of Nextel (or equivalent) for structural support. A third conceptual insulation system — the advanced carbon/carbon (ACC) system — employs side panels to support inner felts and uses metal clips to fasten the tiles to a titanium skin.

The three systems were compared by one-dimensional transient computer analyses of temperature variations within the tiles when the tiles were subjected to heat pulses at several values of heat flux. The thickness of the interior insulation was varied for each of the systems.

For heat fluxes near the tolerable limit of the front surfaces, the calculated heat-shield mass required to keep the skin temperature of the vehicle within limits was nearly the same for the three heat-shield concepts. For lower heat fluxes, there were significant differences in weight among the systems. Such factors as cost, ease of fabrication of a titanium skin versus one of polyimide/graphite, and control of the heat stored in the system in the absence of convection will determine the selection of a heat shield.

The fourth conceptual system includes a multilayer insulating blanket under a heat shield of FRCI. Such a blanket would allow the use of a tile structure of reduced weight and under some circumstances could thereby enable the reduction of the overall weight of the vehicle.

This work was done by W. C. Pitts of **Ames Research Center** *and M. S. Murbach of Sterling Software Inc. To obtain a copy of the report, "Heatshield Design for Transatmospheric Vehicles," Circle 139 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 20]. Refer to ARC-11749.

New Products

A new commercial airline data-link control panel design using a touch-sensitive screen was recently announced by the Collins Air Transport Division of Rockwell International Corporation, Cedar Rapids, IA. The DLC-800 control panel, a menu-driven control display, is designed to be used with Collins DL-700 data link systems. It is completely compatible with other data link management units that use the ARINC 429 data bus. Airline-programmable software enables a carrier to create distinctive symbols, display formats and messages. Circle Reader Action Number 591.

Machinery

Inflatable Probe Would Manipulate Delicate Parts

Delicate parts would be grasped gently.

Marshall Space Flight Center, Alabama

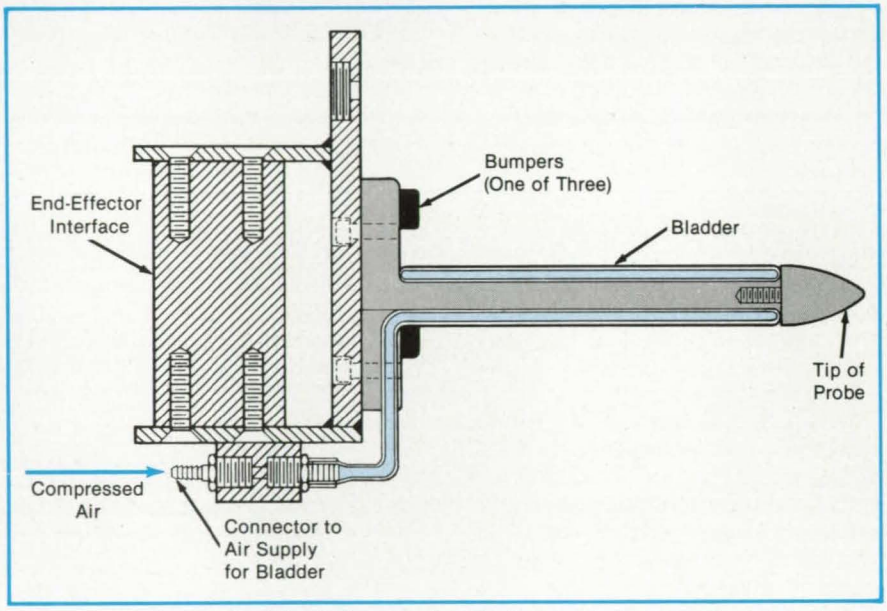
A proposed inflatable probe would grasp parts gently. Unlike many existing robotic end effectors with hard grasping fingers, the proposed mechanism would not apply high contact pressures and is therefore less likely to damage delicate parts.

The rigid probe would be surrounded by a bladder (see figure). The probe would be inserted in a hole of slightly larger diameter in the part to grasped. The depth of insertion would be limited by three resilient bumpers, which could serve as stops to control the position and orientation of the part if necessary.

Once the probe was inserted, the bladder would be inflated to a preset maximum pressure, expanding against the inside of the hole in the part to grasp it firmly but gently. After moving the part to the desired position, the bladder would be deflated and the probe withdrawn.

The principal disadvantage of the concept is the need to provide a hole of the specified diameter in every part to be handled. However, this may be offset by the advantages of simplicity and reliability of the inflatable bladder.

This work was done by Carter K. Lord of Olis Engineering for **Marshall Space Flight Center**. *For further information, Circle 2 on the TSP Request Card.*



A **Cylindrical Bladder Would Be Inflated** against the inner wall of surrounding hole in the part to be grasped.

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

Carter K. Lord
Olis Engineering
Olis Enterprises, Inc.
P.O. Box 408#D
Sedalia, CO 80135

Refer to MFS-26045, volume and number of this NASA Tech Briefs *issue, and the page number.*

Powered Lift for Paraplegics

People with paralyzed legs can transfer themselves to and from wheelchairs.

Ames Research Center, Moffett Field, California

A battery-operated lift is designed to aid paraplegics in moving about locally. It can raise or lower a paraplegic from or to a bed, toilet, or wheelchair, for example. The paraplegic controls the operation of the lift with a toggle switch and a joystick.

A prototype (see figure) has been constructed, and further refinements are expected. The lift includes a rolling frame with a body support that is raised and lowered on a column by a pair of drivescrews. The user positions the wheelchair within the frame and places his arms over a pair of curved, padded armpit hooks. The user flips the toggle switch so that the hooks rise on the column. As they rise, the user's weight bears down on them, and the weight is transferred through a cam that causes a pair of padded leg supports to move inward, just behind his knees. The user's body is thus supported at four points.

When the supports reach the desired height, the user flips the toggle switch to stop the upward motion and uses the joystick to move the lift forward, backward, left, or right, as necessary. The joystick controls two independent dc motors, enabling the lift to be positioned precisely and rotated. The motors and a rechargeable

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Circle Reader Action No. 372

battery are in a compact enclosure at the base of the column.

To return to a wheelchair, the user simply reverses the procedure. He uses the joystick to position himself over the chair and operates the toggle in the reverse direction to lower himself into the seat.

This work was done by of Ben Aubert 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 20]. Refer to ARC-11638.

Books and Reports

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

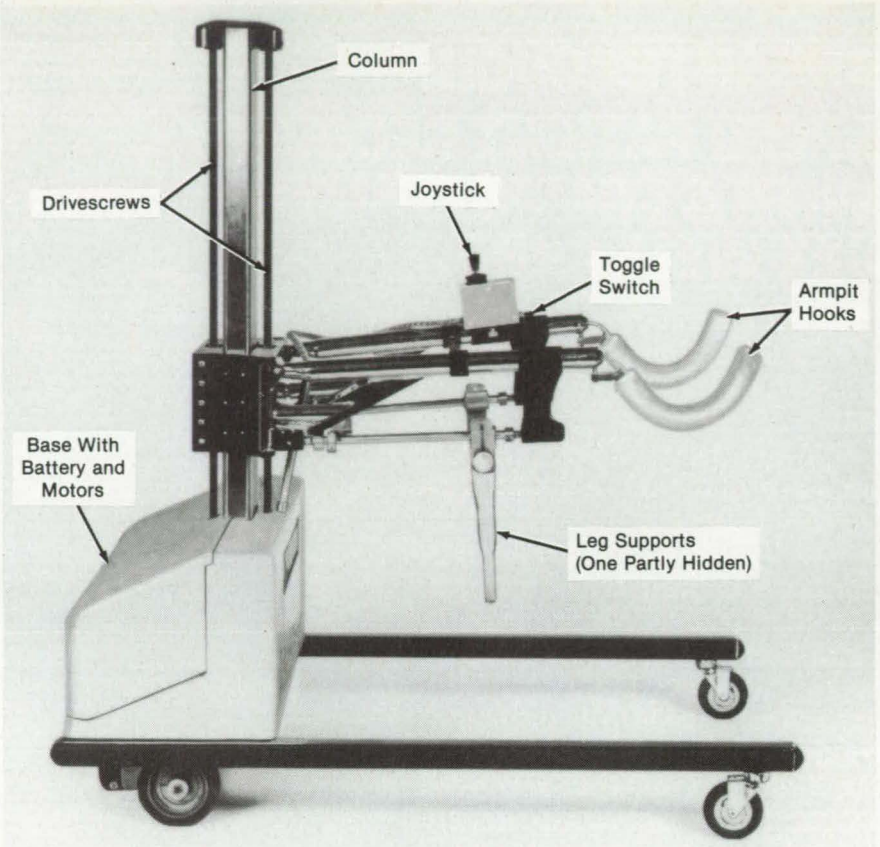
Variable-Reluctance Motor for Electric Vehicles

A scaled-down motor performed as expected.

A report describes research on a variable-reluctance electric-motor drive for eventual use in electric-vehicle propulsion. The primary design and performance criteria were the torque and power output per unit mass of the motor, the cost (with emphasis on the inverter circuit needed for the motor), and the drive efficiency (with emphasis on the motor). For each criterion, an optimized drive design was developed, and these designs were then unified to yield a single electric-vehicle drive.

The theoretical treatment of variable-reluctance-motor drives led to the design of a 60-kW motor with a mass of 65 kg. To reduce the cost of the inverter, a three-phase system was selected. (Three is the minimum number of phases for a self-starting variable-reluctance motor). There are four rotor poles and six stator poles. An alternating polar alignment of the phase windings (NSNSNS) eliminates the mutual inductance between the phases and maintains flux symmetry in the back iron. The windings are bifilar.

The stator-pole angle is 32°, which is a compromise between a large overlap region and a large winding-slot volume. The rotor-pole angle is 45°. The rotor-pole pitch was designed to allow for a large maximum-inductance region in the phase-inductance profile to provide extra time to remove currents. The radial gap between the rotor and the stator was designed to be the smallest permitted by manufacturing limitations. The number of turns on each stator pole is constrained by the current levels required for operation with a 240-V supply.



The **Prototype of the Paraplegic Lift** is operated by a toggle switch and a joystick. The lift can be plugged into a household electrical outlet for recharging when it is not in use.

Because the inverter circuit includes only three power switches, its cost is lower than that of competitive circuits. The circuit enables independent control of the currents in each phase, thereby enhancing the capability for optimum output and efficiency. The power switches must block a forward electromotive force of 480 V, with a 240-V safety margin. Though the switches could be silicon-controlled rectifiers, gate turn-off thyristors (GTOT's) are preferred because of their simpler commutation requirements. The GTOT's selected have voltage, current-at-turn-off, and root-mean-square-current ratings of 1,300 V, 600 A, and 400 A, respectively. Each GTOT can be commutated with a field-effect transistor at turn-on and with a silicon-controlled rectifier at turnoff.

To test the motor-design concepts, a 3.8-kW version was designed and built by scaling down all the dimensions of the 60-kW unit by a factor of about 2.5. The smaller motor was not thermally designed, however; the scaledown was only magnetic for verification of the mathematical design models. The small motor performed as expected, showing excellent agreement with the predicted scaled-down electromechanical characteristics. Provided that the thermal constraints are satisfied, it thus appears that the 60-kW unit will perform as expected.

This work was done by Jeffrey H. Lang of Massachusetts Institute of Technology for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Variable-Reluctance Motor Drives for Electric Vehicle Propulsion," Circle 113 on the TSP Request Card.*
NPO-16993

New Products

Selecting and ordering Micro Switch pressure sensors is easy with the company's "Specifier's Guide for Pressure Sensors." Sensors in the catalog include absolute, differential, gage and vacuum gage measurement devices with pressure sensing ranges from ±5 inches water pressure to 250 psi. Many are offered with temperature compensation. Housings are constructed from plastic, die-cast aluminum or stainless steel, and versions are available to meet MIL standards for shock, vibration and moisture resistance. Circle Reader Action Number 587.

Intel Scientific Computers, Santa Clara, CA has announced its second generation hypercube family of concurrent supercomputers. New hardware and software developments make the iPSC/2 family easier to program and up to ten times faster than first generation hypercubes. Standard systems are available in configurations from 16 to 128 processing nodes, with up to a gigabyte of memory. **Circle Reader Action Number 590.**

Fabrication Technology

Grinding Inside a Toroidal Cavity

Weld Lines can be ground smooth within about 0.001 in. (0.025 mm).

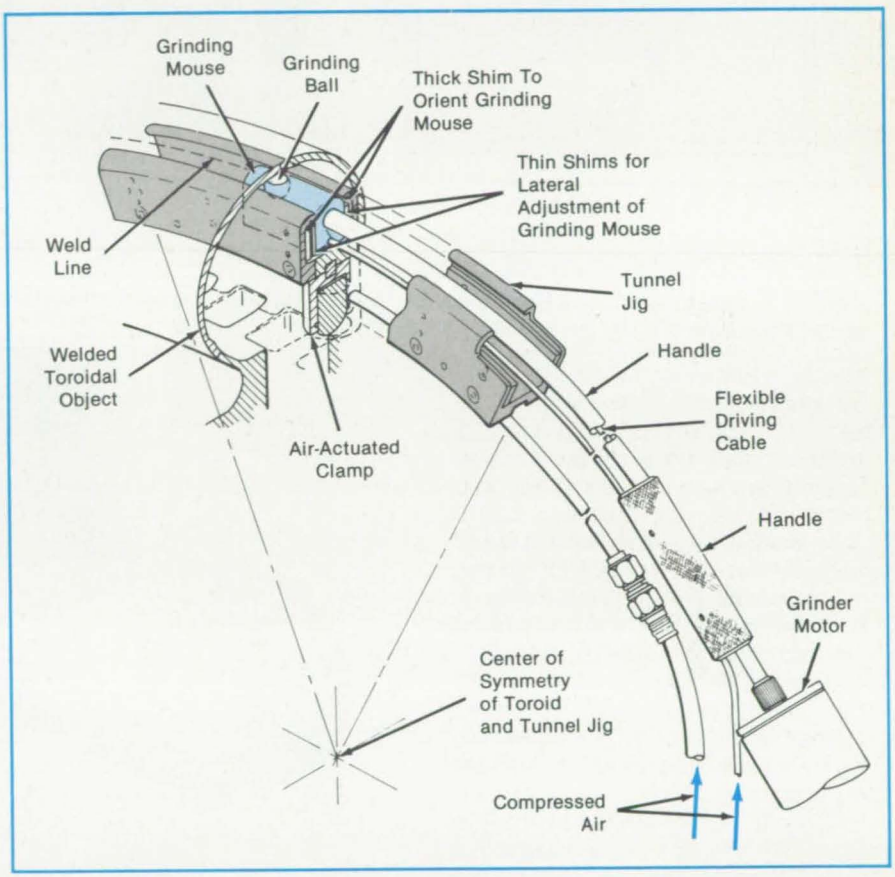
Marshall Space Flight Center, Alabama

A grinding tool for smoothing longitudinal weld lines inside a toroidal cavity includes a curved tunnel jig to guide a grinding "mouse" along the weld line (see figure). The curvature of the tunnel jig is matched to the shape of the toroid so that the grinding ball in the mouse can follow a circular arc of the correct radius as the mouse is pushed along the tunnel. The tool enables precise control of grindout shape, yet is easy to use.

Weld-free areas of the toroid serve as position references for the alignment of the tunnel jig with the toroid. During grinding, the tunnel jig is clamped against the inner wall of the toroid by an air-driven piston. (Screw clamps could be used instead.) The depth of the grind is controlled by adjusting the distance by which the grinding ball protrudes from the mouse.

Shims are placed along the inner sides of the tunnel jig to control the lateral position of the mouse on each grinding pass. The steps between passes can be made small enough so that the ridge between adjacent grind paths is 0.001 in. (0.025 mm) or less. The ground surface can then be polished to achieve a smoother finish if desired.

A flexible driving cable connects an external air-powered or electric motor to the grinding ball in the mouse. The handle used by the operator to slide the mouse through the tunnel is attached to the mouse by a curved rod. The perpendicular force of the grinding ball against the surface to be ground is provided by a small air-powered cylinder on the side of the mouse opposite that of the grinding ball.



The **Grinding Tool** smoothes out protruding material along weld lines inside a toroidal chamber. The curved tunnel jig guides the grinding mouse.

This work was done by Walter Mayer, James F. Adams, and Richard K. Burley of Rockwell International Corp. 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 20]. Refer to MFS-29249.

Hybrid Electrostatic/Acoustic Levitator

Particles and drops can be rotated and vibrated.

NASA's Jet Propulsion Laboratory, Pasadena, California

A levitator for liquid drops and small particles includes both electrostatic and acoustic components for versatility in the manipulation of samples. The sample is levitated electrostatically and rotated or vibrated acoustically. Because the electrostatic and acoustic forces are independent of each other, the hybrid levitator is especially suitable for studies of drop dynamics. Like all-acoustic or all-electrostatic systems, it can also be used in studies of containerless material processing.

The levitator (see Figure 1) includes two dish-shaped electrodes that generate the levitating electrostatic field. A liquid-

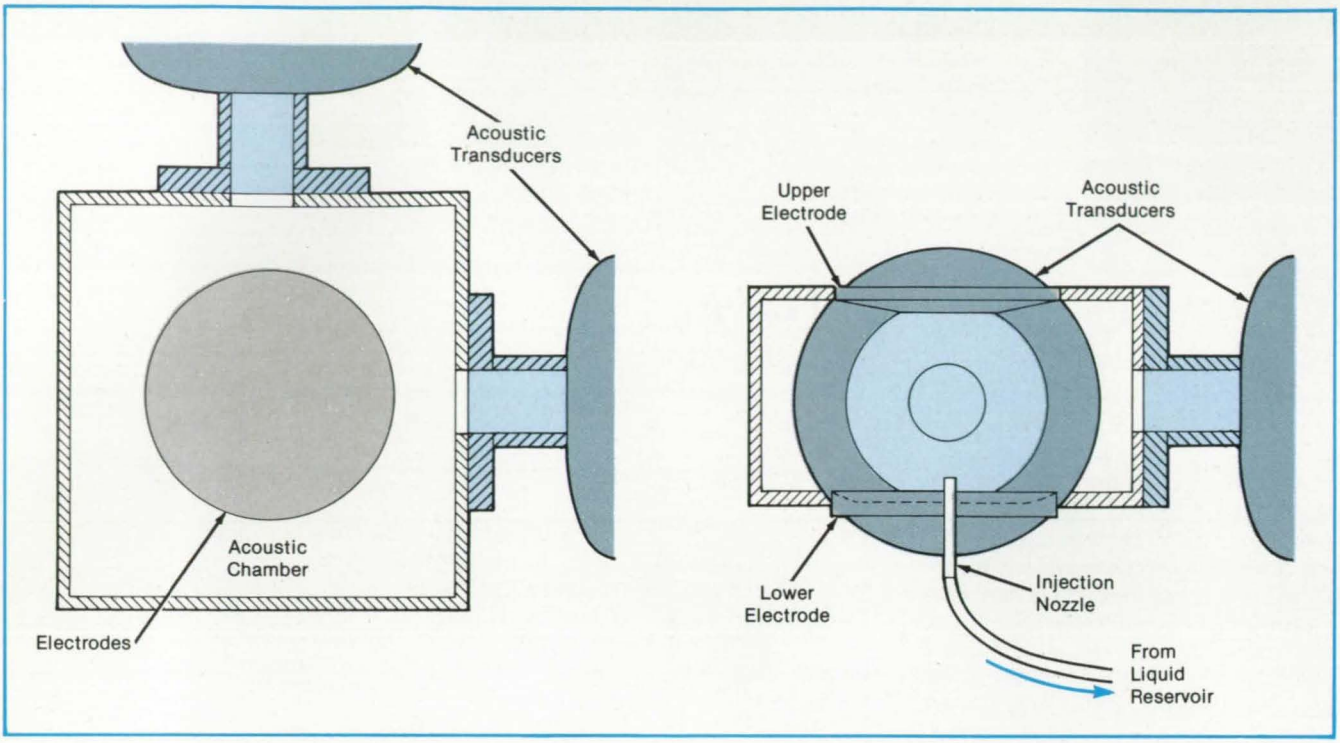


Figure 1. The **Vertical Levitating Force** is applied to the sample by the upper and lower electrodes. Torques or vibrational forces in the horizontal plane are applied by the acoustic transducers.

injection nozzle enters the levitation chamber through a hole in the center of the lower electrode. An acoustic transducer is attached to each of two orthogonal vertical faces to produce orthogonal acoustic standing waves in the chamber.

To facilitate the adjustment and stabilization of the vertical position of the sample, the electrostatic portion of the levitator is controlled by a digital feedback system. The acoustic transducers are locked to each other in frequency and phase. To apply an acoustic torque to rotate the sample, a phase difference of 90° is imposed. The torque is varied by adjusting the amplitude of the sound.

A nonrotating sample can be made to vibrate by fixing the phase difference at zero and sinusoidally modulating the amplitude. Both a nonzero phase difference and amplitude modulation can be used to produce rotation and vibration. If the sample is a liquid drop, it can be rotated until it breaks in two (see Figure 2). The levitator can also manipulate aluminum shells, glass shells, and wooden spheres.

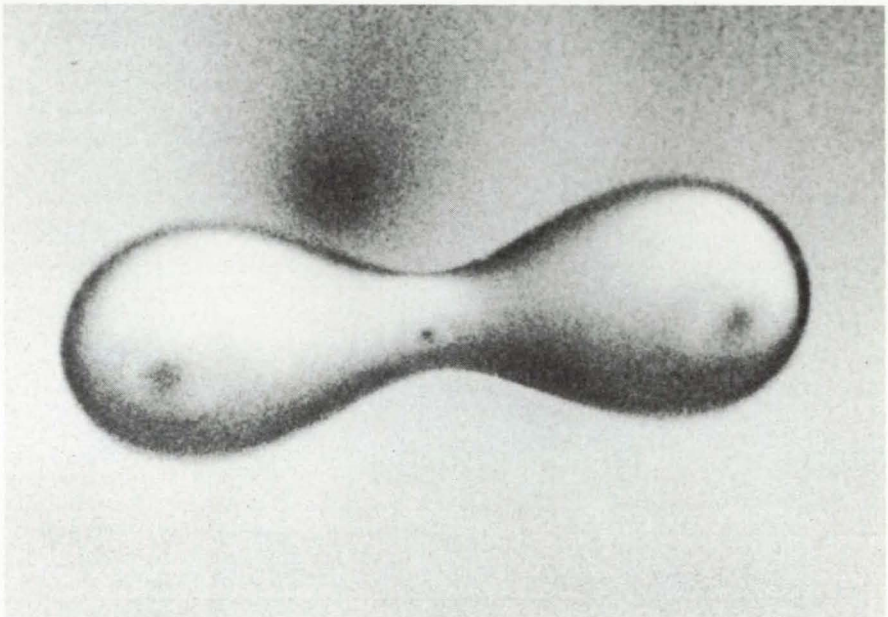


Figure 2. An **Electrically Charged Water Drop** about 4 mm in diameter was levitated electrostatically and rotated acoustically until it assumed a dumbbell shape and broke apart.

This work was done by Won K. Rhim, Eugene H. Trinh, Sang K. Chung, and Daniel D. Elleman of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 27 on the TSP Request Card.*

NPO-16834

New Products

Yokogawa Corporation of America (Peachtree City, GA) introduces a high-speed analyzing recorder that accepts one or two inputs with frequencies ranging from DC to 1 MHz. A 5 MHz sampling rate enables signals to be time sliced and converted from analog to digital with 10-bit resolution every 0.2 microseconds, resulting in extremely high accuracy. The Model 3656 simultaneously measures the signals, displays the waveforms on a 7-inch CRT and plots in color on hard copy. An optional data memory module with up to 32K capacity for each channel is available, and allows duplex plotting. Three triggering modes from either internal or external sources can be set at any level over the input signal's amplitude. The trigger initiates CRT traces, the plotter and the memory module. For memory mode, a pre-trigger, selectable in steps from 0 to 100% of signal amplitude is provided. **Circle Reader Action Number 596.**

Radio Shack, a division of Tandy Corporation (Fort Worth, TX), has released the OS-9 Development System for their Color Computer 3. The OS-9 Development System is a complete editor/assembler with full screen editing and specialty I/O drivers. The OS-99 Level Two operating system is required to take advantage of programming tools provided by the development system. **Circle Reader Action Number 592.**

Mathematics & Information Sciences

Optical Temperature Sensor for Gas Turbines

The new design promises accuracy even in the presence of contamination.

Lewis Research Center, Cleveland, Ohio

An improved sensor is being developed to measure gas temperatures up to 1,700 °C in gas-turbine engines. The accurate measurement of gas temperatures within a gas-turbine engine is difficult because of the severe temperature, pressure, and vibration environment. The discharge gas of the turbine-engine combustor is particularly difficult to measure because the major constituents of the gas are hot, chemically active products of the combustion of a fossil fuel.

The sensing element of an existing optical thermometer (DILS, NBS) is a thin single crystal of sapphire, with a tip coated to form a blackbody cavity. When immersed in the gas stream, the sensing element eventually reaches the temperature of the stream and emits thermal radiation. The radiation is transmitted through a fiber-optic light pipe to a radiation detector.

In principle, this sensor will function reliably only if the thermal energy is transmitted to the detector without changes in intensity induced by the fiber-optic waveguide. It is known, however, that inside the gas-turbine engine, the combustor and turbine parts tend to accumulate a thin but optically absorbing deposit of various substances. In a modern engine, this deposit consists primarily of atmospheric dust that has been ingested by the engine and pyrolized. In engines of older designs, some carbon particles may also be present.

The existing sensing device, although having a blackbody cavity at the tip, has no protection against the formation of deposits on the uncoated portion, which is also exposed to the gas stream. It is expected that optically absorbing deposits will form on the exposed sensing element over an extended time. This will cause some of the light to be absorbed at the interface between the sapphire crystal and the deposit. Thus, the calibration will be shifted, and the displayed temperature will be in error. As an example of this effect, when a silicon diode detector of near-infrared radiation is used at a tip temperature of 1,000 °C, a drop in transmission of energy by 10 percent would result in an error of approximately 10 degrees.

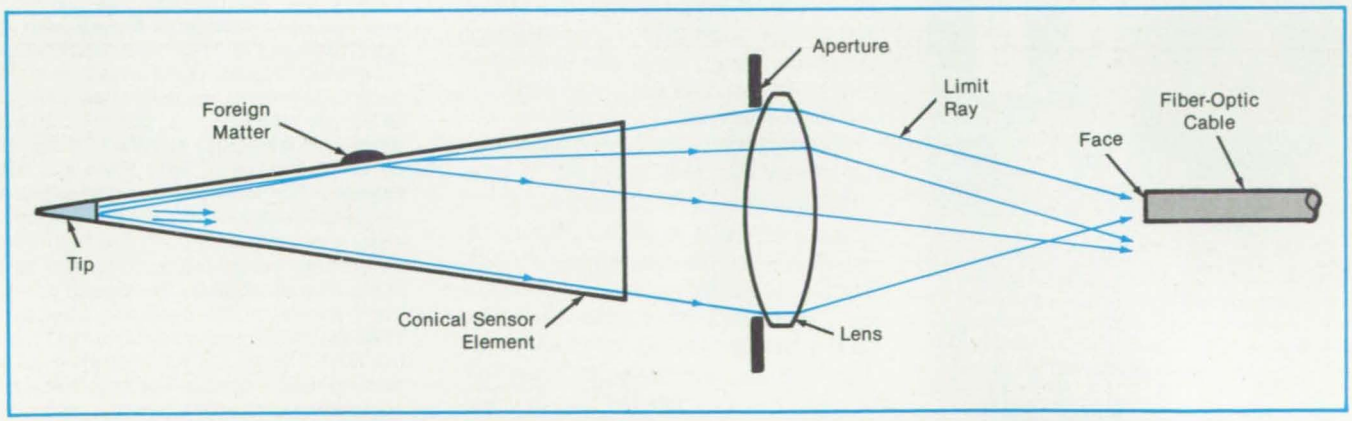
Another deficiency of existing sensing elements is in the inherent weakness of a cylinder when loaded as a cantilever beam. This loading comes from the drag of the flowing gases acting on the cylinder to produce a bending moment that is greatest at the base of the cylinder.

The foregoing deficiencies should be overcome by a new sensor design. The new sensor element (see figure) is a cone of a solid, refractory, and optically transparent material; for example, single-crystal sapphire. The tip is coated with a durable and emissive material; for example, iridium. When the cone is heated by the combustion gas, radiant-energy rays are emitted. The limit (marginal) rays just pass by the aperture, are collected by the lens, and are brought to a focus at the face of the fiber-optic cable. Rays between the margins that originate at the tip also pass through the aperture and are focused onto the fiber-optic face. Rays that glance off the cone surface (where some of the ray energy is absorbed by foreign-matter deposits) continue on to be collected by the lens and focused away from the fiber-optic face.

It can be shown, then, that only the rays that are emitted from the tip and that do not intersect the cone will be collected and focused onto the fiber-optic face. All other rays — that is, all rays that intersect the cone surface — will not be focused onto the fiber-optic face. This design, therefore, makes the sensor respond only to the radiation emitted by the tip, and deposits of foreign matter on the sides of the cone have no effect on the measurement.

This work was done by P. W. Mossey of General Electric Co. for **Lewis Research Center**. *Further information may be found in NASA CR-175108 [N86-28729/NSP], "1700 °C Optical Temperature Sensor."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia



The **New Sensor** has a conical shape for mechanical strengths and an optical configuration that is insensitive to deposits of foreign matter on the sides of the cone.

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

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Lewis Research Center [see page 20]. Refer to LEW-14276.

Books and Reports

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

Equations for Fading-Memory Filters

Simplified solutions are based partly on the exponential decay of effects of previous states.

A report discusses simplified recursive solutions for the equations of a class of fading-memory filters. Under appropriate assumptions regarding noise and the exponential decay of the effects of previous states, the filter equations can be reduced to analytic formulas in closed form.

The general filter problem involves a linear system that passes through a sequence of discrete states, each of which depends on the previous state. The filter is not a piece of equipment but rather a set of equations that provides a sequence of estimates of the states that fit the measurements of the states and the mathematical model of the system as closely as possible according to a weighted-least-squares criterion. Transitions between, and measurements of, the states include state-independent white noise. The filter calculations are complicated matrix and matrix-inverse operations at each discrete time.

The choice of weighting matrices for the least-squares calculation determines the filter equations. One such choice results in Kalman filtering, which offers recursive solutions for state estimates and for a state-estimate-covariance matrix. However, Kalman filters attempt to fit all past data into a single model, a disadvantage when the system varies with time. When the model is in error, large errors occur in the state estimates.

In this study, a weight that decays exponentially with time is applied to older measurements. This approach entails the loss of information as past measurements are discounted but compensates by overcoming most of the mismodeling and instability associated with Kalman filters. The fading-memory filter has the added advantage that an exponential decay of past data is intuitively comprehensive to most users.

A simplification is achieved by assuming that the state-noise-covariance matrix is proportional to the time-propagated state-estimate-covariance matrix. Even though this assumption departs from the modeling of the state noise in the physical system, it is useful in practical problems where the state noise is unknown, difficult to model, or not of the assumed constant-white-noise form. The equation for the filter-decay factor α_n then becomes

$$\alpha_n = \exp(-T/\tau_n)$$

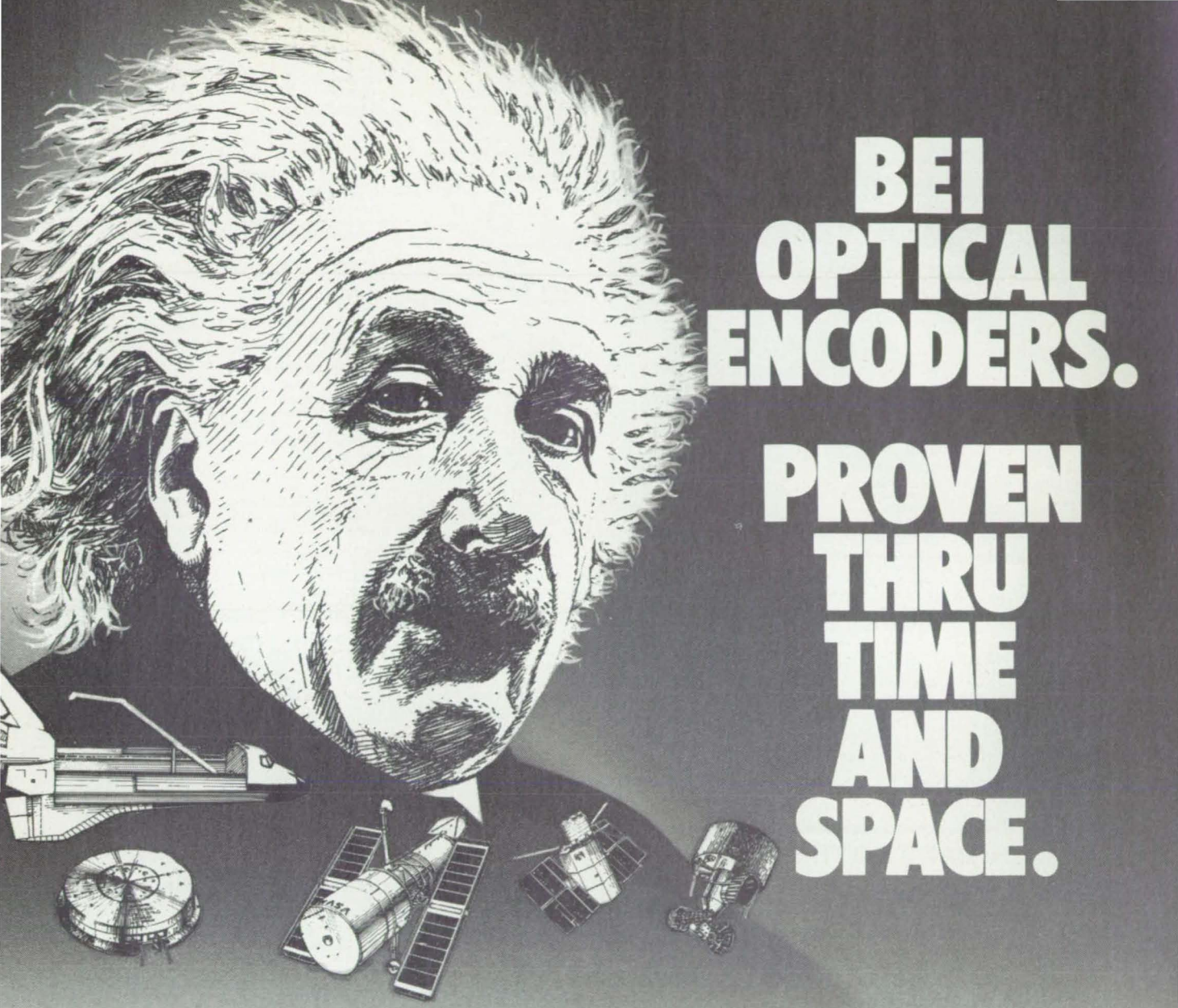
where T is the filter sample time and τ_n is the filter time constant. The filter response to an input impulse is thus similar to the response of a resistor/capacitor combination to a step-voltage input.

Filter equations are derived for a system with time-invariant state-transition, measurement, measurement-noise-covariance, matrices and filter-decay factor. For the steady-state case, the filter is expressed as a z-transform transfer function in the form of a matrix between m inputs (measurements) and n outputs (states). As examples, closed-form analytic tracking-filter solutions are found for second- and third-order fading-memory filters used in a Global Positioning System receiver. In general, this class of fading-memory filters is computationally efficient, and the solutions are stable.

This work was done by J. I. Statman of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Simplified Solution for a Class of Fading-Memory Filters," Circle 31 on the TSP Request Card.*
NPO-17089

New Products

MAX 2, a single board computer for IBM PC/ATs and compatibles, has been introduced by International Meta Systems, Inc., Torrance, CA. The computer operates at between 20 to 40 million instructions per second (MIPS) at an estimated cost of $9,000 per million floating point operations per second (MFLOPS). The MAX 2 supports up to 16 Mbytes of user RAM and 256 Kbytes of register-like context memory. A single user machine, the MAX 2 is designed for engineers, scientists, and high-level programmers requiring powerful, low cost computing capabilities. Because of its non Von-Neuman architecture and adaptable WISC (writable instruction store computer), the MAX 2 is useful for fifth generation development projects. For scientific and engineering applications, languages on the MAX 2 are FORTRAN 77 and C.
Circle Reader Action Number 575.



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NASA NEWS BRIEFS

CONTRACTS UPDATE

A major aeronautical flight experiment will be conducted by the Boeing Commercial Airplane Company for NASA's Langley Research Center. Boeing will test the effectiveness of a hybrid system designed to achieve laminar air flow control at high subsonic speeds. The system, which combines air suction near the wing's leading edge with contouring of the wing surface for reduced drag, could improve transport aircraft fuel efficiency by as much as 20 percent.

Contractors have been selected for the first of a two-phase systems definition study for the proposed Shuttle-C. Martin Marietta Manned Space Systems; Rockwell International, Space Transportation Systems Div.; and United Technologies Corp., USBI Booster Production Co. will each submit designs for the unmanned, cargo-carrying launch vehicle. Shuttle-C would have a lift capacity of 100,000 to 150,000 pounds to low-earth orbit, giving the U.S. space program a launch vehicle with nearly three times the payload capacity of the present Space Shuttle.

NASA and the Department of Defense have selected three firms to continue airframe development on the experimental National Aero-Space Plane. Awarded 36 month, $25.5 million contracts were the General Dynamics Corp., Ft. Worth Division; McDonnell-Douglas Corp., McDonnell Aircraft Co.; and Rockwell International Corp., North American Aircraft Operations.

Langley Research Center will sponsor a design study for a helmet-mounted display system able to present color 3-D images in stereo. The helmet will be used in flight simulator research, with possible adaption to actual flight, according to Langley officials.

Five aerospace firms have been awarded design and definition study contracts for a Space Shuttle advanced solid rocket motor. The 9-month, $3.3 million contracts were awarded to Aerojet Solid Propulsion Company, Atlantic Research Corp., Hercules Aerospace Company, Morton Thiokol, Inc., and United Technologies Chemical Systems Division.

NASA has chosen Grumman Aerospace Corp. for a Space Station Program Support Contract (PSC). The PSC provides for Space Station systems engineering and integration in addition to management support to the Space Station Program Office. Grumman's proposed cost for the 11 year performance period is $841 million, with a priced option for additional support of $406 million.

A new commercial initiative, supported by NASA and the Departments of Defense and Commerce, will aim at making the sophisticated computer language Ada widely available to American industry and business. Ada is believed to have substantial potential for enhancing U.S. economic competitiveness through manufacturing applications, such as industrial automation. The language is presently being employed in a variety of defense and aerospace programs and has been chosen for use aboard Space Station.

The U.S Air Force and NASA have signed an agreement establishing reimbursement policies for DOD flights on the Space Shuttle and NASA flights on DOD-procured expendable launch vehicles. Under this "quid pro quo" agreement, NASA and DOD will each maintain launch capabilities that can be used by the other in assuring access to space at minimal additional cost. Pricing provisions apply to launches scheduled through fiscal year 1991. The estimated DOD price for Shuttle hardware will be $115 million. NASA's estimated ELV prices will be $93 million for Titan IV, $25.6 million for Delta II, and $24.6 million for Titan II.

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Erratum: In NASA Tech Briefs October 1987 issue, page 55, the title of brief NPO-16380 and NPO-16381 should have read "Coating a Hydrogen-Maser Chamber with CF_4."

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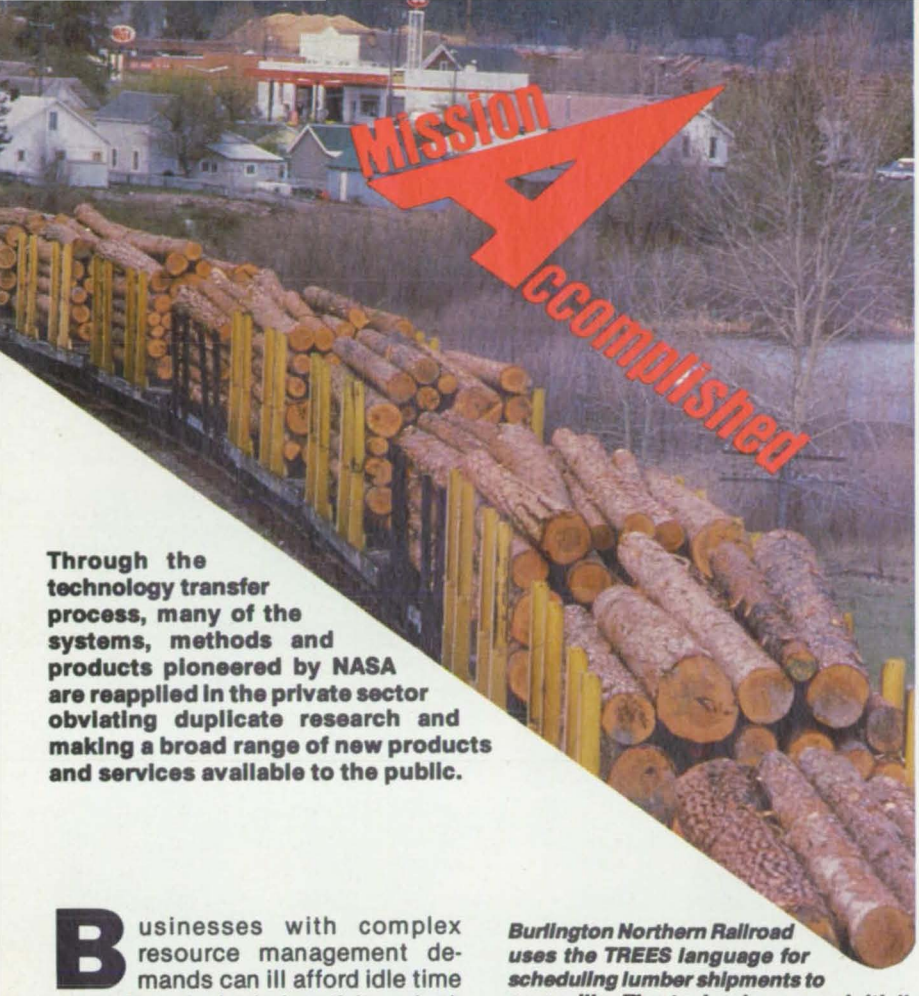


Through the technology transfer process, many of the systems, methods and products pioneered by NASA are reapplied in the private sector obviating duplicate research and making a broad range of new products and services available to the public.

Burlington Northern Railroad uses the TREES language for scheduling lumber shipments to saw mills. The technology was initially developed for NASA by Information Sciences, Inc., now the research and development arm of Avyx.

Businesses with complex resource management demands can ill afford idle time or bottlenecks in their activity schedules. Aerospace, transportation, health care, food service—all of these industries rely on smooth operational flow. To help them keep pace, Avyx Inc. of Englewood, Colorado has introduced TREES-pls, a programming language for IBM and IBM-compatible computers. Originally developed to coordinate NASA's space shuttle program, TREES-pls can be applied to scheduling, resource allocation, project control, and information management functions.

The TREES language is based on built-in libraries of project management routines. A value-added reseller or developer creates an application that uses the system's inherent tree-structured data management, which arranges alternatives heuristically, greatly accelerating the scheduler's decision-making process. The hierarchic tree structures can be modified and manipulated during program execution, making it useful for artificial intelligence applications such as symbolic manipulation and knowledge representation.

The product's most attractive feature, according to Avyx president John Willoughby, is its flexibility. "In the past," he said, "management has spent millions of dollars developing one-of-a-kind solutions to activity scheduling problems. TREES-pls offers a cost-effective alternative; its common logical architecture can be applied to different problems with minimal adjustment or customization." The end result, according to Willoughby, is an up to 80% programming cost savings.

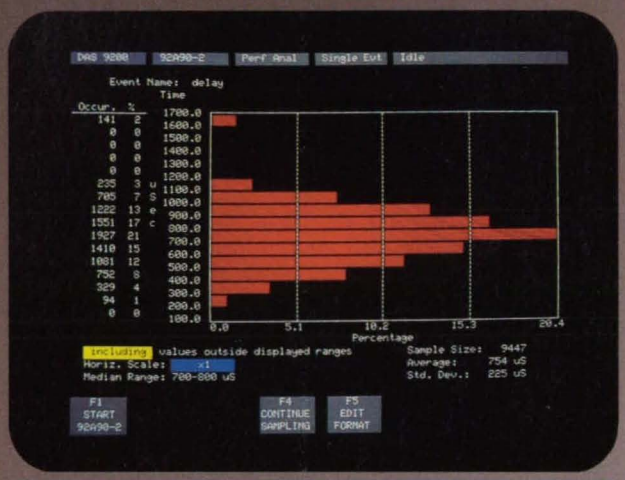
NASA's Johnson Space Flight Center currently uses TREES-pls to schedule various science activities planned for space station. The technology is also being used for deep space tracking network activities and for designing operational concepts for communications satellites.

In non-aerospace applications, E.J. Gallo Winery uses TREES-pls to schedule production of its champagne, and Burlington Northern to allocate lumber to saw mills.

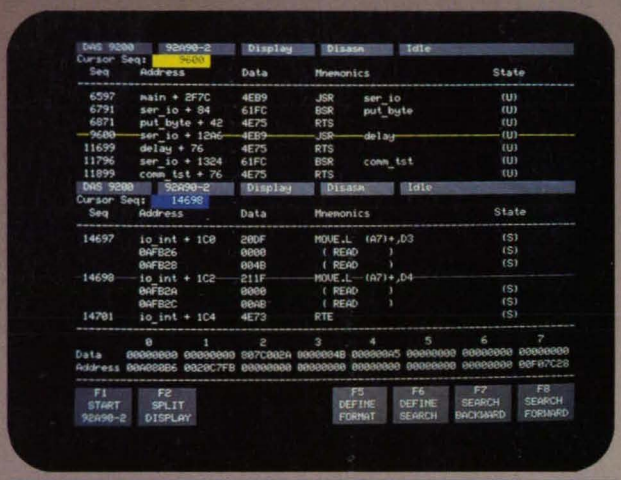
By next year, according to Willoughby, Avyx will introduce TREES-pls on a full line of workstations—including Apollo, DEC, and Hewlett-Packard, and on mainframes such as the VAX-8000. An end-user version is in the planning stages.

The MS-DOS package costs $995. Mr. Willoughby expects sales to exceed $500,000 this year, with growth to $2.5 million in 1988 as TREES-pls begins to branch outward. □

DAS9200 DIGITAL ANALYSIS: NOW TEK MAKES THE IMPOSSIBLE LOOK EASY.



Software Performance Analysis, like this distribution of a subroutine's execution times, helps you easily understand the activity of your code.



Step backwards through acquired data, including subroutines, stack and register models, using time-correlated split-screen displays to pinpoint problems.

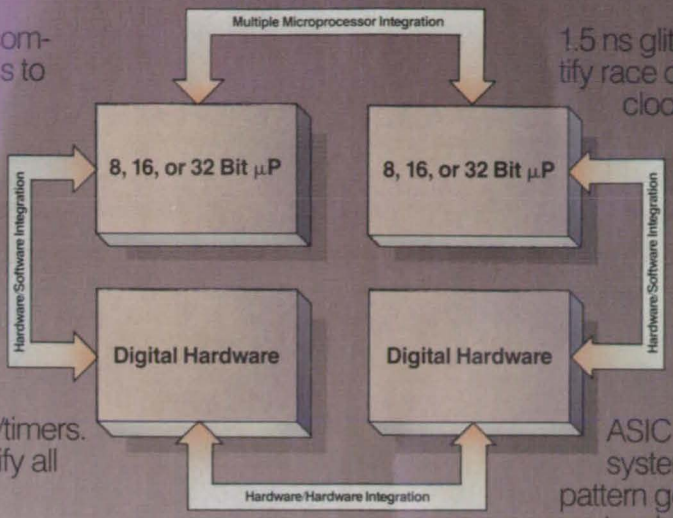
In every dimension— speed, channel width, memory depth, trigger capability, modularity and ease of use—the DAS9200 dwarfs what's been possible before.

The DAS9200 features a tightly coupled, high-speed architecture in which multiple card modules can act as a single unit. Large color-coded displays, pop-up menus, performance analysis graphs,

multi-tasking and more combine to take logic analysis to levels like these:

1 State-driven triggering at 200 MHz. You can use up to 384 channels of sync and async data acquisition. You can assurance-test high-speed logic at full speed, using 4-level state tracking and high-speed counter/timers. You can monitor and verify all timing measurements in a circuit.

2 Symbolic, real-time software debugging. Register deduction and stack simulation let you pinpoint problems like stack overflow or incorrectly restored pointers—without breakpoints or manual notation.

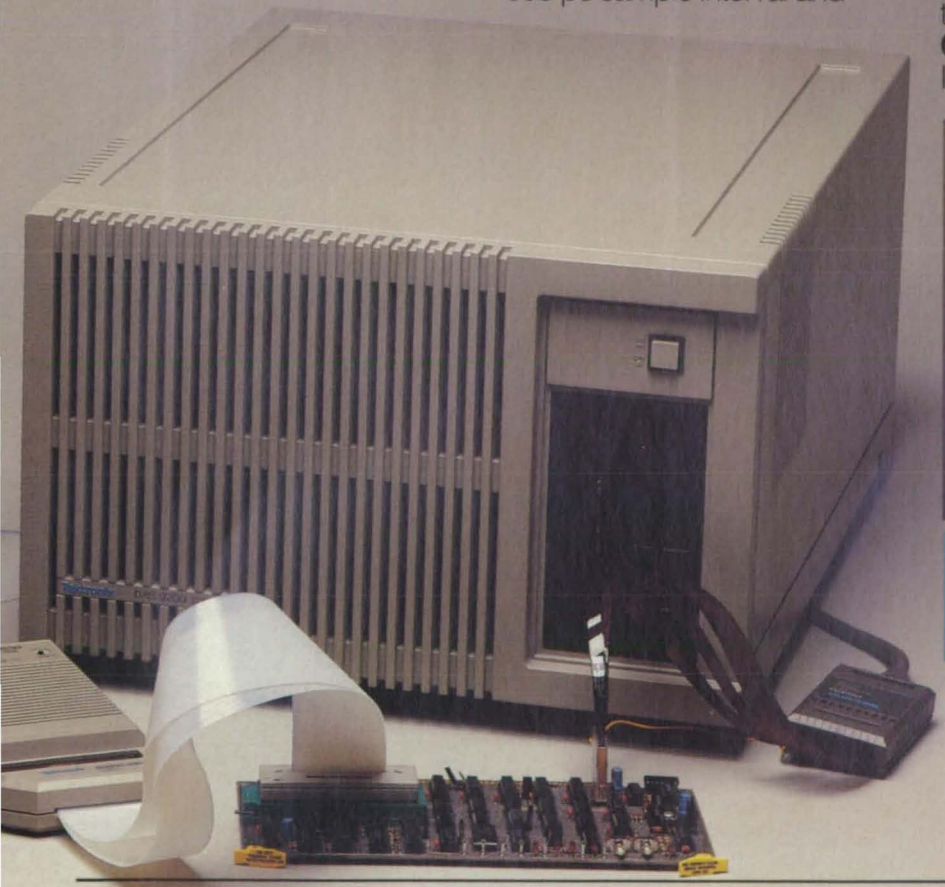


3 Simultaneous integration of up to six microprocessors. Use the dual timebases and real-time handshaking between system modules to set up split-screens displays that scroll in precise time alignment.

4 160 channels of acquisition at 2 GHz. Use up to 500 ps sample interval and 1.5 ns glitch detection to identify race conditions, spurious clocks and setup/hold violations in any logic family. System probes feature input capacitance of <1 pf.

5 Easy ASIC verification at up to 50 MHz. The DAS9200 is available as a low-cost turnkey ASIC device verification system. Featuring 50 MHz pattern generation, 8K bit vector depth, and 1 ns edge placement, it offers the power, precision and simplicity to be an attractive alternative to centralized systems.

6 Stop wishing for the impossible in digital analysis: Compare your wish list against the complete list of DAS9200 capabilities. Contact your Tek sales engineer, or call toll-free for more information. **Call 1-800-245-2036.** In Oregon, 231-1220.



Available in desktop and rack-mount versions, the DAS9200 mainframe can be augmented with up to three expansion mainframes for a total of 28 card slots.

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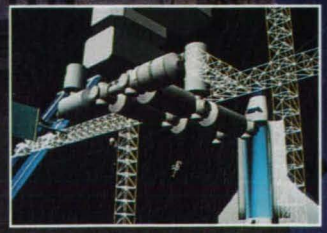

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